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Environmental Evaluation of the Water Options in the Indio River Watershed
Project No.SAA-117595
Final Report

Prepared for:
Panama Canal Authority

Prepared by:
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Panama – May, 2004

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EXECUTIVE SUMMARY

The Panama Canal Authority (ACP) selected URS for preparation of the environmental analysis of the water options identified in the Indio, Caño Sucio and Toabre rivers. This analysis shall establish the feasible and preferred options from the point of view of the socio-environmental impacts and the possibility of properly managing them. As part of this effort, URS must deliver two Environmental Analysis reports, one for the water options within the Rio Indio watershed and a second one for the options involving at least two of the three watersheds. This report refers to the environmental analysis conducted for the options within the Rio Indio watershed.

BACKGROUND

Currently the ACP is working in a set of studies to prepare a Modernization and Expansion Master Plan for the Canal. Those studies include the definition of new water sources given that the increases in demand, for the transit of vessels and for supplying the population needs, will exceed the capacity of the current system, which depends on Alhajuela and Gatun Lakes. Previous effort identified that most promising water options are within in the Western Region of the Canal Watershed (ROCC), located to the west of the Canal and Lake Gatun (Figure RE-1), with an area of roughly 2131 Km^2 and a mean annual runoff of 4410 million cubic meters (MCM). For the purpose of comparison, the Eastern Region, which currently provides the water for the system operation has an approximate surface area of 3310 Km^2 and 4655 MCM annual runoff.

The intention of the ACP is for the selected alternative to be designed, built and operated according to its own Environmental Manual, complying with all laws and regulations of the Republic of Panama and with the guidelines and requirements of the international funding organizations such as the Inter-American Development Bank (IADB) and the World Bank.

POTENTIAL ENVIRONMENTAL IMPACTS AND RISKS OF WATER RESOURCES PROJECTS

Large-scale manipulation of the landscape, to harvest water resources for a specific purpose, is nowadays a well-known cause for the generation of significant socio-environmental impacts and risks[(20)]. Building dams and reservoirs typically displace local communities and alter the local geodynamics and the natural evolution process. When doing this an additional load is imposed upon rural populations, which are typically poor and new conditions are established for the regional ecosystems. Among the main socio-environmental impacts and risks of developing water resources projects in the tropical lowlands, such as the conditions in the Rio Indio watershed, the following shall be mentioned:

- The displacement of population and the difficulties and hardship that relocation imposes upon that population including material losses, erosion of social values, increased exposure and susceptibility to some disease and the overall effect of the unknown.
- Deforestation and destruction of natural ecosystems and the habitat normally associated with them, due to the induced development, an effect that triggers a series of processes leading to an overall and progressive deterioration and impoverishment of the regional environmental and social conditions.
- Erosion and sedimentation in the watershed, important for the useful life of the reservoir, as well as for the environmental conditions within the lake, which may be significantly increased by deforestation and construction activities.
- The risk of eutrophication and deterioration of water quality in the reservoirs, which are also influenced by the on going activity in the watershed.
- The risk of infestation by waterweeds, which may favor the increase of insects that are disease vectors and influence the quality of the water and the reservoir, limiting is value to society.
- Reduction or disappearance of wildlife species, particularly migratory species, as a result of altering terrestrial and estuarine areas, which may provide habitat, as well as changes in the hydroperiod.
- The loss and destruction of archaeological sites.

Current knowledge about these problems indicate that the great majority of them may be prevented, reduced or controlled when the socio-environmental impacts and risks evaluation process is an intrinsic element of the project life cycle. This strategy leads to the generation of an environmental improvement program for the watershed, including the reservoir's direct and indirect areas of influence, mainly those located upstream, by means of properly managing and using the environmental goods and services available.

THE INTEGRATED MANAGEMENT OF WATER RESOURCES

The integrated management of water resources (IMWR) is a process that promotes the coordinated development and management of water, soil, and associated resources, to maximize the social and economic benefits in an equitable manner without compromising the sustainability of the vital ecosystems[33]. The IMWR process has drawn particular attention after 1992, when the International Conference on Water and the Environment was held in Dublin and after the United Nations Conference on Environment and Development held in river of Janeiro. Since then, IMWR has found global support in the international community. In the particular case of the ACP, the IMWR approach coincides very closely with both the institutional mandate and

policies and could be seen as a process that will assist in its efforts to deal with water issues in a sustainable and cost effective manner.

OBJECTIVES OF THE ENVIRONMENTAL ANALYSIS

The prime objective of the Environmental Analysis is to incorporate the socio-environmental considerations to the selection process for the water option needed to properly supply the Panama Canal system. The selected option shall comply with the environmental analysis requirements established by the ACP environmental manual, the ANAM procedures and the guidelines and requirements of the international funding organizations such as the World Bank and the IADB. More specifically, the following objectives shall be mentioned:

1. Identify, qualify and quantify, based on existing information, the potential socio-environmental impacts that could be caused by each of the water options considered in the watershed, detecting potential synergies in the process.
2. Determine the needs for socio-environmental management and improvement, which would be required for the socio-environmentally feasible implementation of the selected water options.
3. Incorporate the opinion of the relevant stakeholders and the civil society to the selection process of the best option.
4. Determine the feasible options when all technical, economic, financial, social and environmental components are considered.

THE WATER OPTIONS IN THE RIO INDIO WATERSHED

The water options considered in the Rio Indio watershed are six. The ACP provided four of them and the URS team generated two. Of the six options, Option 1 has been more studied and many of the conclusions in this study are based on information directly applicable to it, which have been extrapolated to the others. These options are described briefly below; their main characteristics are shown in comparative form in Table RE-1 and its geographic distribution in Figure RE-2.

Option 1: Indio 80-40. This option includes a dam over Rio Indio, in the site known as Tres Hermanas Hill (UTM: 994700N, 590300E), with crest elevation at 83 meters above sea level-masl. This dam gives origin to a reservoir that would normally operate between elevations 80 and 40 masl with a maximum volume of the 1577 MCM and a minimum of 283 MCM, which provide a useful storage of 1294 MCM. At maximum operation level (80 masl), the reservoir floods an area of 45.6 Km^2 and 17.7 Km^2 at minimum operation level (40 masl). The water would be transferred from the reservoir to Lake Gatun by a tunnel 8.35 Kms long and 4.5 m in

internal diameter. At the dam site the river mean annual discharge has been estimated in 814 MCM and this system will contribute a total of 15.5 lockages per day to the Canal operation, which represents 1177 MCM/yr. This option has a total investment cost of B/.230 million and its annual operation cost is estimated to be B/.1.94 million.

Option 2: Indio 45-40. This option is a reduced version of the previous one with a smaller dam and a maximum normal operation level of 45 masl. At this level the reservoir stores a total of 400 MCM and floods a total of 22.5 Km^2. These changes reduce the water contribution to only 1.4 lockage/day (106 MCM/yr) while reducing the investment cost to B/.185 million and the operational cost to B/.1.39 million/yr.

Option 3: Alto Indio 50-40. Option 3 considers a dam located a little upstream from the one indicated previously (UTM: 991000N, 592000E), which would create a reservoir that would normally operate between elevations 50 and 40 masl with maximum and minimum volumes of 90 and 40 MCM, respectively. The flooded areas would be 26.5 and 17.7 Km^2 at elevations 50 and 40 masl, respectively. The water would be transferred to Lake Gatun by a tunnel that could vary between 8.5 and 9.0 Kms in length and 4.5 m in diameter. At this point the mean river discharge is estimated to be 648 MCM/yr and the system could contribute 0.7 lockage/day (53 MCM/yr) with an estimated investment of B/. 185 million and an annual operational cost of B/.1.25 million.

Option 4: Alto Indio 45-40. This option is a reduced version of the previous one, with the maximum normal operation level at 45 masl for a total volume of 55 MCM and a surface area of 22.5 Km^2. This option generates a contribution of 0.3 -lockage/day (23 MCM/yr) with an estimated investment cost of B/.145 million and an annual operation cost of B/.1.25 million.

Option 11: Teria - Alto Teria. Option 11 proposes two reservoirs over the Teria River, which is a tributary of Rio Indio. The first of those reservoirs (Teria 1) would be created by a dam located upstream from the mouth of the Teria river (UTM: 985500N, 596000E) with a maximum capacity of 270 MCM at elevation 130 masl, flooding an area of 7.6 Km^2. The reservoir would vary between 130 and 90 masl and at the later elevation it would have a 50 MCM volume. The second reservoir (Teria 2) is located in the upper portion of the sub-watershed (UTM: 975525N, 596657E) and has a capacity of 245 MCM at elevation 265 masl and 40 MCM at 225 masl, which would be the minimum operation level. The combined useful storage of both reservoirs is 425 MCM and the regulated mean annual discharge is 234 MCM.

Table RE-1:
Comparative Summary of Critical Information for the six Options Considered in the Rio Indio Watershed

Project Features	Option 1	Option 2	Option 3	Option 4	Option 11		Option 12		
Hydrology	Indio 80-40	Indio 45-40	Alto Indio 50-40	Alto Indio 45-40	Teria 1	Teria 2	Teria 1	Teria 2	C. Indio
Rainfall (mm/yr)	3078	3078	3078	3078	3740	4240	3740	4240	4340
Mean flow (m^3/s)	25.8	25.8	25.8	25.8	7.4	3.4	7.4	3.4	6.4
Reservoir									
Watershed (Km^2)	381	381	256	256	94	35.6	94	35.6	60.9
Maximum level (masl)	80	45	50	45	130	265	130	265	300
Volume (MCM)	1,577	400	90	55	285	245	285	245	30
Surface area (Km^2)	45.6	22.5	26.5	22.5	7.6	8.25	7.6	8.25	1.1
Minimum level (masl)	40	40	40	40	90	225	90	225	295
Volume (MCM)	283	283	30	30	70	40	70	40	10
Transfer/Tunnel									
Length (Km)	8.35	8.35	8.5-9.0	8.5-9.0	4.0	-------	4.0	-------	-------
Diameter (m)	4.5	4.5	4.5	4.5	4.5	-------	4.5	-------	-------
Estimated Cost									
Construction cost ($ M's)	$230	$185	$ 185	$145	$350		$401		
Annual cost ($M's)	$1.94	$1.39	$1.25	$1.25	$3.98		$4.38		
Estimated Yield									
Lockage/day	15.5	1.4	0.7	0.3	5.1		5.3		
MCM/yr	1,177	106	53	23	387		502		

The water from the Teria 2 reservoir passes to Teria 1 by gravity following the river and the water from Teria 1 then goes to either Ciri Grande or Ciricito rivers by means of a tunnel 4-4.5 Kms long or 4.5 m in diameter. This system contributes 5.1 lockage/day (387 MCM/yr) with an estimated investment cost of B/.350 million and an annual operation cost of B/.3.98 million.

Option 12: Teria - Cabecera Indio. Finally, option 12 is a modification of Option 11. The change consist in the addition of water from the upper portion of Rio Indio by means of a diversion reservoir (UTM: 968000N, 596000E), which is estimated to transfer 70% of the estimated discharge (203 MCM/yr) through a 1.5 Kms long channel that will transfer the water to the Teria sub-watershed. The estimated contribution for this system was 5.3 lockage/day (502 MCM/yr) with an estimated investment of B/.401 and operational costs in the order of B/.4.38 million per year.

CONDITIONS IN THE RIO INDIO WATERSHED AND ITS AREA OF INFLUENCE

The Rio Indio watershed is the hydrographic system immediately adjacent to the west of Ciri Grande River, running from the continental water divide to the Caribbean Sea. The total catchments area of the watershed has a total surface of 565 Km^2 and the length of its main channel has an approximate length of 98 Km. However, the area of the Rio Indio watershed that is part of the ROCC is only 386.6 Km^2, which is approximately 68% of the total area. Regarding the mean flow, the river section within the ROCC drains an area with runoff greater than the mean contributing about 72% of the total annual discharge.

The prime interest area includes the section of the watershed upstream from the dam site proposed for option 1 and the areas immediately adjacent to the main channel downstream from the reservoir. These areas include territories from three Provinces of the Republic of Panama (Cocle, Colon and Panama), five Districts (Penonome, El Valle, Chagres, Capira and Donoso) 11 "corregimientos" (Rio Indio of Penonome, Chirigui Arriba, El Valle, La Encantada, Ciri Grande, Ciri de los Sotos, El Cacao, Santa Rosa, Gobea, Rio Indio de Donoso and Salud).

The population in these areas is poor or extremely poor and the majority of the environmental goods and services once provided by natural ecosystems have been significantly reduced. The deterioration of the natural conditions worsens the state of poverty the local communities live in. The quality of life indicators and the basic services of health, education, potable water, electricity, telephone and transportation are significantly lower than the national mean and the area is known to export population, particularly young women, who go to the urban centers looking for jobs.

The main causes of the environmental deterioration are the deforestation and the wild fires, which change the landscape, naturally dominated by forest with structural development, to a mosaic of pastures and stubble. With deforestation and wild fires, the natural nutrients cycle losses its main reservoir, which is the forest biomass. Those forest ecosystems are very fragile to the nutrient loss, since they lose their high productivity and associated biological diversity as well as their capacity to regulate and buffer other important processes such as the water cycle and its effect over the erosion and sediment transport processes.

Main Biophysical Characteristics

The **geological** record indicates that the upper and mid portions of the watershed originated from volcanic activity, during the Tertiary, while the lower portions originated from the deposition of sediments derived from the former during more recent times. The **topography** is primarily steep to moderate with stone out crops, which indicate the rocky nature of the underlying formations. The region is **warm** (annual mean of 22-26°C) and **rainy** (annual mean of 2600-4700mm/yr) whit strong leaching power, which led to formation of poor soils with many restrictions for traditional agriculture and ranching. Under those conditions, there is a significant surface water **runoff,** which reaches an annual average over 2100 mm/yr for the area of the watershed within the ROCC, with a range of 1800-3600 mm/yr.

In its natural state the native ecosystems were mainly **evergreen tropical forests** of great vertical development and biomass. Estimates based on the climatic and edaphic conditions and point observations suggest that the dominant trees of the primary forest in this region of Panama could have reached 50-52 meters and the ecosystem probably had a complex structure of up to four tree levels in addition to the understory vegetation and a **high biological diversity**. Given the conditions of high rainfall and temperature, which quickly remove the nutrients that are not part of the living biomass, the evolutionary strategy of the ecosystem led to mechanism that minimize the period of time that nutrients are found in inorganic soluble form. The ecosystem, which depends on this close nutrient cycle (limited interchange with the outside), is very susceptible to **deforestation** and **wild fires** since, particularly the later mineralize the nutrients, opening the cycle, increasing their solubility and favoring the washing off by water, significantly increasing their export rate.

Due to those reasons, the regional potential use is primarily for forestry and conservation with a great capacity for the production of water and for the development of nature based tourism activities. However, the current condition is very different and the majority of the forests (78%) have been eliminated (Figure RE-3) as well as most of the habitat for wildlife species. Spontaneous colonization, the fragile nature of the native ecosystems and the wild fires caused

by the migrant agriculture has impoverished the region and progressively converting it to pastures primarily for extensive cattle ranching; which is also unsustainable in the mid and long term. This impoverishing process of the natural ecosystems leads to the social, cultural and economic impoverishment of the local communities, in a vicious cycle that accelerates itself increasing the rate of destruction of natural goods and services, particularly those sensitive to forest fires.

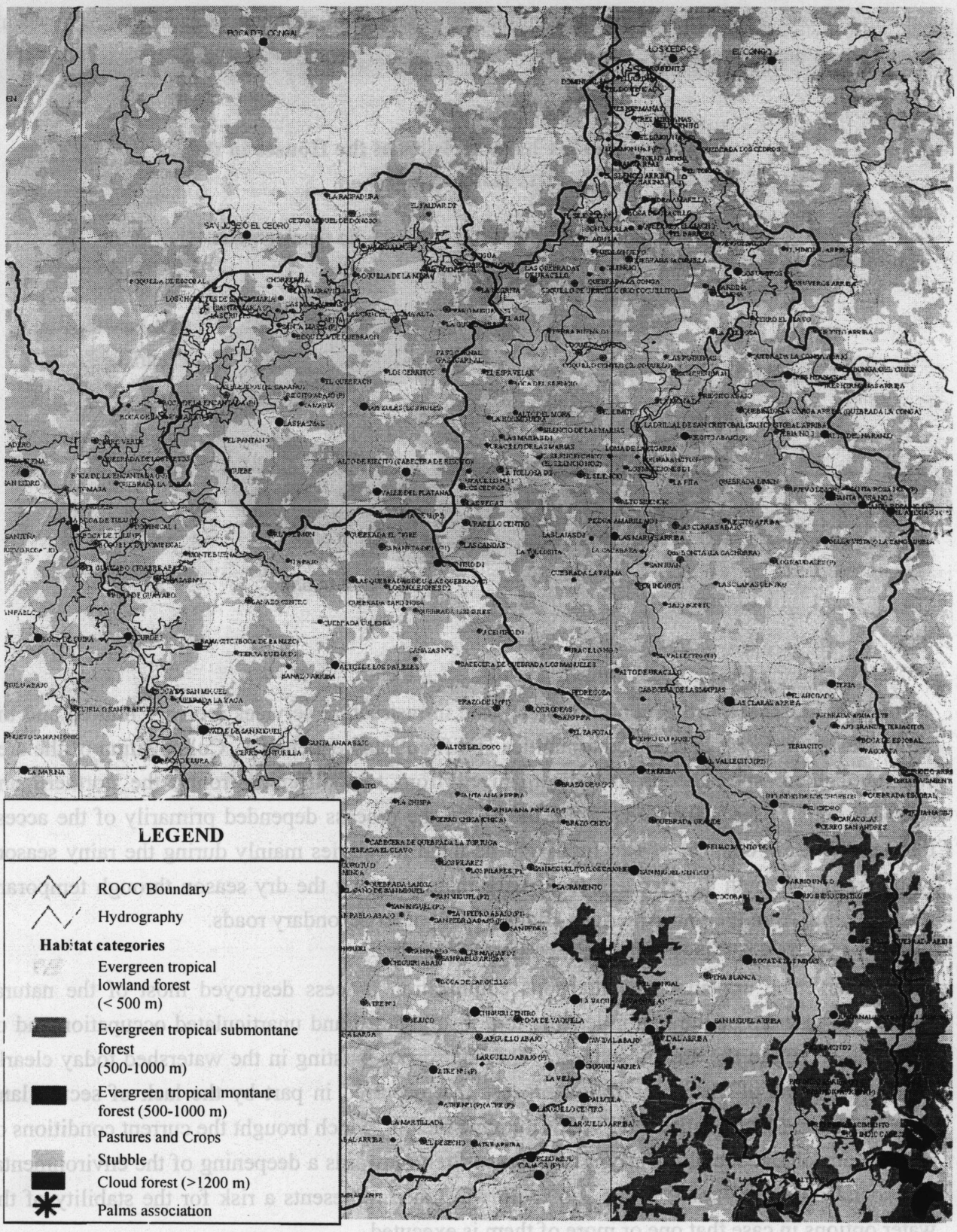
Socioeconomic Aspects

The impoverished ecosystems lead to further deterioration of social and economic conditions and impoverishment of residents of the local communities. This cycle of socio-environmental degradation has been common in other areas of the humid tropics in Latin America, including Panama, when landless farmers move into wetter environments looking for lands for their agricultural activities. Consequently, the population in the Rio Indio watershed, as well as the rest of the ROCC, is very poor; with a mean income equivalent to less than one third of the national mean and migrates towards regions in the country looking for opportunities of a better life. For comparison purpose, in the following table several characteristics of the population in the Rio Indio watershed and the entire ROCC are shown with the equivalent values for the national averages.

Table RE-2:
Comparison of some characteristics of the population in Rio Indio and the ROCC with the National Averages

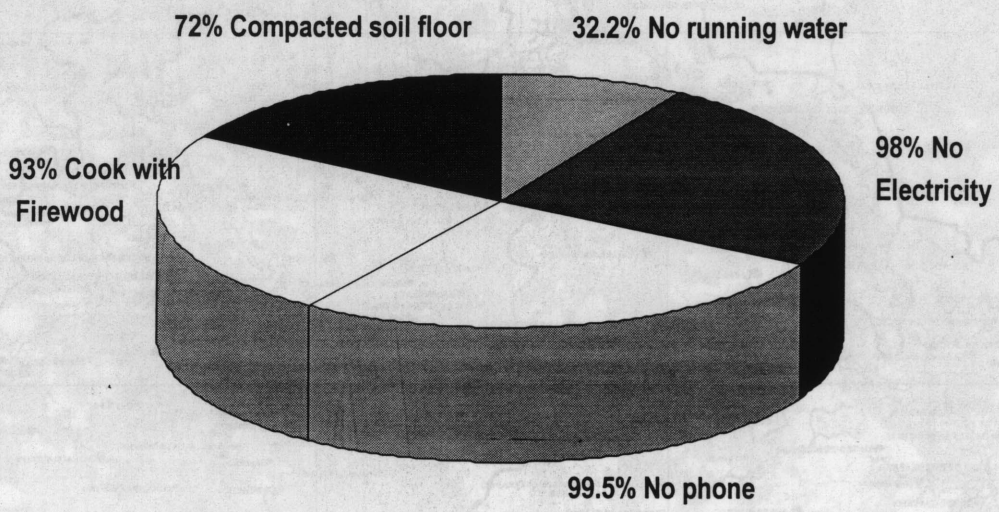
Population Feature	National	ROCC	Rio Indio
Population	2,830,177	35,727	7,732
Density Hab/Km^2	32	16.8	20
Birth rate (per thousand inhabitants)	25	35.7	39
Infant mortality (per thousand born alive)	23.2	34	42
Growth rate (1990-2000)	2	0.96	0.1
Life expectancy (in years)	73.9	68.5	68.5
Monthly median income (B/. per employed population)	271	72	68
Illiteracy (% of population 10 years or older)	8	9.6	10

Figure RE-3: Condition of the Natural Habitat in the Rio Indio Watershed and Adjacent Areas



The analysis of the Census 2000 information in the Rio Indio watershed indicated that at that time there were a total of 1,464 houses in the area. The main characteristics of those houses are presented in the figure below.

Figure RE-4: Characteristics of the Houses in the Rio Indio Watershed

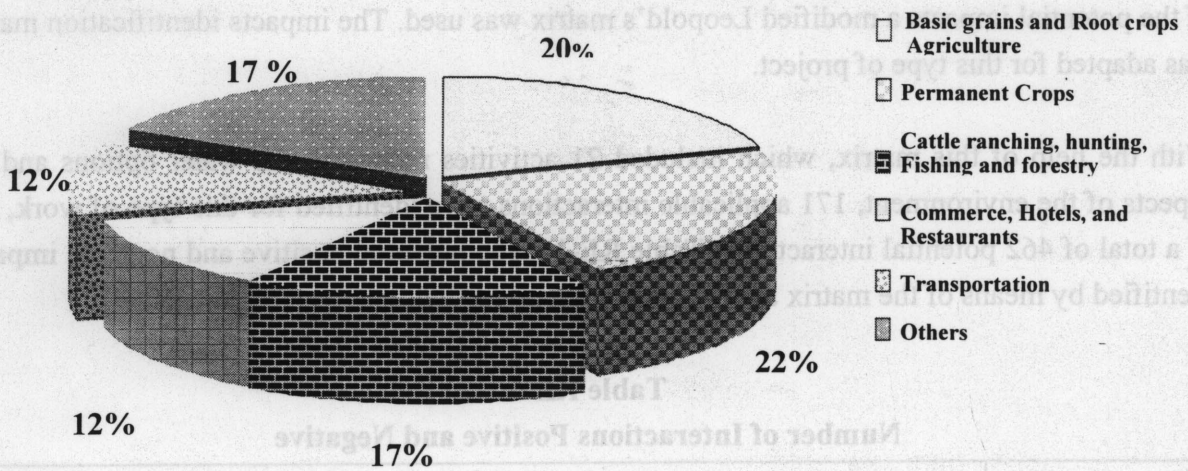


As one could expect in this condition, the basic infrastructure services are very limited and the simple access to most of these communities is difficult and expensive. Colonization of the area was unplanned, spontaneous and disorganized from two different fronts, the northern and southern ends of the watershed. From the north, the process depended primarily of the access through the main channel of Rio Indio and its main tributaries mainly during the rainy season, while from the south colonization took place mainly during the dry season through temporary roads coming from the Pan-American Highway and other secondary roads.

In summary, the unplanned spontaneous colonization process destroyed most of the natural goods and services of the region leading to a disorganized and unarticulated occupation and of the territory within the area of interest. The landscapes existing in the watershed today clearly show the effects of that colonization process that occurred in part by the lack of secure land ownership and other political and socioeconomic factors, which brought the current conditions of environmental and social poverty. The apparent trend towards a deepening of the environmental and social impoverishment in the Rio Indio watershed represents a risk for the stability of the water options in case that one or more of them is executed.

Within the agricultural activities, the ones contributing more to the watershed GDP are the permanent crops and the subsistence agriculture, while vegetable crops represent only 0.2% of the total GDP. Grains agriculture (rice, corn) and root crops contribute 33% of the local GDP. The more important item for the generation of cash income required for the exchange with the exterior world is permanent agriculture, and the main crops of this type are coffee, bananas, plantains, oranges, and pixbae. This activity is far the most efficient, since it represents 36% of the regional GDP, while utilizes only 9% of the surface area. This information is summarized in the figure below.

Figure RE-5: GDP BY TYPE OF ACTIVITY



Archaeological Resources in the Rio Indio Watershed

The inventory prepared by the environmental and cultural data gathering study [53] reviewed the 11 sites previously known in the ROCC and identified 72 additional sites. Based on this report, the archeological sites in the Rio Indio watershed are described below:

- **Uracillo / Pn-50.** This is a village first reported by Stirling in 1951. This is one of the more sites important in the entire ROCC and is considered to be important at the regional as well as the national level. It was inhabited during the Mid Ceramic Period and reached its maximum development by 750 – 900 AD.
- **Prehistoric Mine / Cp-52**. This is another important site in this watershed, from where cryptocrystalline material was obtained. This site is also of regional and national importance regarding the first known technologies and use of raw material in Central America and the wider Caribbean area.

- **Small Village / Cp-41**. This is a moderate potential site in the Rio Indio watershed that includes several rocky shelters and a small village, from approximately 550 – 750 AD, with several documented burials.
- **Other Sites**. Other sites include mainly rocky shelters a few cemeteries (Cp-44), some with petroglyphs (Cp-37 and Cp-43) and a few other with potential to find untouched sealed deposits (for example C-35 and Cp-58).

IDENTIFICATION AND EVALUATION OF IMPACTS

The identification and classification of the potential socio-environmental impacts and risks took in consideration the typical activities of this type of infrastructure; relating those activities to the socio-environmental variables that could be affected by means of matrices. For the identification of the potential impacts a modified Leopold's matrix was used. The impacts identification matrix was adapted for this type of project.

With the help of this matrix, which included 21 activities related to the water options and 22 aspects of the environment, 171 applicable interactions were identified for this type of work, out of a total of 462 potential interactions (Table RE-3). The potential positive and negative impacts identified by means of the matrix analysis are summarized below:

Table RE-3
Number of Interactions Positive and Negative

Type of Impact	Phases					
	Planning	Construction	Operation	Abandonment	No Action	Total
Positive	1	19	4	4	11	39
Negative	8	97	11	1	15	132
	9	116	15	5	26	171

In the planning phase 9 impacts were identified of which 8 are negative and 1 positive. The later relates to the employment of people in the area during the information gathering works and for transportation services by horse or boat. The negative potential impacts identified in this phase are related to the socioeconomics aspects, derived from the speculation that could occur, affecting the people, the community cohesion, the agricultural and livestock production, the land tenure, and the infrastructure. During the construction phase, as may be seen in the Table above is when the greater number of impacts are expected to occur. The positive potential impacts are related to the employment generation and the increase of trading. The potential socio-environmental impacts and risks will be described in the paragraphs below.

In the operation phase the positive potential impacts are related also to the generation of employment and to the increase of tourism. In the abandonment phase the one negative potential impact identified relates to the project workers losing their jobs. Finally, not executing the project (no action), also generates socio-environmental impacts. The positive potential impacts are related to the implementation of regional development projects and the negative impacts to the land use trends and its effects of impoverishing the regional socio-environmental conditions.

Geology and Seismology

In general terms, the construction and presence of the civil works associated with any of the six options could affect the geologic and geotechnical conditions of the area. More than impacts these potential effects shall be consider risks, since it is not certain they would occur. The issues to be considered are the seismic risk, land slides, and geologic stability.

Conceptually speaking, the potential impacts and risks of geologic and geotechnical nature are similar for the six options analyzed. The impact level will depend on the option and in general, it will be proportional to the magnitude of the project, particularly the size of the reservoir and the height of the dam. In our opinion the risk of occurrence of these phenomena is smaller in the primarily volcanic formations anticipated to be flooded by the reservoirs over the Teria River and Cabecera Indio. However, during construction of the projects those risks could be greater for these options (11 and 12) given the steep slopes of these areas and the greater difficulty to access the working areas. In the case of the transfer tunnel construction there is a smaller risk associated to the magnitude of the tunnel for Options 11 and 12, which is estimated to be only 50% of the other options. Obviously this reduces also the total amount of excavated material that needs to be disposed during the construction phase.

In the operation phase the potential impact of a catastrophic seismic event could be relatively greater for the Teria River and Cabecera Indio reservoirs (Options 11 and 12), in the event of dam failure. Considering the location of these reservoirs in the upper sections of the watershed, the sudden discharge of the impounded water as a result of the dam collapse could affect a larger area. This is to certain extent worsened by that these alternatives include more reservoirs than the rest of the options. However, the risk is partially compensated by a smaller volume of water stored when these reservoirs are compared with option 1. Options 2, 3 and 4 have a lower intrinsic risk since they are located at similar elevation than Option 1 and include smaller water volumes than even the Teria River reservoirs.

Overall, option 1 is the one showing the greater geologic, geotechnical and seismic risk, since it includes the greater reservoir and associated structures. Then follow options 11 and 12, and the options with lower risk are the remaining 2, 3 and 4.

Soils

The water options in the Rio Indio watershed have the potential to affect the soils in the area since the reservoirs and related infrastructure will take over the space currently used by different types of soils. These impacts would be produced mainly during the construction phase of the water option(s) selected for implementation (Table RE-4). In addition, it is expected that induced development in the area, which most likely will occur during the construction and operation phases, will further affect soils with significant restrictions for agriculture use by erosion and accelerated leaching. These soil impacts may be prevented by the implementation of a zoning and land use plan within the Rio Indio watershed and the adoption of appropriate soil conservation practices, which shall be incorporated to all agriculture and forestry activities.

Table RE-4
Potential Direct Impacts on Soils as a Consequence of the Water Options Considered in the Rio Indio Watershed

CLASS / DESCRIPTION		HECTARES PER OPTION					
		1	2	3	4	11	12
III	Arable, with severe limitations in the selection of the plants, requires especial conservation or both	4.4	4.4	4.4	4.4	0.0	0.0
IV	Arable, with very severe limitations in the selection of the plants, requires very careful management or both	220.3	220.3	220.3	220.3	203.1	203.1
VI	Non arable, with limitations severe, suited for forests, pastures, reserve lands	2,960.7	1,959.9	1,133.6	1,092.7	1,332.5	1,474.4
VII	Non arable, with limitations very severe suited for forests, pastures, reserve lands	2,302.5	858.7	442.9	416.2	942.6	975.7
VIII	Non arable, with limitations that restrict its use in the commercial production of plants	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	**5,487.9**	**3,043.3**	**1,801.2**	**1,733.6**	**2,478.2**	**2,653.2**

To compare the impacts by each of the water options on the regional soils, the total area affected by the reservoir, dam and other works such as quarries borrow pits new roads and camps, was taken as the main indicator. Option 1 is the one directly affecting a larger surface area, followed by about 50% of its value by options 2, 11 and 12 and by about one fourth of its value by options 3 and 4. The potential soil impact from the development of the water options in the indirect area of influence during the construction and operation phases (induced development), is considered a risk of similar magnitude for all the options and shall be prevented through the implementation

of a zoning plan and promotion and enforcement of soil conservation and protection measures with project funds.

Water Resources

The water options in the Rio Indio watershed have the potential to affect the water resources since both the reservoirs and the associated infrastructure would modify the water flow and may contribute several contaminants. The potential impacts on water resources in the Rio Indio watershed have been divided in four functional categories: a) reduction of the water level and flow rates downstream from the dam; b) sedimentation in the reservoir and the potential impacts on its operation and downstream river conditions; c) risk of eutrophication in the reservoir(s); and d) water quality in the fluvial channel downstream from the reservoir and the construction and borrowing sites. These impacts are expected primarily during the final construction phase (filling of the reservoir) and during the operation phase of any of the water options. The impact category more important in the construction phase is the risk of water quality deterioration downstream from the dam-sites and downstream from any other construction sites.

The direct and indirect impacts on water quality during the construction and operation phases and the induced development on both phases are directly associated with the increase of suspended sediment, and the discharge of wastes both of biodegradable and hazardous nature. These impacts may be prevented with appropriate management measures, which shall be enforced throughout the entire project cycle.

With the construction of the project there will be a significant attenuation of the water flows in the main channel of Rio Indio downstream from the dam, and therefore, a reduction in the risks of flooding. The dam sites for each of the options are located at different distances from the ocean: the dam site for options 1 and 2 is located 31.2 Kms from the river mouth; the site for options 3 and 4, 38.7 Kms; and the first dam site for options 11 and 12 is 52.7 Kms.

The analysis of the existing information suggests that sedimentation in the reservoir would not be a potential problem and the need for maintenance dredging is not anticipated. Available information indicates that the rates of erosion are in the order of 1.4 mm/yr and that in a 100 year period the expected storage loss is less than 2% of the initial capacity for Option 1, which is the largest. However, it is important to emphasize the need to make all efforts to maintain similar conditions in the future. To that effect, the zoning and soil conservation plan previously mentioned and the periodic and systematic maintenance of roads to prevent land slides, are of paramount importance.

The analysis of potential impacts on the river bed downstream from the dam, due to the reduction of sediments, which are trapped in the reservoir, indicate that the potential degradation of the river bed would be insignificant. However, sediments could accumulate near the mouth of the Rio Indio tributaries since the reduction of flow downstream also decreases the capacity of the river to transport sediments. Similarly, bank stability below the dam is not expected to be a problem either.

On the other hand, the analysis of the eutrophication risk indicates that it is relatively low (Figure RE-6) and, although with small differences, it is expected that the reservoirs associated with all options would have a well oxygenated water layer of 15 meters or more. More specifically, reservoir conditions in options 2, 3 and 4 would similar than those in the existing reservoirs (Alhajuela and Gatun), and conditions for options 1, 11 and 12 will be even better. Under those trophic conditions it is expected that any of the reservoirs option, would provide an adequate habitat for the development of fish communities, which could greatly contribute to the economy and nutrition of the population in the local communities.

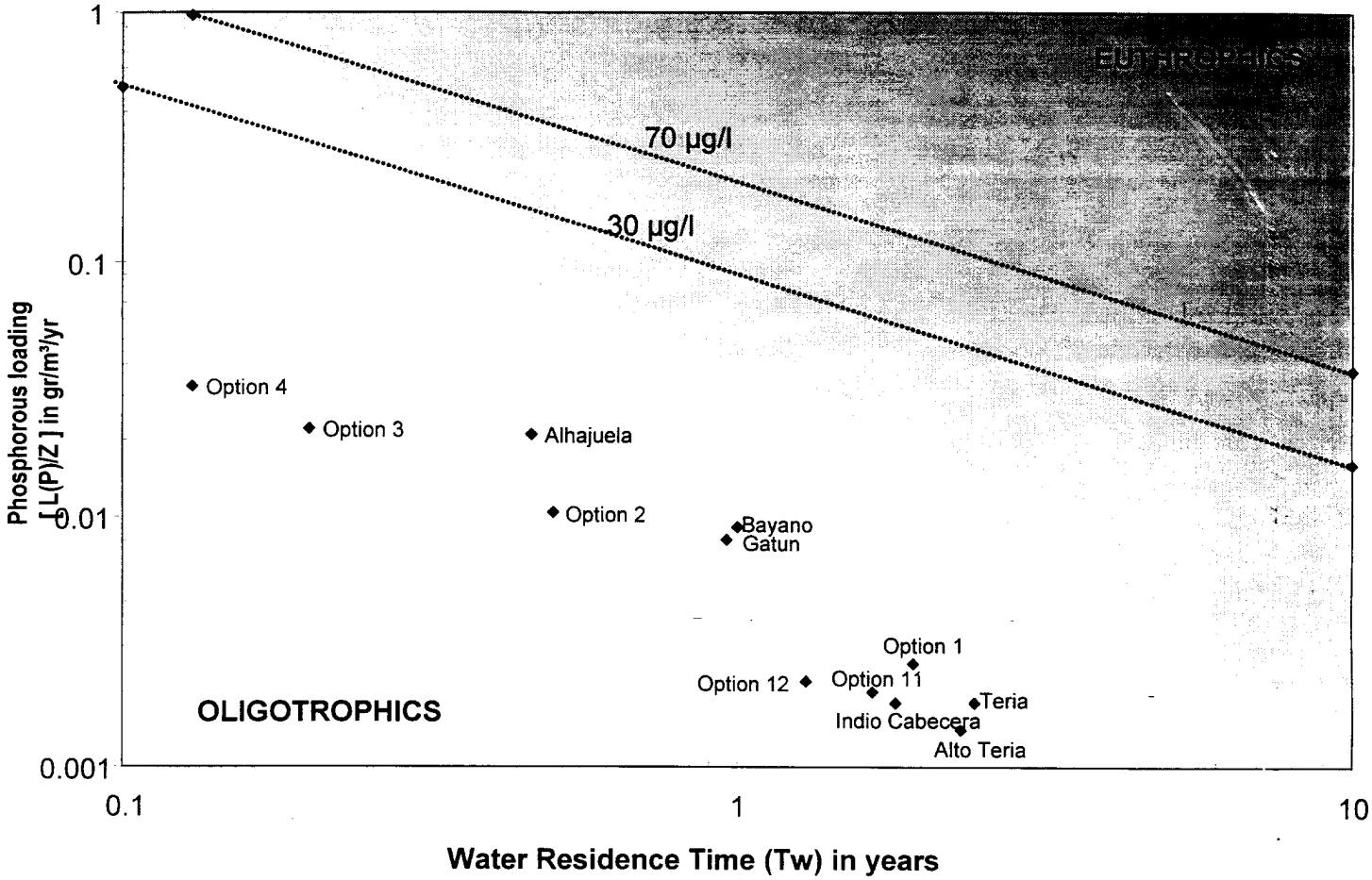
Air Quality and Noise

The potential direct and indirect impacts on air quality and noise in the Rio Indio watershed and nearby areas, as a result of the implementation of one of the water options are mainly associated with the increases in the traffic of vehicles and the earthwork related to construction activities. In the case of air quality the potential change in the rates of wild fires incidence have also been considered to be important.

In order to determine the areas that could be affected by vehicle emissions and noise generation, it was assumed that the majority of emissions would be located along the main project access roads, quarry areas and work sites. Based in the URS previous experience with road projects and gas and air suspended particles dispersion principles, a 45 meters band was established at each side of the roads, where concentration of atmospheric contaminants could exceed safe levels. Therefore, it was assumed that impacts will be limited to that 90m band.

To determine a similar area of influence for noise the URS team used the Guidelines of U.S Department of Housing and Development – Noise Assessment for noise caused by vehicle traffic. Using a mean day-night time value of 60 dB as the desired sound pressure value outside the receptor structures, the effective distance needed (from the noise to the center of the street) shall be approximately 80 m. Therefore, to identify those receptors that could be potentially affected a 160 m wide band (80 m to each side of the road center line) was used.

Figure RE-6: Location of the water options in the Rio Indio watershed, and the Bayano, Alhajuela and Gatun reservoirs in the eutrophication distribution chart.



Once the potential impact band was established, the towns that could be negatively affected by each of the options were identified. The results of this analysis indicate that Options 1, 2 and 12 are the ones showing the largest number of affected towns, then follows Option 11 and the lower values have been assigned to Options 3 and 4. In the case of noise, although Options 1 and 2 affect a greater number of towns, Options 11 and 12 are the ones affecting a larger amount of sensitive receptors.

Regarding forest fires, the actual presence of the civil infrastructure and particularly the water bodies that would be part of any selected option would reduce the total surface area susceptible to fires. Therefore, it is expected that the incidence of fires will decrease due to that effect. However, the induced development and the increased utilization of the watershed ecosystem could make fires to increase. As a conclusion it can be said that with good environmental management the possibilities to reduce forest fires are very good.

Terrestrial Plant Communities

The more significant direct impact expected to occur during the construction phase is the destruction of vegetation in the construction and flooding areas. It is important to emphasize that the mature forests are found fragmented in the three basins and these fragmented forest could be affected by any options. This impact is directly proportional to the magnitude of the water option and therefore greater for Option 1. The forest, pastures, and stubble areas that would be affected per option are indicated below (Table RE-5).

Table RE-5
Potential Direct Impacts of the Water Options on the Vegetation

Options	Forest	Pasture	Stubble	Hectares
1. Indio 80-40	1148.01	1938.46	1642.30	**4728.77**
2. Indio 45-40	541.68	1019.46	868.30	**2429.44**
3. Alto Indio 50-40	351.83	538.26	507.10	**1397.19**
4. Alto Indio 45-40	336.96	508.16	488.30	**1333.42**
11. Teria Sub-watershed	224.94	183.68	747.18	**1155.80**
12. Teria + Indio Cabecera	236.62	207.40	785.07	**1229.09**

In addition, the effect of induced development that any of water options is expected to cause, could contribute to increase the rate of land use changes, thus promoting cutting of additional areas. The cutting of arboreal vegetation is the one that could have greater negative effect over the terrestrial communities both in terms of direct as well as indirect impacts.

Diversity of Terrestrial Fauna

The development of one or more of the water options in support of the modernization and expansion of the Panama Canal could adversely affect the diversity of the terrestrial fauna in the Rio Indio watershed. However, all the proposed water options would flood terrestrial habitat that has a relatively low value given the deterioration it has suffered. The majority of impacts may be reduced and mitigated by means of appropriate ecological restoration aimed to compensate for the impacts that would be caused. In general terms the forest and particularly the mature forest is the more important habitat type for the native species. In the previous Table (RE-5) is clear that Options 1 and 2 are the ones affecting a greater extension of forest habitat.

Another direct impact also considered during the construction phase is the potential mortality of fauna that could occur when vegetation is cleared and when the area is flooded. If is necessary, a rescue effort is recommended for those species that have limited mobility mainly amphibians and small reptiles, eggs and newly hatched birds, and immature mammals.

Aquatic Plants

The potential infestation of the reservoirs with high levels of aquatic plants may also have negative consequences on public health, human activities, and the aquatic fauna in general. However, the risk of excessive proliferation of aquatic plants in the long run in the reservoirs is relatively low.

It is expected that during the first few years the system would be affected by floating plants (water lettuce and water hyacinth), which are easily dispersed by the wind action and would be favored by the high nutrient levels that are typical of the initial stabilization phase of the reservoir. However in the long run, if the eutrophication process progresses slowly, as predicted, a change towards Hydrilla dominance could be expected. With deep light penetration and clear water column is possible that Hydrilla establishes in those areas the reservoirs with depths lower than 10 meters.

Fish and Aquatic Macro-Invertebrates

The expected impacts of the construction of one or more reservoirs in the Rio Indio watershed, on fish and aquatic macro-invertebrates populations, will show up primarily in the long run and during the operation phase of the selected water option. Those impacts are primarily associated with the physical barrier of the dam, which restrict the movement of those species up and down the river and by the reduction of the water flow in the section of the river downstream from the dam. On the other hand, the construction of a new environment provide additional habitat for some species already existing in the hydrographic system as well as for other that will certainly arrive.

There two impacts that are considered to be significant. The first one is related with the potential development of fisheries, which will positively contribute to the nutrition and every day diet of the local populations and that could also become an attractive and significant income alternative for a group of local residents. The second one is the possible disappearance of five fish species (*Sycidium altum* and *Awaous banana, Agonostomus monticola, Joturus pichardi* and *Pomadasys crocro*) and five crustaceans (*Macrobrachium carcinus*, *M. acanthurus, M. crenulatum, Atya scabra* and *Potimirim glabra*), of the watershed sections upstream from the dam, these species cannot complete his biological cycle because they need the estuarine area to the reproduction.

Potential Population Displacement

The relative impact of the six water options under consideration in the Rio Indio watershed is not lineal regarding their potential social impact, since there is no arithmetic relationship between the reservoir and the affected population. The reason for this is that the location of the population settlements depends on factors different than the factors that determine the water contribution of

each option under consideration. Therefore, each option has different potential impacts associated with it, which are not necessarily related to the contributed water flow (Table RE-6)

Table RE-6
Population that could be Directly Affected by the Water Options

Option	Houses	Population	Comparative Impact Index on the population
1. Rio Indio 80-40	327	1,568	**1.00**
2. Rio Indio 45-40	199	939	0.60
3. Alto Indio 50-40	72	316	0.20
4. Alto Indio 45-40	67	286	0.18
11. Sub-watershed Teria	174	900	0.57
12. Teria + Rio Indio Cabecera	181	950	0.61

Potential Impact on the Community Cohesion

Although there is no precise way to determine the direct impact of the options on the community cohesion, an approximation can be made using the number of settlements affected by each option (Table RE-7). Although the number of settlements is a gross approximation of the possible impact of each option, the size of the settlement is also very important, since it is much more difficult reconstruct the social cohesion of the individual settlements as their size increases. Field data indicated that the number of settlements with more than 10 houses is relatively small, but significant.

Table RE-7
Impact of the Water Options on the Population by Settlements Size

Alternative	Settlements	Settlements with 10 houses or more	Settlements with 20 houses or more
1. Rio Indio 80-40	37	14	3
2. Rio Indio 45-40	23	9	2
3. Alto Indio 50-40	8	4	0
4. Alto Indio 45-40	7	4	0
11. Teria Sub-watershed	17	5	3
12. Teria + Rio Indio Cabecera	18	5	3

Public Health Risks

From the point of view of disease and potential deterioration of public health vector transmitted disease shall be considered as the first priority. The one vector transmitted disease that stands out in the watershed is Lehismaniasis. Although this disease is not directly related to water habitat since neither its etiological agent, nor the vectors or wild hosts populations would be affected by the execution of the selected water option, it is possible that the movement of population to other

locations during the resettlement program expose humans to areas of high incidence of infested hosts. Other vector-transmitted diseases, which shall be very closely monitored given their relationship with the aquatic habitat, include malaria, Venezuelan equine encephalitis, Yellow fever and dengue.

Potential Impact on Employment and Income

All the options considered have the potential of employment and income generate much between the local population, especially on those settlements that could be displeased, any time it is invested in training programs that allow the economically active population to acquire new skills and to increase his productiveness, will be available. An efficient manner to facilitate this is through of training executed by independent entities, under contract with ACP. Although it is difficult to predict the proportion of labor that could be qualified under this system, the magnitude of the employment may be estimated based on increasing participation proportions of local labor in the construction works for the selected water option, as shown in Table RE-8

Table RE-8
Potential Impact of the Local Employment on the Regional GDP

Option	Number of Families	% of labor participation			Impact on GDP[1]		
		10%	25%	50%	10%	25%	50%
1. Rio Indio 80-40	327	78,480	196,200	392,400	1.42%	3.54%	7.08%
2. Rio Indio 45-40	199	47,760	119,400	238,800	0.86%	2.16%	4.31%
3. Alto Indio 50-40	72	17,280	43,200	86,400	0.31%	0.78%	1.56%
4. Alto Indio 45-40	67	16,080	40,200	80,400	0.29%	0.73%	1.45%
11. Teria Sub-watershed	174	41,760	104,400	208,800	0.75%	1.88%	3.77%
12. Teria + Rio Indio Cabecera	181	43,440	108,600	217,200	0.78%	1.96%	3.92%

The effect of the additional employment for the displaced population on the regional GDP may become substantial. If one adult, in 10% of the displaced families is employed in the construction works with a B/.200 a month salary, the annual impact over the current regional GDP could reach up to 1.42%. Now, if 50% of the displaced families have an adult working in the construction, the additional impact could reach 7.08%. In both cases the greater effect is associated with Option 1.

Potential Impact on the Trade and Marketing Channels

The physical change that Rio Indio would undergo with the construction of the civil works associated with any of the options, would alter the communication and trade patterns within the

[1] Evaluated over GDP of the ROCC

area. This will affect the populations located along the river, which will probably see a significant reduction of their commercial activities as a result of a net substitution of the commercial traffic from the fluvial mode to a terrestrial mode. This transformation shall be expected, given the presence of access roads included within the program for the construction of the water options and by the presence of the dam. In the upper portion of the watershed a connection with the market centers such as Capira and El Valle already exist. The marketing and exchange channels are well defined, and it is very unlikely that they will show a radical change as a result of the construction activities.

Impact on the Local Infrastructure

Since the presence of infrastructure in any given area is normally directly proportional to its economic importance, it is not surprise to find that the infrastructure potentially affected by the water options is relatively small (Table RE-9). The churches are the more abundant type of infrastructure, followed by cemeteries, schools and the community centers. The number of health centers is relatively limited considering the number of people, which is another indicator of the low quality of life prevailing in the region.

It is important to point out that the population affected by the loss of this infrastructure transcends the displaced population. Every piece of social or economic infrastructure has an area of influence that in most cases overlaps only partially with the areas that would be flooded. As a result, a school may serve three towns, of which only one will be flooded. However, the total impact of losing that school includes the population of the three towns.

Potential Impacts on the Agricultural Production

The loss of production could represent an average of el 42% of the family consumption. Therefore, the cost of the agricultural production that would be lost by flooding is a very important component of the total regional income. Since the agriculture of the region is primarily of subsistence nature and changes location from year to year, the evaluation used the total area suited for crops as a point of departure to assess the impact on the total production (Table RE-10). According to the socioeconomic data gathering study, a typical farm produces a gross income of B/.232 per capita[2]. Therefore, *annually* the production value that would be lost could range between B/.66 thousands and B/.364 thousands in the areas directly affected by each of the options.

[2] This estimate is based on 42% of the per capita income of B/. 547 documented for the region. The remaining 58% comes from family transfers and from non agricultural activities.

Table RE-9
Potential Impacts of the Water Options on the Local Infrastructure

Infrastructure	Rio Indio 80-40	Rio Indio 45-40	Alto Indio 50-40	Alto Indio 45-40	Teria Sub-watershed	Teria + Indio Cabecera
Buildings	**No.**	**No.**	**No.**	**No.**	No.	No.
Schools	11	3	1	1	7	7
Health Centers	3	1	0		2	2
Recreation Area	6	4	2	2	5	5
Cemeteries	8	4	3	3	2	2
Church	15	6	2	2	5	6
Community Board	9	4	1	1	3	3
Roads	**Km.**	**Km.**	**Km.**	**Km.**	**Km.**	**Km.**
Permanent	1.00	0.00	0.00	0.00	0	0
Dry season	18.80	8.70	4.40	3.60	0	0
Horseback	71.80	40.80	8.40	7.80	0	0
Facilities	**No.**	**No.**	**No.**	**No.**	**No.**	**No.**
Telephone Antenna	3	2	0	0	1	1
Electric poles	0	0	0	0	0	0
Cabled bridge	0	7	3	1	5	6
Concrete bridge	0	0	0	0	0	0
Wooden bridge	8	0	0	0	0	0
Convenient stores	16	7	1	1	4	4
Bus stops	0	0	0	0	0	0
Phone cabin	3	0	0	0	0	0
Storage tank.	2	0	0	0	2	2

Table RE-10
Annual implicit Value of the Production Affected by the Six Water Options (B. /)

Option	Population	Implicit value
1. Rio Indio 80-40	1,568	363,776
2. Rio Indio 45-40	939	217,848
3. Alto Indio 50-40	316	73,312
4. Alto Indio 45-40	286	66,352
11. Teria Sub-watershed	900	208,800
12. Teria + Rio Indio Cabecera	950	220,400

Regarding the impact on livestock, it is difficult to estimate a direct impact given that the animals can move. In other words, they could be transported to areas out of the flooding perimeter without loosing their value. The impact is only proportional to the cost of transportation. On the other hand, the inventory of animals that would have to move is only an approximation, since the actual herd is constantly moving within the several "corregimientos" in the area.

Potential Impact on Mining Concessions

There exist five mining concessions that include portions of the Rio Indio watershed according to the socioeconomics data report of the Western Region[53]. However, since this information comes from a study conducted in the year 2000, during the execution of this study the URS team contacted the Department of Mineral Resources of the Ministry of Industry and Commerce, who indicated that none of those concessions is currently valid.

Archaeological Resources

The available information indicates that impacts on the known archaeological resources are different for each one of the six options (Table RE-11). The sites that could be impacted according to the inventory of the cultural study[25] consider those sites that are of high and medium importance, which are identified by the site code (for example, Pn-50); and include the sites of lower importance, which are considered only as the total number.

Table RE-11
Potential Archaeological Impacts of each Water Option

Options	Archaeological Sites that could be Impacted			Weighted Impact
	High Importance (1 site = 10 points)	Moderate Importance (1 site = 5 points)	Low Importance (1 site = 1 point)	
Option 1	1 site (Pn-50)	1 site (Cp-37)	14	29
Option 2	1 site (Pn-50)	1 site (Cp-37)	5	15
Option 3	without sites	1 site (Cp-37)	3	8
Option 4	without sites	1 site (Cp-37)	3	8
Option 11	without sites	3 – (Cp-35; Cp-43; Cp-44)	15	30
Option 12	without sites	3 – (Cp-35; Cp-43; Cp-44)	2	18

Landscape, Scenic and Recreational Resources

The local population uses several sites throughout the area for recreational activities as diverse as swimming, boat rides, horseback ridding, fishing, hunting and walking, among others. In order to identify those towns that could see their recreational and scenic resources affected the GIS database of the socioeconomic study provided the basic information about location of towns and sites, which was superimposed on the description of the several water options (Table RE-12).

Summary of Potential Socio-environmental Impacts and Risks

To finalize the section on impacts, Table RE-13 at the end of this executive summary presents a summary of the impacts, their associated mitigation measures, and an overall ranking by option. Option 1 received the highest score of 99, since as stated before is the largest and the impacts are for the most part directly related to the magnitude of the reservoir and associated works. Option

11 follows with a score of 84; being the most significant potential impacts in this option those related to water resources, air quality and noise. Option 12, got a score of 75 points, with a trend very similar to Option 11, regarding the type of impacts that are more significant. Option 2 is ranked in fourth place with high values for the potential impacts on air quality aquatic communities, and noise. The lower scores went to Options 3 and 4 (45 and 46 respectively); these are the options that would have a smaller impact on the physical medium, the biological diversity, and the socioeconomics and cultural aspects.

Table RE-12
Scenic and Recreational Resources that could be Affected by Option /1

Option	Town	Site of Local Interest	Type of Associated Activity
1 - Indio 80-40	Boca of Uracillo San Cristobal La Conga Abajo Tres Hermanas	Rio Indio and Uracillo Plains Rio Indio, water falls, ponds Rocks / Petroglyphs Indian rocks, waterfalls	Swimming and boating Touring, fishing, hunting Touring
2 - Indio 45-40	Boca of Uracillo San Cristobal La Conga Abajo	Rio Indio and Uracillo plains Rio Indio, waterfalls, ponds Rocks / Petroglyphs	Swimming and boating Touring, fishing, hunting Touring
3 - Alto Indio 50-40	San Cristobal La Conga Abajo	Rio Indio, waterfalls, ponds Rocks / Petroglyphs	Touring, fishing, hunting Touring
4 - Alto Indio 45-40	San Cristobal La Conga Abajo	Rio Indio, waterfalls, ponds Rocks / Petroglyphs	Touring, fishing, hunting Touring

Source: Prepared by URS with data from the database of the socioeconomic study of the ROCC
1/ the information is not available for options 11 and 12.

It is important to point out here that these scores take in consideration only the impacts that would be generated by each option, independently of the benefit (water production) each one of them may contribute to the Canal system. In order to perform a complete comparison amongst the options the water yield "benefit" must be taken into account. That comparison is included in Chapter 6.0 of the study and later in this executive summary.

ENVIRONMENTAL MANAGEMENT PLAN

Based on the previous considerations we concluded that in order to make the execution of any water option feasible from the social and environmental standpoint an environmental management plan (EMP) is needed to work primarily in two main axes: the adequate relocation and the improvement of the living conditions of the local communities; and the recovery, improvement, and conservation of the environmental goods and services associated with the watershed's original ecosystems. Therefore, the two main components of the EMP are:

- A **resettlement human development plan** that properly compensate the losses and difficulties, and that particularly improve the living conditions of the communities, families

and people that could be affected by the implementation of the water option(s), which may be selected; and

- A **recovery and protection of the biophysical conditions plan** for the Rio Indio watershed, with the purpose as much as possible reestablishing the environmental goods and services, thus reducing the environmental risks for the operation of the Canal.

These two main components of the EMP include a set of measures fro the prevention, reduction and control of the potential socio-environmental impacts and risks, which are directly aimed to avoid and minimize the effects of the potential negative socio-environmental impacts and risks and maximize the positive ones. In essence the plan includes actions oriented to prevent the socio-environmental impacts and risks that can be prevented, reduce those that cannot be prevented, compensate for the net effects that could not be prevented or reduced, and maximize the potential directs and indirect benefits.

In Addition to these two main components, in order to complete the EMP it is necessary to include other plans and programs, which will facilitate the EMP meeting its main goals and objectives. Among these the more important include:

- A **socio-environmental monitoring plan** with the parameters and indicators that shall be measured and the frequency of information gathering for each one of them. The monitoring activities seek a double purpose; on one hand periodically verify that the measures for prevention, reduction and control are meeting their objectives; and for the second part document the state of socio-environmental "health" in the area of influence.
- A **program for verification and control**, with its execution mechanisms including activities with a structure similar to those of the monitoring plan, with the purpose of demonstrating and documenting that the planned actions are effectively being executed. Rather than to determine the environmental "health" of the region, this program aims to measure the effectiveness of the environmental management and the administrative procedures in place. The National Authority for the Environment (ANAM) will be, by law, responsible for this program and the ACP must coordinate with this institution to execute this program..
- A **contingency plan,** which include the measures to prevent, reduce, control, or respond to any emergency conditions. The plan includes the prevention and control measures for spills of hazardous substances such as oil, fuel, and paints, amongst others; as well as any other contingencies particularly during the construction phase. During the operation phase an evacuation and protection plan for the communities downstream the dam shall be available, in case of dam failure.

- A **proper budget,** which shall cover the costs of the measures for the prevention, reduction and control of the socio-environmental impacts, the monitoring, and verification and control activities that together conform the EMP.

Below is a brief description of the main components of the EMP, and in Table RE-13 at the end of this summary are the main measures considered for the prevention and control of each one of the identified impacts.

Resettlement and Human Development Plan

The resettlement and human development plan includes the actions for the prevention, reduction and control of the potential socio-environmental impacts and risks to the population, which could be direct and indirectly affected in case that any of the considered water options is implemented. The prime objective of the plan is to prevent, reduce and control the potential negative socio-environmental impacts and risks, maximize the positive ones and improve the local socioeconomic infrastructure to make sure that the inhabitants in the area of influence of the selected option end with improved living conditions than those prevailing prior to the execution of the water option.

The execution of any of the water options under consideration would have directs and indirect impacts on the population currently living in the areas of potential flooding. At the family level those impacts include the displacement from those areas of the affected families, its belongings, production and subsistence means, and their communities' social and cultural web. At the communal level the impacts include the loss of the social and economic infrastructure, the displacement of the nucleus of commercial activity and the informal institutional network in which the every day life of the community goes about.

On the other hand, the execution of any of the water options would also have positive impacts, such as the generation of paid employment in one of the poorest regions of the country, as well as the opportunity to acquire new and enhanced productive skills, which could generate a greater permanent income to the affected families. Finally, the execution of the water options provides an opportunity to improve the level of regional development and the public socioeconomic infrastructure, supported by the scale economies that the construction activities for any of the options would bring about. The potential impacts and risks on the socioeconomics and cultural aspects were described in the section of impacts.

It is certain that the water options under consideration would have directs and indirect impacts on the population of the Rio Indio watershed. To minimize those impacts at least the following three main factors shall be taken into account:

a. **An appropriate estimation of the compensation for the affected population**. The compensation figures, the administration and payments of those values and the minimization of the local inequalities that these compensations may cause are of great importance to reduce the social impact and to improve harmony among the displaced and the non-displaced citizens. Primarily, the program shall avoid the over heating of the local economy, which may occur as a result of the sudden injection of cash resources to a reduced population group. This possible over heating could lead to high levels of local inflation, which would harm the population in the receptor communities, giving rise to a local discord factor. As will be shown below, the compensation should avoid the generation of winners and losers within the local communities.
b. **Create an environment of opportunity.** When the extreme poverty conditions are suddenly disrupted by a high level of social and economic assistance an incentive for aid dependence may be created. In other words there is a risk for creating a dependence attitude that will not lead to local development. Therefore, the compensation mechanisms shall be aimed to the construction of opportunities (vg: development of the local economic infrastructure and local training and education) and no to the mere and simple transfer of money.
c. **Provide public goods**. To avoid resentment from the non-compensated families, the mitigation program must emphasize the provision of public goods, such as electricity, potable water, basic education, good quality of public health services, and those communication and transportation means that would benefit the displaced as well as the non-displaced sectors of the regional population. In this way there is significant consistency in the distribution of the benefits amongst both groups, providing at the same time the local share of the Canal expansion benefits[3].

Recovery and Protection of the Biophysical and Cultural Conditions Plan

The plan for the recovery and protection of the biophysical and cultural conditions in the area of influence includes the actions for the prevention, reduction and control of the potential impacts to the environmental goods and services provided by the ecosystems within the watershed;

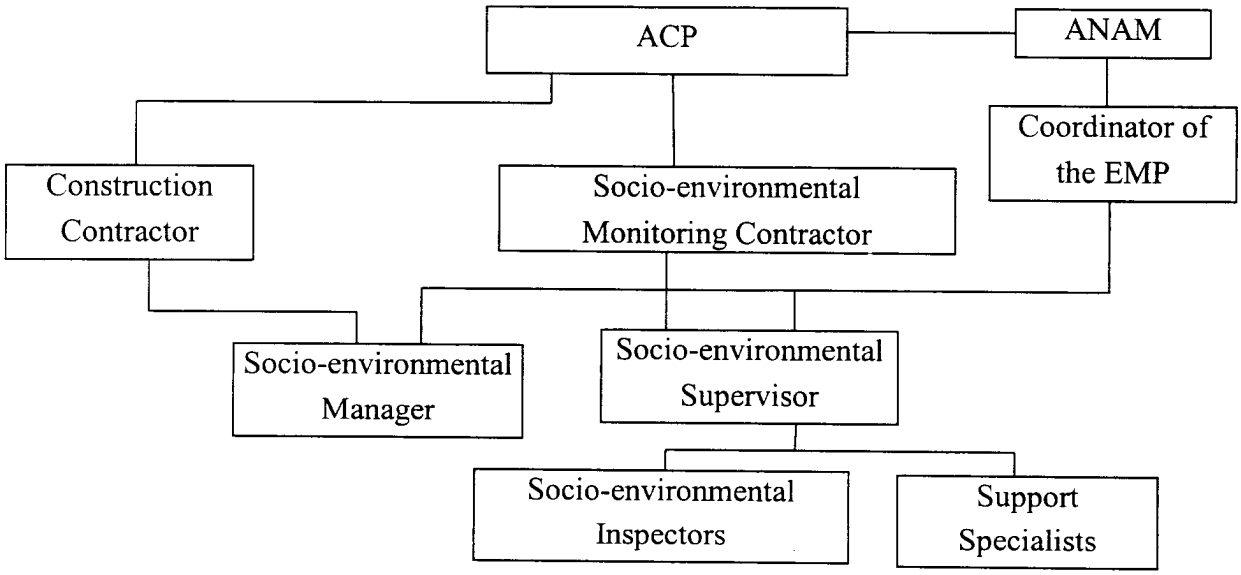
[3] These three points are critical factors and are completely consistent with the lessons learned on the subject of involuntary displacement and the resettlement of families in conditions similar to those of the Rio Indio watershed, which are summarized in: World Bank, 1996. "Resettlement and Development: The Bankwide Review of Projects Involving Involuntary Resettlement 1986-1993." Environment Department Paper No. 032, Washington DC. Those lessons indicated that the **proper estimation** of the compensation, together with the constant supervision and **enforcement of the agreements** with the displaced are of outmost importance for the success of the resettlement program.

particularly, those that could be directly or indirectly affected by the implementation of one or more of the water options under consideration. This plan includes the mitigation activities organized by programs, which focus on specific subjects. The structure of each of the programs is similar and includes a brief justification, its objectives and the description of the prevention, reduction and control measures. These measures may be tailored to each of the main execution phases such as final design, construction, operation and the eventual abandonment. The details associated to the measures of prevention, reduction and control were organized in the following programs.

A. Air quality protection and noise control program;
B. Seismology and geology program;
C. Erosion and sediments transport prevention and control program;
D Water quality protection program;
E. Recovery and protection of biodiversity program;
F. Monitoring and control of aquatic plants program;
G. Conservation and management of fish and macro-invertebrates program;
H. Conservation and study of archaeological sites program;
J. Other programs.

Organization Chart for the execution of the EMP

The anticipated organization for the execution of the environmental management plan according to the functions attributable to each participant is shown in the following diagram.



EMP Budget

The costs associated with the EMP vary between B/.12 and 33 Million for the six options when the indemnification cost due to the removal of vegetation, which would have to be paid to ANAM, are taken into consideration (Table RE-14). The main line items of the EMP are clearly to the communities' relocation and the socioeconomic conditions improvement program. Then follows the erosion and sediment transport prevention and control program.

Table RE-14
EMP Global Budget for each Option in the Rio Indio Watershed

	OPTIONS					
	1	2	3	4	11	12
Duration of the Construction Phase (years)	5	3	3	3	5	5
A. Mitigation, Monitoring, Verification and Control						
Ressettelment and Human Development	18,414,574	10,620,217	14,399,986	9,053,914	18,985,118	15,631,523
Air Quality and Noise	S/C	S/C	S/C	S/C	S/C	S/C
Seismology and Geology	S/C	S/C	S/C	S/C	S/C	S/C
Erosion and Sediment Transport	4,750,000	2,850,000	2,850,000	2,850,000	4,750,000	4,750,000
Water Quality	450,000	290,000	290,000	290,000	450,000	450,000
Terrestrial Biodiversity Recovery	996,960	370,800	272,640	261,120	1,013,520	412,560
Aquatic Plants	115,372	88,748	88,748	88,748	115,372	115,372
Fish and Macro-Invertebrates	149,740	115,185	115,185	115,185	149,740	149,740
Archaeological Sities	1,300,000	780,000	780,000	780,000	1,300,000	1,300,000
Other Program	S/C	S/C	S/C	S/C	S/C	S/C
SUB - TOTAL	26,176,646	15,114,950	18,796,559	13,438,967	26,763,750	22,809,195
B. Indemnification due to vegetation removal						
Forest	5,740,035	2,708,385	1,759,135	1,684,785	1,124,685	1,183,085
Pasture	969,230	509,730	269,130	254,080	91,840	103,700
Stubble	1,642,300	868,300	507,100	488,300	747,180	785,070
SUB - TOTAL	8,351,565.0	4,086,415.0	2,535,365.0	2,427,165.0	1,963,705.0	2,071,855.0
GRAND TOTAL	34,528,211	19,201,365	21,331,924	15,866,132	28,727,455	24,881,050

S/C = No cost, included in the construction contract.

It is important to point out that the costs for monitoring and verification and control herein included are only to cover the construction phase. The costs during the operation phase shall be reviewed once the construction has been completed. The costs have been estimated using the information available for the water options and should be regarded as indicative only. During the preparation of the final EIA for the selected option and more precise information is acquired, EMP costs shall be determine with an error margin no greater of the 10% and shall include contingencies, this margin of error is considered to be acceptable by the international institutions of credit as the World Bank and the BID.

COMPARISON OF ALTERNATIVES

The selection of one or more feasible water options to support the Canal Modernization and Expansion Program is carried out based on two fundamental criteria:

(i) The option, or options, considered feasible must significantly contribute to the future Canal operation, with a 99.6% water reliability level;

(ii) Among all feasible options, the preferred option must minimize both economical and financial costs as well as those considered social and environmental.

These two criteria complement each other perfectly. The first criterion indicates that the preferred option must contribute enough water flow, to maintain the reliability of the Canal's water level under a higher demand scenario. Whereas the second criterion imposes certain limits on the feasibility of some options because they could be too expensive, affect many people, or cause unacceptable environmental impacts.

The process of impact identification and evaluation performed on the water options considered in this study clearly determined that the issues with greater relevance are those associated to social costs. Therefore, in order to evaluate and select one or more water source options a Linear Programming Model[4] is used, which minimizes the social cost to be obtained by the water sources, subjected to four limits as described below:

a. The selected option, or options, must provide the required water to maintain a reliability level or 99.6%.
b. The water contribution obtained for the future operation of the Canal must be of 15 lockage per day or more, (data gathered from Engineering Division, ACP).
c. The social - environmental management cost must be reasonable.
d. The direct construction costs must not be too high.

The number of potentially displaced families, for each alternative, has been selected as a social cost indicator for the implementation of one or more of the water source options. Even though this does not represent the total social cost, it is without doubt the most significant aspect, and all other costs are directly related to it.

[4] Linear Programming Models originated in the military, where it was widely used for route optimization and logistical problems. They are currently used in transportation, food production, and manufacturing, in order to optimize a large number of inputs and variables that interact in a very complex way. References about Linear Programming are vast, but the most considerable is Gass, Saul. I., 1985. *Linear Programming: Methods and Applications*. 5th Edition. New York: International Thomson Publishing.

The goal of the linear programming model is to minimize the objective function:

$$\phi(\mathbf{x}) = c\mathbf{x}$$

Subjected to the following conditions:

$$\mathbf{Ax} >\leq \mathbf{b}$$

$$\mathbf{x} \geq 0$$

Where **x** is a vector for variables x1,..., x6 that represents the twelve water source options to be evaluated; **A** is the most relevant coefficient matrix for the final evaluation; **c** is the vector for displaced families in each option **x;** and **b** are the limiting vectors. Matrix A is not square, which indicates that it has more columns than lines, so the relation **Ax = b** provides an array of values for **x** that could minimize the objective function, **cx**.

In the case of the water sources within the Rio Indio Basin, **x** is binary, in other words, each **xi** (i= 1,..., 6) takes a value of 1 or 0 depending if the option is chosen or not. This forces the model to chose each option fully, or reject it entirely within the final solution. Also, given that the options are considered exclusive; a restriction has been introduced in the model that will not allow for combinations. In other words, it reflects the fact that the combination of various civil works (dams, channels, tunnels, etc) has been considered in the definition of each analyzed option.

The relation **Ax >≤ b** shows the restrictions imposed by the cost and physical limitations vector on the selection of options. This means that each matrix component has a limitation that is taken into account when a solution is generated. Sometimes this limitation has a minimum value, and other times a maximum value. Vector **b** must include the environmental management costs required to assure that: potential negative impacts are mitigated in an appropriate way by means through preventive measures or compensation activities, and the physical restrictions related to the sustainable management of natural resources and biodiversity.

The results indicate that Rio Indio 80-40 option is the preferred alternative for the additional supply of water for the Canal (Table RE-15), even though the social costs are higher than the other options. The number of lockage per day for Rio Indio 80-40 is greater than the minimum required to reach the water confidence level: 15 additional lockage. However, this reservoir affects 327 families that would have to be evacuated, resettled and compensated. The cost per vessel transit for other options to reach significant water contributions for the Canal operation, more than 6 lockage per day, is considerably higher than the Rio Indio option.

Using the same model a sensitivity analysis was performed. In this case, the objective function was changed to maximize water production for the operation of the Canal, keeping the same restrictions previously applied. The solution yielded by the model was exactly the same, which demonstrates the confidence level of selecting Option 1: Rio Indio as the preferred option among those that are feasible.

Table RE-15
Selected Option in the Rio Indio Watershed

Number of displaced families		**327**		
Selected Option - Option 1: Rio Indio 80-40				
Limiting factors				
Variable	**Value**	**Limit**	**Status**	**Remainder**
Socio – environmental costs (x $1,000)	33,143	<= 40,000	Does not limit	6,854
Proportion of affected forests %	9.1%	<= 30.0%	Does not limit	20.9%
Proportion of affected area %	11.97%	<= 15.0%	Does not limit	3.03%
Proportion of displaced population %	25.33%	<= 35.0%	Does not limit	9.67%
Risk of eutrophication - µg P/lt	0.0017	<=0.03	Does not limit	0.0283
Displaced families	327	<=400	Does not limit	73
Production of water (106 m3/yr)	1,201	>=0	Does not limit	1,201
Recovery time (yrs)	1.77	<=2	Does not limit	0.23
Direct cost of construction ($ K)	230,430	<=400,000	Does not limit	169,570
lockage / day	15.8	>=15	Does not limit	0.8

CONCLUSIONS OF THE COMPARISON OF THE WATER OPTIONS

In general terms, Option 1, Rio Indio 80-40 is the recommended option under different model scenarios and restrictions. Selection of water source options by the model are driven by two main variables: (i) the number of required lockage to improve and maintain the level of water reliability of the Canal, and (ii) minimization of the impact on the number of families displaced by each of the options. These two variables have environmental and financial restrictions, which could affect the selection of a particular option.

The selection of Option 1 is a very strong choice over any of the other options since it provides a significant amount of water for the Canal at a relatively low cost per lockage and with an intermediate total impact on the population and a rather modest impact on biodiversity. Actually, when the water yield is taken into account the impacts per lockage are lower than for any of the other options. Although there options that directly displace a smaller number of families, their water contribution for the Canal are only a fraction of what Rio Indio 80-40 provides. Furthermore, none of the identified impacts for any of the six options is considered a "fatal flaw". In other words with the socio-environmental management measures in this study, which

may be refined when additional information becomes available, any of the options could be constructed and operated in a social and environmentally feasible manner.

As a final conclusion, it can be established that Option 1: Rio Indio 80-40 is the best considering water production, costs, and social – environmental impacts. In second place, Option 12 could be considered only if the production of 5 lockage per day becomes attractive for the ACP within the efforts for modernization and expansion of the Canal. The other options should not be considered feasible, either because of their poor water contribution to the system or because of the implementation costs.

PUBLIC PARTICIPATION

This effort also included the analysis of the information available about public participation promoted by the ACP, particularly local communities in the watershed, in the planning process to date. In addition to this review a public participation plan was drafted. The main objective of this plan is to continue the process of identifying the communities' concerns and incorporating their views, preferences and suggestions, to the extent possible, to the selection process for the best water option. The proposed participation plan includes a detailed program for the public events, a mechanism for the democratic selection of the participants, a format for the invitation to the events, a group dynamic methodology, a list of expected results, a mechanism to devolve the relevant final results to the communities, a budget and a schedule for implementation.

Based on the existing information the team identified the possible topics, which may emerge during the events, and what the specific opinions of local communities' representatives may be on each issue. The execution of the Public Participation Plan is expected to have the following positive effect over the water options evaluation and selection process:

- Facilitate the design, presentation and discussion of mitigation, compensation, and resettlement plans, as well as the conditions and required agreements for their execution;
- Allow an active participation of the different social segments (women, young and elder) who would be identified during the invitation process for the programmed events;
- Allow the clarification of doubts and questions the local residents have about the water options, mitigation and compensation measures, and resettlement, amongst others;
- Promote the direct dialog and open communication between interested the parties;
- Clarify the topics associated with the modernization and expansion of the Canal and the water options that are being considered in the region (rumor control);
- Establish formal agreements and a schedule of activities for their implementation;

- Establish the conditions for the appearance of a representative local leadership willing to dialog.

Finally, based on the information analyzed, the following conclusions may be reached:

- The existing information generated by the participation process conducted to date allows for the identification of several opinions and issues that may come out during the execution of the Plan;
- The opinions that have been identified do not necessarily encompass the opinions of all the participants groups that can be identified as relevant for the process (displaced, isolated, downstream communities, etc.);
- The analysis conducted is a good indicator of the topics that should receive especial attention during the execution of the Participation Plan.
- In general terms, the preoccupations and concerns of the local residents are focused on the issues associated with land tenure / titling and the construction of public infrastructure to cover the basic needs, more than environmental topics.

Table RE-13: Summary of the Potential Socio-environmental Impacts and associated Mitigation Measures for the Water Options in the Rio Indio Watershed

Potential Socio-environmental Impacts	Option	Score	Acc. Score	Prevention and Control Measures
A. Potential Impacts on the Physical Environment				
1. Geology and Seismology The geologic and geotechnical characteristics of the watershed do not present any adverse condition that could not be mitigated by means of a conventional design and appropriate construction methods. In addition, in the dam site of options 1 and 2, no active flaws were detected nor materials capable of liquefaction during an earthquake. - in the construction phase the risks will be due to: Landslides: i) roads (greater risk in options 11 and 12 due to steeper slopes); and ii) in the other projects. The construction of the tunnel with a concrete covering to avoid water filtrations and the presence of dangerous gases. Inadequate disposal of waste material (greater volume with the largest option: 1, 12, 2, 11, 3 and 4, respectively). - in the operation phase the risks will be for: Landslides: i) roads (greater risk in options 11 and 12 due greater fluctuations in elevations: option 1, 12, 11 and the rest). Earthquake: the possibility that an earthquake affects the project is relatively small. Water filtration through, below or around the dam: i) filtration is considered to be minimal; ii) on a fault occurring, the greatest damage (downstream) would be caused by options 11 and 12 because they are higher up in the watershed.	1	10		1. Geology and Seismology • Performance of detailed geological and geotechnical studies of the option selected an incorporate them to the design. • Use of appropriate design and construction methods. • Maximum talus slopes, depending on type of rock. • Monitoring and control of seepage and hazardous gases. • Adequate disposal of waste material. • Road maintenance (adequate collection and disposal of material). • Earthquake monitoring network • Consider the incorporation of drainage to the dam foundation; instruments to detect seepage.
	2	5		
	3	5		
	4	5		
	11	9		
	12	9		
2. Soils The biggest percentage of the soils of the watershed has little agricultural value (classes VI and VII). - The greater the size of the project (reservoir) the bigger impact to the soil (1, 12, 2, 11, 3 and 4). - Development induced by the project can provoke deforestation and greater agricultural activity.	1	8	18	2. Soil Conservation • Zoning of land use; • Control of induced settlements.
	2	5	10	
	3	4	9	
	4	4	9	
	11	7	16	
	12	7	16	

Table RE-13: Summary of the Potential Socio-environmental Impacts and associated Mitigation Measures for the Water Options in the Rio Indio Watershed

Potential Socio-environmental Impacts	Option	Score	Acc. Score	Prevention and Control Measures
3. Water Resources Quality of water resources in the watershed is good, but may deteriorate during the project construction, if measures are not implemented to minimize runoff and spills and to treat residual waters. During operation water quality of the reservoir will be monitored to determine changes and eutrophication risk, in order to take the necessary preventive and corrective measures. A. Water level and water flow below the dam: - During operation the maximum water flow under the dam will have a significant attenuation (about 85 to 90 %; HEC-5), therefore, a reduction in floods (negative effects on terrestrial and aquatic ecosystems but lower risks to goods and loss of human lives). - During operation there will be an attenuation of the riverbed downstream. The degradation of the bed will be insignificant (stabilization efforts are not needed), but the reduction of water flow may lead to changes in the mouths of tributaries; the reduction in transported sediment could increase erosion of the canal immediately below the dam; the reduction of the capacity of the river to transport sediments may lead to accumulation of sediments at the mouth of tributaries, which may affect navigation. B. Erosion and sediment transport: -During construction water quality may deteriorate due to the sediments from the earthworks. -During operation sedimentation in the reservoir will not be a problem and dredging will not be required; Less than 2 % of the reservoir capacity will be lost after 100 years(1.4 mm / year; 1.04 ton/m^3). C. Quality of the water and eutrophication risk: -During construction, deterioration in water quality due to the contribution of sediments (erosion), residual waters and hydrocarbon spills. -During operation, the concentrations of dissolved oxygen will be: i) water below the dam sites: lower concentrations in the layers near to the bottom and more than anything by the amount of organic material present in the water when the reservoir is filling, affecting ecosystems and water quality; This situation can be alleviated by changing the depth of the water exits; ii) Gatún water quality would not be affected by the transfer from any of the options; it will not be necessary to change the depth of the intakes. -During operation, the temperature or thermal stratification will be a more or less stable, this thermal stratification will be influenced by the presence of winds, especially during the dry season; Water options 3, 4 and the reservoir at the Rio Indio Headwaters, the water will circulate with certain frequency partly due to its comparative low average depth. The thermocline will be between 10 and 15 meters deep. -Light penetration will be up to 15 meters deep. -During operation, the risk of eutrophication is low. Concentrations of phosphorus and chlorophyll in the water options, in ascending order, the following: 12, 11, 1, 2, 3 and 4.	1	5	23	3. Water Resources • Monitoring of erosion and sedimentation processes and delivery of sediments to reservoir • Set up of a system of incentives and fines for those improving or deteriorating the water quality, directly or indirectly, respectively. • Set up of minimum ecological flow to maintain the current vital functions of ecosystems • Measures such as water barriers, filtering fences and talus stabilization • Maintenance of structures for erosion prevention and control. Monitoring of sediments and changes in land use • Prevention and control measures for erosion, and wastewater and spills. • Arrange water outlets at different depths. Monitoring of oxygen concentration in water column. • Monitoring of temperature in the entire water column. • Trees and vegetation to be flooded should be cut.
	2	5	15	
	3	6	15	
	4	6	16	
	11	7	23	
	12	7	23	

Table RE-13: Summary of the Potential Socio-environmental Impacts and associated Mitigation Measures for the Water Options in the Rio Indio Watershed

Potential Socio-environmental Impacts	Option	Score	Acc. Score	Prevention and Control Measures
4. Air Quality The most important impacts on air quality are principally related to the emission of dust from the areas devoid of vegetation and by the traffic of trucks that transport material on the tertiary roads. - During construction more than during operation, options 1 and 2 would affect the air quality of a slightly greater number of towns, but options 11 and 12 would affect the biggest number of sensitive receptors (schools, churches and health centers), than the other alternatives. - During construction, laborers will be exposed to dust and possibly other substances. - During operation, the incidence of forest fires. The area of the reservoir would not be susceptible to fires (positive impact). But better access to the area might intensify the alteration of the vegetation coverage and to contribute to more zones with fires.	1	6	29	4. Air Quality • Prevention, reduction and control measures such as watering of roads and periodical and systematic maintenance of vehicles and pollutants control. • Provide workers with equipment for protection against dust. • Program for control of induced settlements and fire prevention and control programs.
	2	5	20	
	3	3	18	
	4	3	19	
	11	5	28	
	12	6	29	
5. Noise The most important impacts of noise are principally related to construction activities of and by the traffic of trucks that transport material. - During construction more than during operation, options 1 and 2 would affect a slightly greater number of towns, but options 11 and 12 would affect the biggest number of sensitive receptors (schools, churches and health centers), than the other alternatives. - During construction, laborers will be exposed to noise, which will exceed safety levels.	1	5	34	5. Noise • Control of schedule for vehicle transit and of systems for noise and vehicle speed, and periodic and systematic maintenance of vehicles and equipment. • Provide workers with noise protection equipment.
	2	5	25	
	3	3	21	
	4	3	22	
	11	3	31	
	12	5	34	
B. Potential impacts and risks on the Biological Diversity				
6. Terrestrial communities Because of the high rate of existing human intervention, biological diversity has a value relatively low in the Rio Indio watershed. The construction of any of the options will inevitably result in the removal of permanent vegetation. The greater the area of the reservoir, the greater the loss of vegetation; None of the socio- environmental impacts and potential risks are significant enough to prevent the execution of the project. - During the construction phase, there would be cutting to construct roads, other projects and the reservoir between 110 (option 4) and 460 hectares (option 12) of mature forest. - During the construction phase, the majority of terrestrial fauna species would be negatively affected by the loss of the habitat, especially the slightly disturbed forest. - During the operation phase, additional habitat will be provided for waterfowl.	1	6	40	6. Terrestrial communities • Set up a system of payment for environmental services for the protection of biodiversity, specially of the watershed forest, specially upstream from the reservoir • Re-vegetate 30 meters along the streams and protect adjacent vegetation • Restrictions on workers against hunting, and plant and animal collection. • Incorporate the ROCC and specially the Rio Indio watershed as part of the Central American Biological Corridor to be incorporating to his conservation programs.
	2	3	28	
	3	2	23	
	4	2	24	
	11	5	36	
	12	5	39	

Table RE-13: Summary of the Potential Socio-environmental Impacts and associated Mitigation Measures for the Water Options in the Rio Indio Watershed

Potential Socio-environmental Impacts	Option	Score	Acc. Score	Prevention and Control Measures
7. Aquatic communities The experience about the growth of aquatic weeds in Panamanian reservoirs indicates that these will invade any of the proposed reservoirs. - During construction, even if the majority of the arboreal vegetation is cut, aquatic weeds will proliferate by the lixiviation of nutrients in naked areas product of the forest removing. - During operation, experience in the country in the control of the aquatic weeds can be counted on. - During the operation phase of the reservoir, fish will be subject to a new regime: from lotic to lentic. The experience in the reservoirs of the country indicates that the introduction of the peacock bass and tilapia generates an important fishing activity for the riverside communities. - During operation, the fish and macro-invertebrates will present the following characteristics: i) 23 species of fish will remain in the reservoir and tributaries; ii) 4 species will disappear upstream with the interruption of his biological cycle; iii) population alterations will not be as drastic downstream from the dam; iv) rapid fluctuations of reservoir level affect the fish that use the banks to lay their eggs (trunks and weeds), since they would become exposed; v) 2 species of scientific importance associated with streams above the reservoir will not be affected; vi) the introduction of the peacock bass and tilapia could generate an important fishing activity for the communities relocated near the reservoir.	1	5	45	7. Aquatic Communities • Monitoring • Integrated control, if necessary. • Design of fish ladder to provide a fluvial alternative to migratory species if proven necessary. • Development of sports fishing and natural tourism in the reservoir • Study of fishing resources. • Train population close to reservoir in aquiculture techniques to breed fish in water tanks. • Contribute to food and economic safety of the communities through sustainable management of tilapia and peacock bass.
	2	4	32	
	3	3	26	
	4	3	27	
	11	3	39	
	12	3	42	
C. Potential impacts and risks on the Socioeconomic and Cultural Aspects				
8. Socioeconomics: The Rio Indio watershed, as with the whole ROCC region contains family nuclei and small communities that mainly live in extreme poverty. - During construction, the following socio-environmental impacts and potential risks that are proportional to the size of every option will appear: It will be necessary to displace between 286 (option 4) to 1,568 persons (option 1); There will be an impact on community cohesion, since once displaced it will be difficult to reconstruct, even more when the establishments are bigger; There will be a strong reduction in the current commercial activities of populations located along the river bank; There will be a loss of infrastructure; There will be a loss of agricultural production that represents 42% of family consumption; There will be local employment and income, if and when the population is trained. Considering the poverty of the region and the dispersion of its population, the direct costs of replacing the economic and social infrastructure are relatively small. The biggest costs are associated with the costs of compensation to the displaced families and the mechanisms for lessen the impact on family and communal cohesion	1	14	59	8. Socioeconomics • Set up of a resettlement and human development plan for communities, families and people affected by the selected option(s), to compensate and improve existing conditions. • Assess which options comply with minimum volume and reliability requirements to ameliorate unnecessary impact on population. • Program for socio-economic improvement of the communities of concern • Prevention, reduction and control of direct displacement impact due to flooding; • Prevention, reduction and control of loss of production for self-consumption and trade; • Prevention, reduction and control due to loss of social infrastructure and social cohesion; • Prevention, reduction and control of loss of economic infrastructure.
	2	11	43	
	3	8	34	
	4	8	35	
	11	12	51	
	12	12	54	

Table RE-13: Summary of the Potential Socio-environmental Impacts and associated Mitigation Measures for the Water Options in the Rio Indio Watershed

Potential Socio-environmental Impacts	Option	Score	Acc. Score	Prevention and Control Measures
9. Cultural resources The current archaeological inventory in the ROCC indicates that 20 archaeological sites of different levels of importance are known to exist. Valuable scientific and cultural information will get lost due to the flood. -The archaeologioal sites that would be affected have been qualified as high, moderate and low importance. Options 1 and 2, report 1 site of high importance and the rest of options none. Nevertheless, the option 11 reports the highest total value, because it reports more moderate's sites (3) and lower (15) importance	1	29	88	9. Cultural Resources Program of investigation and salvage or recovery of archaeological sites with moderate to high significance.
	2	15	58	
	3	8	42	
	4	8	43	
	11	30	81	
	12	18	72	
10. Recreational and scenic resources -Water options 1 and 2 tend to affect a greater number of inhabited sites that report resources of community interest.	1	11	99	10. Recreational and scenic resources Develop a community program for the development of natural and adventure tourism, using landscapes and scenery goods and services
	2	7	65	
	3	3	45	
	4	3	46	
	11	3	84	
	12	3	75	

Figure RE-1: Panama Canal Watershed showing the Western Region and the Rio Indio Watershed

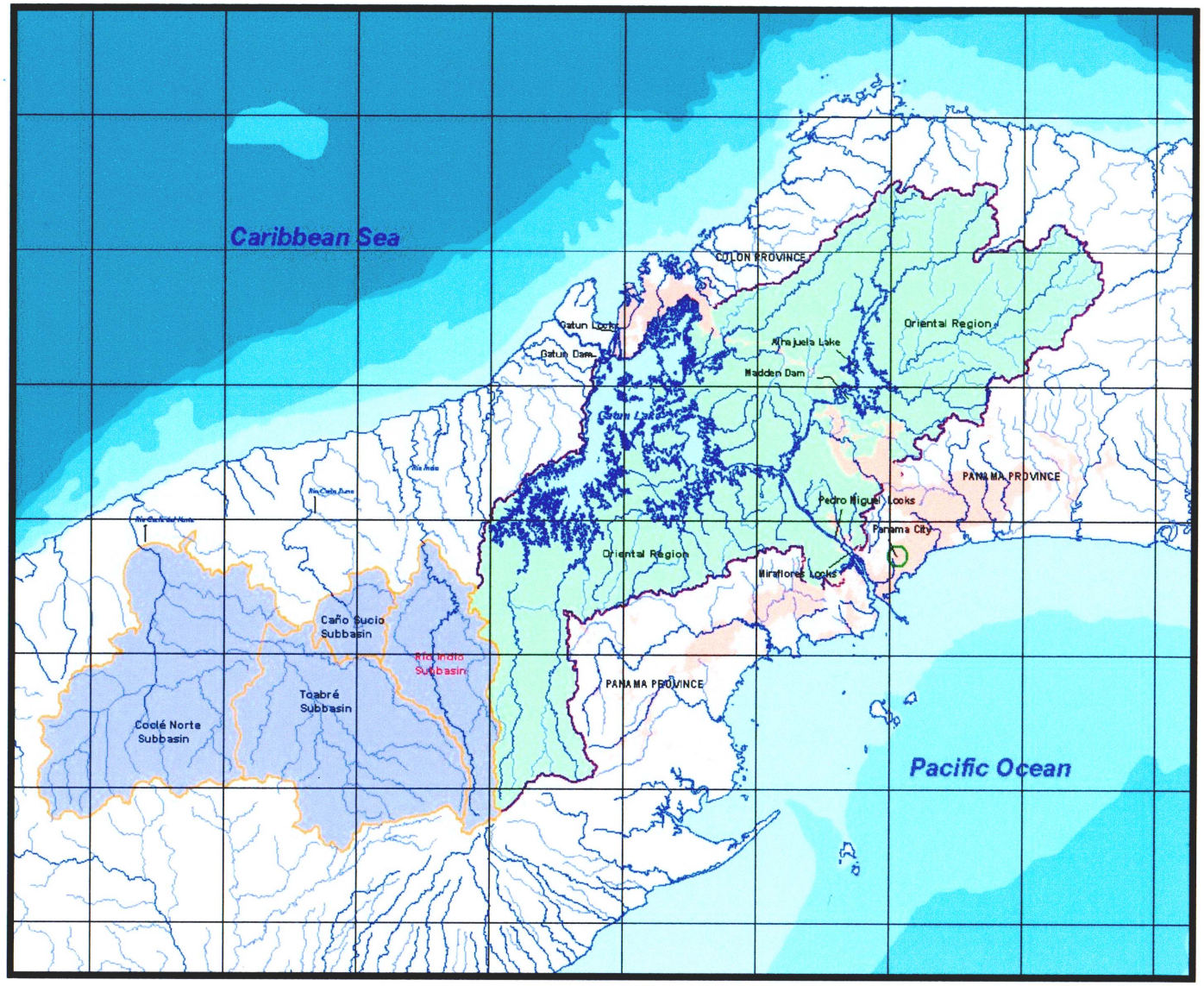
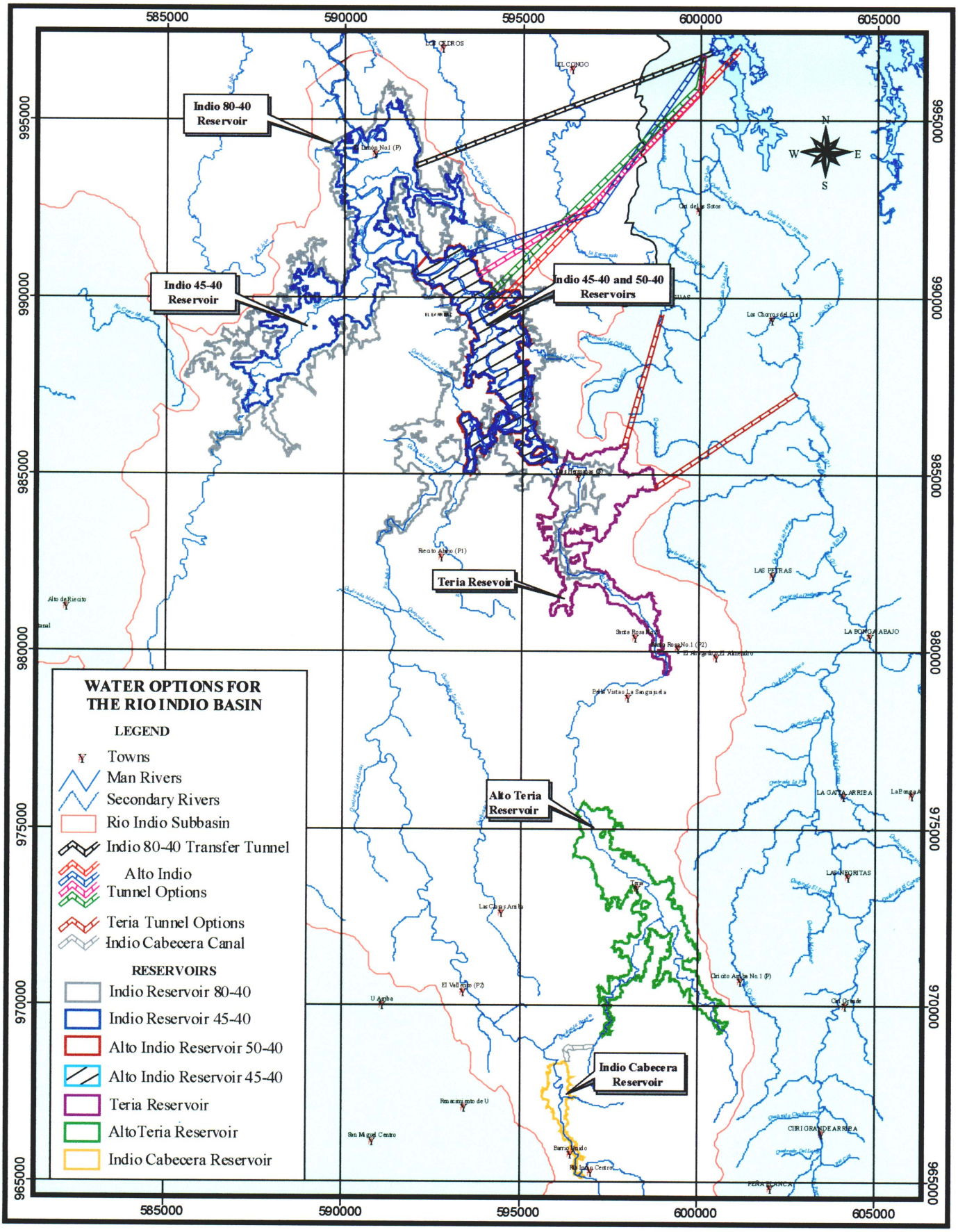


Figure RE-2: Main Components of the Water Options in the Rio Indio Watershed



1.0 INTRODUCTION

The Panama Canal Authority (ACP) is currently performing a series of studies to assess the feasibility of a new set of locks, alternative systems to raise and lower vessels, and upgrading the navigation channel to prepare a Master Plan for the Modernization and Expansion of the Canal. Part of these studies include the definition of new water sources, since at present, the operation of the Canal and the supply of potable water to the main urban centers in the country is completely dependent on the water availability in Gatún and Alhajuela reservoirs. This availability, which is limited even with the current traffic levels, and insufficient for the operation of the Canal at maximum capacity during dry years, may be even more restricted in the future, as the demand from vessels traffic and water consumption by the population increases.

Within this context, ACP contracted URS HOLDINGS, INC. (URS) for the execution of the contract for the environmental analysis of the water options in the Western Region of the Panama Canal Watershed (ROCC). More specifically, under this agreement, URS performed an environmental analysis of twelve water options in the Indio, Caño Sucio and Toabré watersheds. The ACP had already identified ten of these options and the URS team working in the project defined two options.

The terms of reference specify that two Environmental Analysis reports must be submitted, one analyzing the water options fully comprised within the limits of the Rio Indio watershed, and another for the water options involving Rio Indio as well as the Caño Sucio and/or Toabre watersheds. This report identifies and analyzes the potential socio-environmental impacts, which may arise as a consequence of the construction and operation of one or more of the water options identified in the Rio Indio watershed.

The ACP's goal is for the selected alternative to be designed, built and operated in accordance with the ACP Environmental Manual, to comply with the regulations and laws of the Republic of Panama, and with the guidelines and requirements of international financing organizations, such as the Inter-American Development Bank (IADB) and the World Bank.

1.1 Background

The search for additional water resources for the supply of the current and future demands, from the Canal and the main urban areas in Panama, has taken into account a series of alternatives both within the area currently regulated by the reservoirs and civil works associated with Gatun and Alhajuela (Madden) reservoirs, as well as in adjacent areas[79]. Thus, the area with greatest

potential for the supply of significant additional water in the future identified is located to the West of the Canal, and it comprises sections of the Indio, Miguel de la Borda and Coclé del Norte watersheds. Said region covering a surface area of about 2131 Km^2 and with an annual average water runoff of 4410 million cubic meters – MCM[53], is known today as the Western Region of the Panama Canal Watershed (Figure 1.1).

The Panama Canal Watershed was defined under Act No. 44 dated August 31, 1999. Under this act, the watershed includes the area currently regulated by the Gatún and Alhajuela reservoirs, also known as the Eastern Region, as well as the above-mentioned Western Region. When the future operation of the Panama Canal is taken into account, it is possible to assert that the Western Region represents its main strategic water reserve. For the purposes of making a comparison and in order to establish the significance of the ROCC, it should be pointed out that the Eastern Region, on which the Canal operation and the water supply to Panama and Colon currently depend, have an approximate surface area of 3310 Km^2 and annual runoff estimated at 4655 MCM.

1.2 Potential Environmental Impacts and Risks of Water Projects

The large scale handling of the landscape for the use of water resources with specific purposes implies the generation of considerable environmental impacts and risks. The negative effects observed after the construction of some large infrastructure works, which considerably modified the environment, have been of great significance, magnitude and duration, and in some cases they have exceeded the benefits obtained [20]. That is why, it is necessary to perform studies to understand how the ecosystems being handled function in order to prevent the occurrence of negative effects, enhance the benefits derived from positive impacts, and adopt adequate measures for mitigation and control in case the first cannot be avoided.

The construction of reservoirs alters the local geodynamics and the natural evolution process so that only pre-adapted organisms, or those that may rapidly adapt themselves to the changes and adjustment of the hydrogeomorphological processes and to the demands of the new environment, can participate in the organization of the new biological community. Similarly to other ecosystems, the structure and operation of a possible reservoir (or reservoirs) depend on the main energy and materials flow into and out of the systems, as well as on the extent of energy and materials exchange between their main components. Some of the aspects requiring special attention are mentioned below.

1.2.1 Population Displacement

The flooding of significant areas for the creation of reservoirs requires the relocation and resettlement of the people previously inhabiting that area. This brings about a series of problems, difficulties, and complications for this population, and may cause the loss of the communities' values and roots as well as material losses which are easier to account for.

In order to achieve social and environmental feasibility, the people or communities affected by relocation and resettlement processes must be particularly treated due to the previously mentioned risks. Consequently, they must be fairly and equitably compensated and appropriate places for their relocation must be secured. This must be a process of constant interaction between those responsible for the creation of new reservoirs, and the people and communities affected in order to prevent negative environmental impacts and social risks, which could eventually delay the construction of reservoirs and infrastructure normally associated with them, due to legal and cultural reasons. It is important to provide them with better living conditions, which will be reflected in better life quality indicators and standards. To that end, land ownership, educational opportunities, and health care must be guaranteed.

On the other hand, if the displacement, relocation and resettlement are not carefully planned and executed within a continuous participatory process, the people or communities may also become more vulnerable to common diseases and to those spread by vectors with life cycles related, in one way or another, to the water. It has frequently been observed that there is an increase of health problems during the construction and subsequent operation of tropical reservoirs[20]. The increase in the population, due to both the construction and subsequent operation of this infrastructure has led to the intensification of human activities in the area around the reservoir, while there is not an equivalent increase in preventive health care services.

However, there are some diseases, which due to their etiology and epidemiology are particularly related to water environments, among them, malaria, encephalitis, dengue, schistosomiasis and onchocerciasis.

1.2.2 Deforestation and Destruction of the Habitats

A frequent phenomenon observed in this type of projects is a significant increase in the rates of deforestation and destruction of natural ecosystems and their associated habitats. This is an effect which triggers a series of processes leading to the progressive impoverishment of the environmental and social conditions of the region. This deterioration may significantly affect the

quality of life of the local population, and the viability of the population of wildlife species, particularly those requiring a wide geographical range to complete their life cycles.

This accelerated deforestation process usually deepens and worsens the effects of the typically disorganized process of space occupation associated with spontaneous colonization, which causes heavy deforestation along the penetration pathway. In the case of the Rio Indio watershed, these processes of deforestation and conversion of forests to unsustainable land farming and cattle raising systems have already been going on for many decades, and there only remain traces of the forests previously covering the entire area.

1.2.3 Erosion and Sedimentation

The generation of sediments in the watershed is very important to ensure a long life, as well as adequate environmental conditions, for the reservoir. In this sense, it is important to point out that the above-mentioned deforestation and the transformation of the vegetation cover expose the land to a stronger impact from climatic agents, and consequently, stronger erosion and sediment transport processes may develop. The sediment delivery or transport to the reservoir may be substantial if adequate measures to manage the watershed are not taken.

Those processes may be significantly accelerated as a result of the works needed for the construction of the reservoirs' infrastructure. Paradoxically, their life, or alternatively its operational cost, will largely depend on the actions and measures implemented to prevent, reduce and control the sediment transport, which at the same time depends on the hydrogeomorphological processes of the watershed. The environmental conditions in the reservoir are related to the improvement or deterioration of environmental quality in the watershed, which shall be subject to a continuous process for environmental and social upgrade in order to ensure a long life for the reservoir and related infrastructure.

Besides reducing the reservoir life, an accelerated sedimentation process may strongly interfere with the abundance and distribution of the biological community in the reservoir. The turbidity caused by materials in suspension usually reduces light penetration, and consequently the photosynthesis in the water column. This undoubtedly affects the trophic structure, particularly at the upper levels of the aquatic ecosystem food chain. The sediment in suspension also provides a substrate to which bacteria, potentially causing different diseases, can adhere. Finally, the deposition of high amounts of sediment limits the growth and development of benthic community and destroys the habitat necessary for the reproduction of many fish species.

1.2.4 Water Quality and Risk of Eutrophication

Eutrophication, or nutrient enrichment of the continental water bodies, is a natural process occurring at different rates depending on the relation between the water body and the contributing area, including the physical and social infrastructure along the water edge. Human actions usually accelerate this process drastically, particularly when they lead to direct or indirect pollution of the reservoir.

The main negative effects of eutrophication are: increase in both dissolved and particulate organic matter, and decrease of the oxygen concentration. The organic matter gives the water unpleasant odors and taste as a result of the constant decomposition. It also absorbs large amounts of light thus decreasing the thickness of the photosynthetic layer. Besides, the decrease of the oxygen concentration to levels of total anoxia has large consequences on the survival of fish and other life forms, which may be used as protein sources by man.

In the conditions reduced by anaerobic decomposition, sediments release a number of compounds which tend to further accelerate the eutrophication process, such as phosphorus and nitrogen, as well as toxic compounds. These chemicals remain adsorbed to the clayey and organic matter particles when oxidized conditions are present, but they are released and somehow incorporated to the food chain when there is a change in the redox potential[(85)]. Also, under these anoxic conditions, compounds such as methane and hydrogen sulfide may be released from the sediments.

Artificial lakes normally have lower water residence time than natural lakes, and therefore, the water quality of the contributing rivers strongly determines the water quality and productivity in the reservoirs. During the filling stage and during the first years of reservoir life, there is usually a transition period characterized by high concentration of organic and inorganic ions, and low hypolimnetic oxygen content. The duration of this transition period depends on several factors, such as water quality of the rivers, submerged vegetation, thermal profile and mixing of the reservoir, fertility of the submerged soil, water renewal rate in the reservoir, and depth of the discharge intake. After this initial period, the concentration of nutrients and organic matter in water decreases, although it remains slightly above the levels found in the tributaries[(67)].

1.2.5 Water Weeds

Another aspect of concern for the development of tropical reservoirs is the risk of massive water weeds infestation, which strongly influences the characteristics of the reservoir and its water,

usually causing a restricted use of some of the anticipated operational purposes. Some of the negative effects of water weeds are:

- The decomposition of organic matter produced by the plants in the water body eliminates the oxygen, which lead to significant deterioration of the water resource;
- The growth of large plant masses, floating or rooted, frequently interfere with navigation, and depending on the design, it may also interfere with water intakes or other structures;
- High infestation by these plants also interferes with using of gill nets and other fishing gear, strongly affecting both commercial and sport fishing:
- Certain disease carrying species, such as the snails harboring schistosomiasis and malaria carrying mosquitoes may find an ideal habitat among these water plants, where they are also usually protected from their natural enemies; and
- During periods of rapid growth, the water plants are able to transpire several times the normal evaporation values in an open surface, thus decreasing the net delivery of water of infested reservoirs.

Some of the factors which determine the infestation of reservoirs by water weeds are: the presence of water plants in the watershed itself, or at a distance which allows easy transport through natural processes; swamp areas or shallow areas in the littoral zone of the new reservoir; submerged remnants of terrestrial vegetation, which provide support to water plants; and high sedimentation rates in specific areas of the reservoir which produce shallow areas with high availability of nutrients.

1.2.6 Other Possible Effects

Depending on the special characteristics of each site, when the evolution of natural systems is interrupted, condition may change from contributing to the praiseworthy purposes of production of goods and services for the population in the region, to become the source of negative effects directly in the reservoir or downstream from it, for example:

- Reduction or extinction of wildlife species along with their invaluable genetic information database, as a result of the destruction of areas, which may serve as their habitat.
- A decrease in the amount of sediments and nutrients from the watershed, which may lead to considerably decreases in productivity of estuarine areas.
- The change in hydroperiod, which may also interfere with the migration of some aquatic species (fish, crustacean), as well as with the productivity of the estuarine system and flood plains.

- The lack of appraisal and rescue of archaeological sites, which is considered to be another negative effect of reservoirs construction.
- The modification of the natural hydrogeomorphological processes, which are the ones that in the long term, adjust the conditions of any watershed through mass movements and readjustment of baseline levels.
- Increase of seismic activity as a result of the water weight.

The current knowledge of these problems indicates that most of them may be prevented, mitigated or controlled, when the socio-environmental impacts and risks assessment is an inseparable part of the project life cycle. This strategy leads to the generation of an environmental improvement program for the watershed, including the areas of direct or indirect influence of the reservoir, mainly those located upstream through appropriate management of the environmental goods and services found therein.

1.3 Integrated Management of Water Resources

The different water options in the Rio Indio watershed, which are part of the studies for the preparation of the Master Plan for the modernization and expansion of the Canal, represent a new challenge for the ACP, which will require an integrated management of the water resources of the areas under study. The integrated management of water resources (IMWR) is a process to foster a coordinated development and management of water, soil and related resources, to fairly maximize the social and economic benefit while not compromising the sustainability of vital ecosystems[33]. In the particular case of the ACP, the IMWR must be considered as a process that will assist it in the effort to deal with water issues in a sustainable and cost-effective way. This is in agreement with ACP's institutional mandate and policies.

The IMWR process has attracted special attention since 1992, after the International Conference on Water and the Environment held in Dublin and the United Nations Conference on the Environment and Development held in Rio de Janeiro. Since then, the IMWR approach has found universal support within the international community. More recently, its significance has been restated in other international conferences on water in Harare and Paris, by the Commission on Sustainable Development in Rio +5 in 1998, and in the three World Water Forums, the last one held in Japan in 2003.

Following is a description of some IMWR concepts, relevant for the watersheds under study, which have been taken from technical document No. 4[33] :

- The IMWR requires a holistic approach, which takes into account the characteristics of the water cycle and its interaction with other natural resources and ecosystems; therefore, it has to take into considerations the resource demand and threats. It also requires actual citizen participation, which is attained only when relevant stakeholders are part of the decision making process.

- The current conditions of water resources in the Rio Indio watershed, as well as in the rest of the ROCC, indicate that the combination of social inequity, economic marginality and lack of programs to overcome poverty in the region have forced most of the inhabitants to overexploit the land and natural resources, which will result in negative impacts to the water options under study.

- The main challenges to be attained by the IMWR in the watersheds under study are: to ensure water supply to satisfy the basic human needs since not all the inhabitants of the watersheds have access to safe water and basic sanitation; to ensure water supply for the production of food and other crops, to develop other work-generating activities; to protect and rehabilitate vital ecosystems including terrestrial ecosystems, given their importance in the regulation of the water cycle, rainfall infiltration, aquifer recharge, regimes for river flows and water quality, as well as aquatic ecosystems, since they produce a range of economic benefits; and to administer the water supply variability or availability in time and space and associated risks (natural drought/flood cycles).

- In contrast to the "traditional" fragmented management of water resources, at its most essential level the IMWR concept addresses the management of both water supply and demand. Therefore, the integration may be considered in two basic categories: the natural system, with its critical significance for the resource quality and availability; and the human system, which mainly determines the uses, the production of waste and pollution threats, and establish the resource development priorities.

- Historically, water administrators have limited themselves to a "neutral role", i.e., to manage the natural system to supply water according to their needs. However, the IMWR approaches should assist them in recognizing that their behavior also affects water demand. Clearly, the consumers can only "demand" the products offered, but water can offer clearly different properties, for example, in terms of quality and availability with low flow rates or during peak demand periods. The design of the prices and rates will affect the demand, in the same way that investments in infrastructure turn the potential demand in actual demand (e.g., preferential rates during the rainy season).

- The integration of freshwater and coastal zone management to reflect the "continuity" existing between them is a component of the IMWR. The freshwater administrators should consider the requirement of coastal areas when managing water resources. This integration is receiving increasing attention through a recent United Nations statement, and the creation of the Global Action Program (GAP). Coincidently, the last annual GAP planning meeting was held in Panama in February 2004.

- Water is a key determinant of the character and health of the terrestrial and aquatic ecosystems, and therefore, the water quality and quantity requirements must be taken into account in the overall assignment of available water resources. The recent UICN publication (2003) on environmental flow describes its benefits for people and nature, and the mid- and long-term consequences on river users if the requirements are not fulfilled.

- Integration of quality and quantity when managing water resources is an essential component of the IMWR. Clearly, it must influence the way in which human systems generate and control pollution.

- Integration of the various water users' interests must be considered in the IMWR, recognizing physical and social relations, and defining mechanisms for conflict resolution.

1.4 The Environmental Assessment Process

In general terms, the Environmental Assessment Process is the procedure which identifies potential socio-environmental impacts and risks, as well as the measures, actions, and investments, which shall be made to prevent, mitigate or compensate them in order to attain the above-mentioned IMWR, in water resources projects. This process is often referred to, by international financing institutions, as Environmental Assessment (EA) that shall not be confused with the Environmental Impact Study, which is a specific document normally used as support for the granting of environmental permits and licenses prior to the execution of investment projects.

It is possible to assert that environmental assessments are processes which help determine and estimate the potential socio-environmental impacts (positive and negative), and direct and indirect risks generated by decision making and execution, the application of strategies and policies, and the conceptualization, design and execution of plans, programs, projects and activities - including their direct and indirect area of influence - on the environment and society.

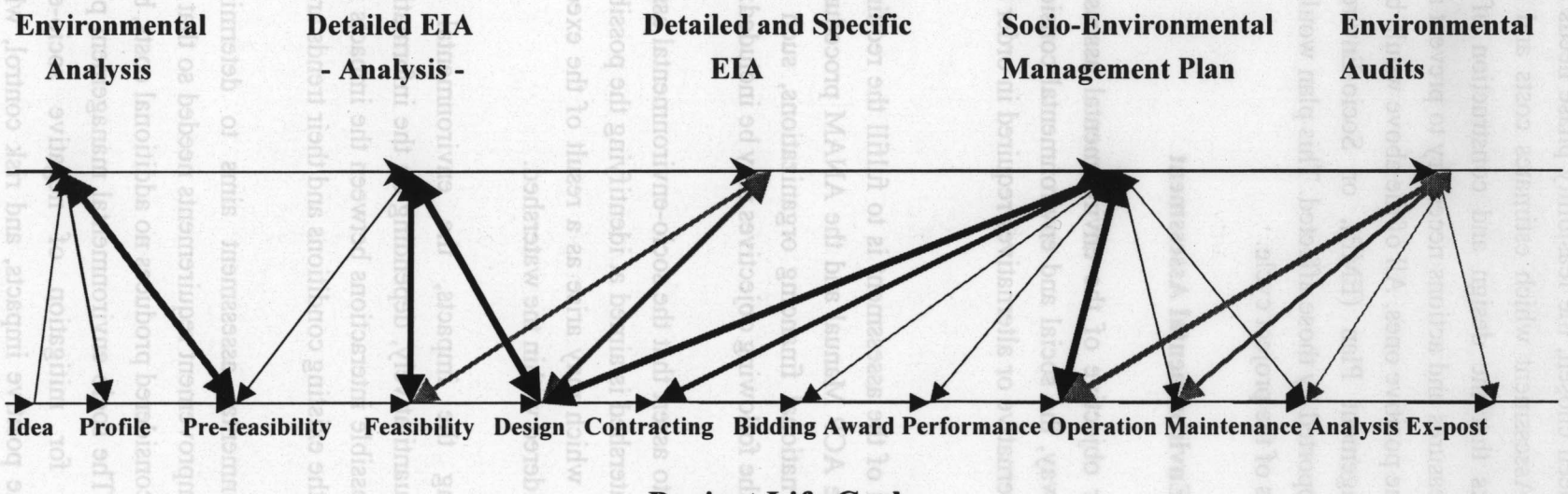
These impacts may benefit and/or harm people and communities in the short, medium and long term.

The participation and coordination with the affected communities must be sought from the beginning, and shall be essential components during all stages of the assessment process. The significant points of the environmental assessment process are organized in the form of an Environmental Management Plan (EMP) (also known as Socio-Environmental Management Plan), which is the instrument used to maintain and improve environmental quality, and consequently the living standards and life quality of the people in the area of influence of the development program under consideration.

The environmental assessments are an inseparable component of the life cycle of any plan, program, or project; and provide feedback for the decision making and execution processes. The environmental assessment process may be conceptualized in several stages, all related and inseparable from the program or project life cycle, and consequently shall be present at the of profile, pre-feasibility, feasibility, design, bidding, award, contracting, execution, operation and maintenance phases of a project (see Figure 1.2).

The process starts with the Environmental Analysis of impacts and risks of the project profile. It is followed by an Environmental Assessment during the pre-feasibility, which aims to establishing and assessing potential environmental impacts and risks, negative and positive, while defining and assessing the actions and investments needed to prevent and counteract the negative, and to enhance the positive. A more in-depth Environmental Assessment is made for those feasible alternatives, and this helps to select the preferred one. At this time, the process of water options in the Rio Indio watershed is considered to be at an advanced pre-feasibility level since there is detailed information for most of the aspects of one of the alternatives being considered, while there is only preliminary information for the others.

Figure 1.2: Socio-Environmental Impact Assessment Process



Note: The line thickness shows the significance of the relationship between the different stages of the EIA with the project life cycle and the number of relationships indicates the significance of each stage and phase. The color differentiates the different stages of the EIA process.
Source: Dr. Luis Ferraté (personal communication)

Once the alternative has been chosen, the feasibility phase needs a more analytic, detailed and thorough Environmental Assessment which estimates costs and benefits of the negative and positive impacts and risks that the design and construction of the proposed works would generate, as well as the measures and actions necessary to prevent and mitigate negative impacts and risks and to enhance the positive ones. All of the above would be incorporated as activities in the Environmental Management Plan (EMP), or Socio-Environmental Management Plan (SEMP), agreed to and supported by those affected. This plan would be incorporated in each and all of the subsequent stages of the project cycle.

1.5 Objectives of the Environmental Assessment

In this Project, the major objective of the environmental assessment is to incorporate, in a complete and systematic way, the social and environmental considerations into the process for the selection of a water alternative or alternatives required in order to guarantee the water supply to the Panama Canal.

In a general way, the goal of the assessment is to fulfill the requirements of the environmental analysis established by the ACP Manual and the ANAM procedures, as well as the guidelines and requirements of international financing organizations, such as the World Bank and the IADB. More specifically, the following objectives may be included:

1. First, it is possible to assert that the socio-environmental assessment of the water options in the Rio Indio watershed is aimed at identifying the possible environmental, social, and economic impacts, which may arise as a result of the execution of one or more of the water options considered within the watershed.

2. Besides identifying the impacts, the environmental assessment qualifies them qualitatively and quantitatively, depending on the information available in each case. In this process, the possible interactions between the impacts identified (synergy) and their significance given the existing conditions and their trends are determined.

3. Third, the environmental assessment aims to determine the socio-environmental management and improvement requirements needed so that the execution of one or more of the alternatives considered produces no additional costs, besides those included in their conceptualization. The socio-environmental management plan includes the strategy and specific activities for mitigation of negative socio-environmental impacts, the enhancement of the positive impacts, and risk control, whether through prevention or

compensation measures. As part of the management plan, the strategies and activities of environmental monitoring, verification and control are also included.

4. The environmental assessment also seek to fully engage relevant stakeholders, including the population directly affected by the water options, the interested parties, and the society at large, through consultation and participation activities, and the incorporation of their relevant criteria, comments and suggestions. The incorporation of relevant suggestions helps improve performance in case one or more alternatives are executed. The participation of the people and communities affected is an essential requirement of the environmental assessment process, and for the success of any project, since when there is support from those affected, legal risks, and investment delays and costs decrease.

5. Finally, the assessment study aims to determine the feasible alternative(s) when technical as well as economic, financial, social, and environmental considerations are made. On the basis of this determination, it seeks to identify the preferred alternative(s) to achieve the water supply goals, which at the same time internalize the actions necessary to control risks and mitigate possible negative impacts on the existing environmental and social conditions in the area of influence, or improve them.

1.6 Structure of the Report

This report is organized in nine sections including an executive summary, seven main chapters, and a section for annexes. The content of each section is briefly described below.

Executive Summary

It clearly presents the results of the Environmental Assessment, including the relevant information on the most significant environmental problems associated to the investment projects.

1. Introduction

This introduction briefly presents the context of the study including the background justifying the need for additional water and the strategic significance of the water resources of the ROCC and the Rio Indio watershed. It provides a general description of the significance of the main environmental issues associated to the development of water projects, introduces the modern vision of Integrated Management of Water Resources and

the role of the environmental studies in the various stages of the project life cycle. Finally, it describes the general structure of the report.

2. Water options

This chapter includes the key information on the different phases: planning, construction, and operation of the water options. The description focuses on the aspects and actions, which may lead to significant environmental impacts. Besides, the description of the structures and construction and operation processes of each alternative follows, whenever possible, the structure suggested by ANAM for the preparation of Environmental Impact Studies for Investment Projects Class III.

3. Conditions Existing in the Study Area

This chapter provides a brief characterization of the conditions existing in the area of influence of the possible water options. It includes socio-environmental parameters considered to be useful for the analysis, such as key aspects of the physical, biological, socio-economic and cultural aspects, and the landscape.

4. Identification and Analysis of Impacts

The chapter on identification and analysis of socio-environmental impacts and risks includes the assessment and determination of the significance of positive impacts to be enhanced and negative ones to be prevented, reduced, and controlled, as well as the risks, which may result from the conception, design, planning, construction, and operation of each one of the options under consideration.

5. Mitigation and Environmental Management Plan

This chapter identifies the measures, actions, and investments which may be executed to prevent, reduce, and control negative socio-environmental impacts and significant risks, as well as to enhance the positive impacts; the mechanism for monitoring the environmental quality and conditions within the area of influence, and the effectiveness of the proposed mitigation measures; and the proposed mechanisms for verification and control of the environmental management.

6. Analysis of Alternatives

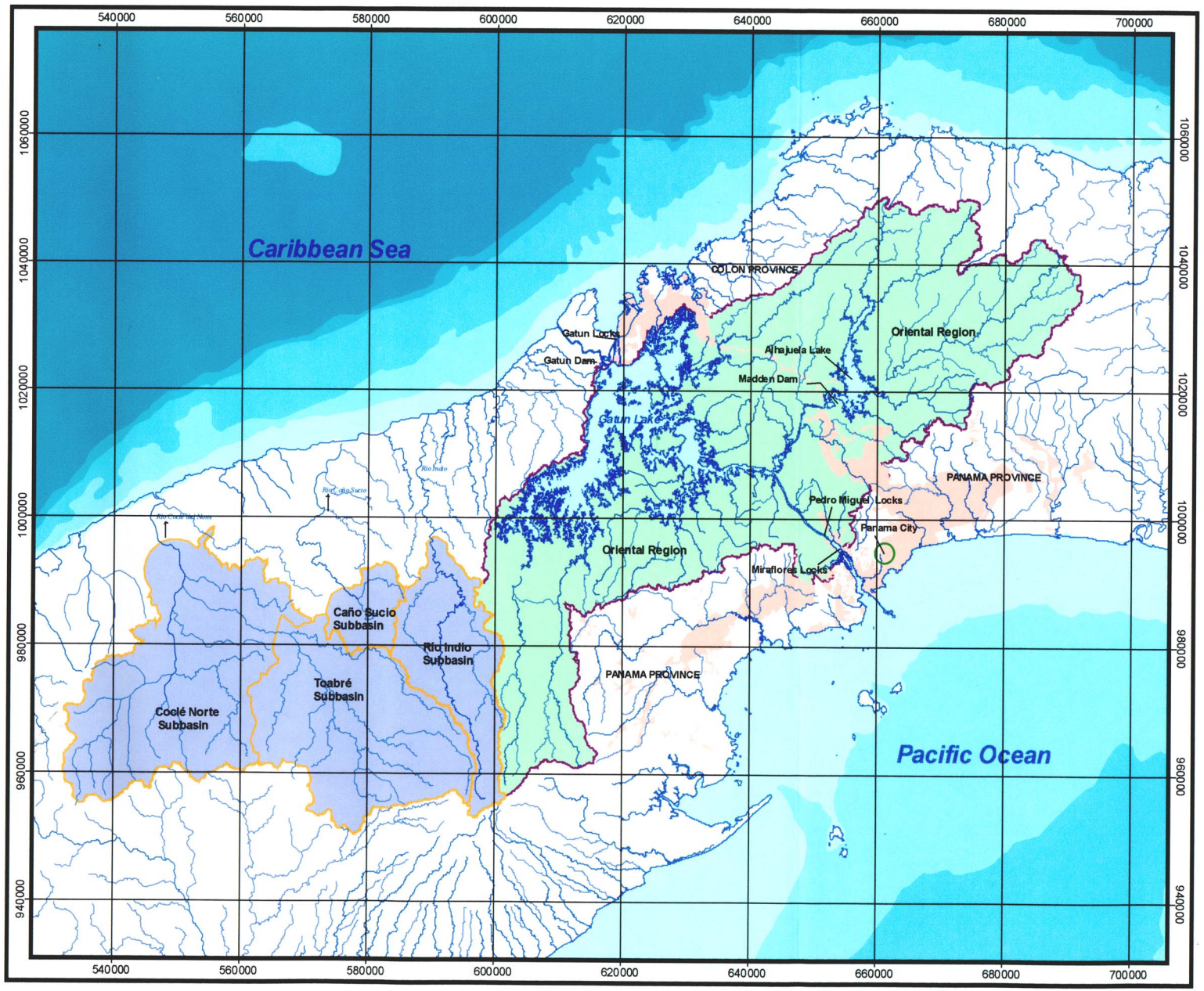
The chapter on analysis of possible alternatives explains the process of comparison and selection of alternatives used to identify the feasible and preferred alternatives and the results obtained from the comprehensive comparison process.

7. Public Participation Plan

The Public Participation Plan describes the participation process the population potentially affected has had to date, and makes recommendations for additional consultations to be held when the ACP considers it convenient, before the final design of the selected water alternative.

Annexes

The annexes include the information necessary to verify the data used in the different aspects of the analysis performed. It also indicates the members of the work team, including the professionals participating in the analysis, their function, and professional background.



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

PANAMA CANAL BASIN

ACP PANAMA CANAL AUTORITHY (ACP)

LEGEND

- Panama City
- Main Rivers
- Secondary Rivers
- Urban Areas
- Western Basin
- Oriental Basin

N W E S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

20 0 20
Kilometers

Regional Location

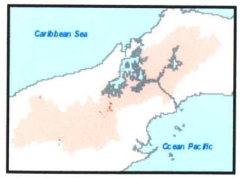


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Figura N° 1-1

2.0 THE WATER OPTIONS

This chapter presents a description of the proposed water options within the Rio Indio watershed. The description involves the different stages – planning, construction, and operation -, and includes the actions, which may have a socio-environmental impact and significant risks. The chapter also includes the information required by ANAM, and is structured in a form similar to the table of contents described in the Executive Decree No. 59 dated March 16, 2000 related to the Environmental Impact Assessment Process for Environmental Impact Evaluations, Category III, in order to facilitate the assessment of its components.

2.1 General Background Information

The Introduction to this report includes specific information related to the general background on the Project includes its full name, identification of owner, and other significant information. However, the focus in this case is the general background generating or leading to the execution of this study.

The Panama Canal Authority (ACP) is currently working on a Master Plan for the modernization of the waterway, with the objective to provide reliable services to the international community pertaining ship transit, from and to the Atlantic and Pacific Oceans. It has been anticipated that the expansion of the Canal to accommodate the anticipated increases in the demand for maritime service, and the increased demand of potable water for the main metropolitan areas of Panama, will exceed the supply capacity of the portion of the Panama Canal Watershed, currently under hydraulic management, during dry years. Since the standard for the operation of the Canal in terms of reliability has been set to the historic 99.6%, additional water sources will be required to operate the Canal during those dry periods.

2.2 Objective

The objective of this chapter is to provide a description of the water supply options associated to the Rio Indio watershed which have been considered in this study so that it provides the identification and assessment of the socio-environmental impacts and potential risks related to the implementation of one or more of those options, and to perform comparative assessments of the different options to establish the alternative which may be most appropriate for implementation after considering all the necessary aspects.

2.3 Location of the Water Options

The water options considered in this report are associated to the Rio Indio watershed, which comprises a sub-basin of the ROCC. The ROCC, defined under Act No. 44, dated August 31, 1999, is located to the West of the Central area of the Panama Canal and Isthmus. It covers a 213,112 hectare surface area. The Rio Indio watershed covers 38,660 hectares of the total ROCC surface area, and is made up of 11 territories, distributed in 5 Districts (Penonome, El Valle, Chagres, Donoso, and Capira) and 3 Provinces (Cocle, Colon, and Panama).

The six alternatives under consideration in the Rio Indio watershed are identified through reference to the name of the ROCC sub-watershed, and to the level of operation of the project. The alternatives are listed below:

- **Option 1: Indio 80-40**
- **Option 2: Indio 45-40**
- **Option 3: Alto Indio 50-40**
- **Option 4: Alto Indio 45-40**
- **Option 11: Teria - Alto Teria**
- **Option 12: Teria - Cabecera Indio**

In the following sections, a description of each water resources alternative is presented. For each option description, the general project information, specific option location, option justification, type of supplies, project scope, estimated project components cost, and sequence of main activities during construction are included. It is important to point out that this description has been prepared on the basis of the available information, which is not homogeneous for the alternatives under evaluation. There is information available at the technical feasibility level for most of the significant issues, only for the water impoundment of the dam site located furthest away downstream on Rio Indio and for the water transfers at Lake Gatun. This information supports the description of one of the six alternatives with a similar level of detail. The information for the description of the other alternatives is only at a conceptual level for at least one of its components. However, if the conceptual information is combined with the existing information at the technical feasibility level, extrapolations may be drawn, and then used to identify and assess most of the socio-environmental impacts and to compare the alternatives.

The information related to the performance of each of the water options under consideration, from the stand point of effective water production for the Canal operation was determined through the simulation of the existing Canal system (Alhajuela and Gatun Lakes) with the ***HEC-***

5 model developed by the US Army Corps of Engineers (USACE), and supplied by the ACP. The procedures and results of the modeling process, included in Annex 2-A, consisted of the initial calibration of the model with the Alhajuela and Gatun lakes, and then with Rio Indio 80-40 (Option 1). Then, the model was run to assess the alternatives which have not been previously assessed.

2.4 Options 1 and 2: Indio 80-40 and Indio 45-40

These two options are located at the same place, which is immediately to the west of the Panama Canal Watershed, and at about 75 km northwest of the city of Panama (Figures 2-1 and 2-2). The significant difference between both options is the level of flooding and hence the height of the dam required to contain the river. Option 2 provides basically no storage. The following description is primarily based on the feasibility study prepared for **Option 1.**

The selected site for the Rio Indio dam is located at the Tres Hermanas Hill, NW of the city of Panama and SW of Colon. The axis of the dam will be slightly concave downstream and will cross the main channel of the Rio Indio at the coordinates 994700N, 590300E (UTM Coordinate System).

2.4.1 Project Justification

The proposed Rio Indio dam site was chosen with a view toward maximizing the water impoundment, while minimizing the volume of material required for the construction of the dam and minimizing the number of saddle dams required to contain the lake. To maximize the water impounded, it is desirable to locate the dam as far downstream in the Rio Indio watershed as possible. The location of the dam was selected on the basis of a "Dam Site Study" that studied 7 locations between the mouth of the river and the confluence of the Indio and Uracillo rivers[79]

The water production derived from this Option will be used to augment the existing supply of water to the Canal, provide for increases in municipal and industrial water demand in and around the Canal Watershed, and possibly as a source of electric power generation in the local and regional market. More detailed information about this alternative may be found in the following references:

- [MWH, 2003]: *Rio Indio Water Supply Project, Feasibility Study, Volume 1*, prepared by MWH in association with Tams Consultants, Inc., Ingenieria Avanzada, S.A. and Tecnilab, S.A, April 2003.

- [USACE, 1999]: *Panama Canal Reconnaisance Study: Identification, Definition and Evaluation of Water Supply Projects, Volume 1*, prepared by the US Army Corps of Engineers, December 1999.

2.4.2 Identification of Components and Works Design

The following section provides a detailed description of the main project components, and includes the works design, types and origin of supplies, raw material, and volume to be used, as well as a description of the project scope, including size of the works, production volume, etc.

The major elements that comprise the Rio Indio Water Supply project are:

- A concrete face rockfill dam and appurtenant works at Tres Hermanas Hill.
- A 4.5 m diameter, 8,400-m long water transfer tunnel from the Rio Indio Reservoir to Lake Gatun.
- A minimum release facility, which may include a 1.6 MW power plant.

For Option 1, the dam will impound a reservoir with a gross storage capacity of 1,577 million cubic meters (MCM) at Elevation (El.) 80, the full supply level. Live storage between El. 80 and El. 40 will be 1,294 MCM. The resulting dead storage exceeds that needed for the estimated sediment deposition. It is estimated that after 100 years, the live storage will be reduced by about two percent. The reservoir area at El. 80 will be 45.6 square kilometers[(65)]. For Option 2, the dam will impound a reservoir with a gross storage capacity of 400 MCM at El. 45, the full supply level. Live storage between El. 45 and El. 40 will be 100 MCM. The reservoir area at the full supply level, El. 45, is 22 square kilometers[(65)]. These physical dimensions are summarized in Figure 2-3[(65)].

Upon completion of the dam and transfer tunnel, the yield of the water supply system for the Panama Canal will be increased by about 1,200 MCM per year with a reliability of 99.6% under Option 1. This is equivalent to about 15.8 additional lockages per day in the Canal system. The demand on the water supply system of the Canal will depend on the future configuration of the Canal system, the adopted reliability of supply, and the continuous supply of water for municipal and industrial (M&I) uses from the system to the Panama Canal Watershed through IDAAN. The implementation of the Rio Indio Project will contribute to assist the ACP in meeting the needs that may arise. For example, if the unconstrained navigation demand schedule presented in[(79)] and an updated M&I demand estimate are used, this option will be able to supply the additional requirements at a 99.6% reliability by the year 2028[(65)] (see Table 2-1).

Rio Indio Dam and Saddle Dams

The proposed Rio Indio Dam will be a concrete-face rockfill dam (CFRD) constructed of durable, free-draining compacted rockfill obtained from the excavation required for the right abutment and from nearby quarries. The slopes of the upstream and downstream faces will be conservatively set at 1.4H:1.0V based on precedent cases for this dam type, foundation, and seismicity at the site. The main body of the dam will be made of rockfill and the downstream shell will be coarse rockfill. The rockfill shells of the dam have a volume of about 2.7 million cubic meters.

The crest of the dam will be at El. 83 and the width of the crest will be 8.0 m. A 5-m high parapet wall will extend 2.0 m above the crest to El. 85. The dam will be about 91 m high from the deepest foundation excavation to the top of the parapet wall (Figure 2-4).

A reinforced concrete facing will act as the impermeable membrane. It will be designed to have low permeability, durability against weathering, and sufficient flexibility to tolerate small expected embankment settling. A 3-m wide zone of filter material and a 3-m wide zone of fine rockfill will underlay the concrete face to provide continuous support. The filter material will be manufactured from igneous quarry material. The average thickness of the concrete will be 0.4 m. Reinforcing steel will be included at a rate of 30 kg/m^3. The facing will be placed in individual slabs, with a width of up to 15 m, and horizontal joints will be inserted when necessary.

With reservoir full supply level at El. 80, two saddle dams will be required, one on the north side of the right abutment, and the second about 4 km south-east of the main dam. The saddle dams will be embankment fills both with upstream and downstream slopes of 2.75H:1.0V and 2.5H:1.0V, respectively. A 3-m wide chimney drain will be connected to a 1-m thick blanket drain in both saddle dams. The crest of the saddle dams at El. 85 will be 8.0 m wide and riprap processed from the igneous quarry will be placed on the upstream slopes.

Foundation Treatment

The proposed treatment programs for the dam foundation will include surface treatment, shallow foundation (consolidation) grouting, curtain grouting, and drainage.

For the plinth slab excavation at the dam toe and under the spillway headworks, dental excavation and concrete will be used to treat local zones of highly weathered, sheared, or otherwise unacceptable rock encountered in the foundation. Required dental treatment should be nominal and

only local. Contingency quantities for backfill concrete have been included to reflect the potential for unforeseen conditions.

Consolidation grouting is not anticipated except in limited areas (e.g. fault or fracture zones) should they become exposed during excavation for the plinth slab and under the spillway headworks. Low pressure cement grouting will be used in these limited zones to fill open cracks or joints in the rock zone immediately beneath the dam foundation. In general, grout takes should be low.

Curtain grouting will be performed from the toe slab of the concrete face and through the spillway concrete (or from a grout slab prior to placing first stage spillway concrete). Grout takes should be low to moderate through most of the curtain. The average grout consumption was assumed for estimate purposes to be about 30 kg/m.

Foundation drainage will be provided for the spillway to control seepage to reduce pore pressures in the rock mass, and hence uplift. For estimate purposes, a drain hole spacing of 5 m was assumed with depths extending to about half the depth of the grout curtain. Holes will have an appropriately inclination in order to maximize the number of joint/fracture interceptions.

Spillway

An ungated chute spillway will be located in the right abutment. The spillway has been designed to pass the probable maximum flow (PMF) of 4345 m^3/s, and a total discharge volume of 243 MCM in 5 days. The details of this design are found in the reference[(65)] (Sections 3.6.1 and 4.1.3, Figures 4-5 and 4-6). The discharge from the spillway to the Rio Indio river bed under PMF conditions will be 950 m^3/s (using a surcharge of 4.0 m above the full supply level), in accordance with the hydraulic simulations run with the HEC-1 program, and documented in the reference[(65)] (Appendix A, Figure 47). This value is 23 per cent higher than the maximum historical flow rate value measured in the Boca de Uracillo station, 772 m^3/s (1991), and indicates a recurrence period greater than 100 years.

The spillway will consist of an approach channel, an ogee control section, a tapered chute, a flip bucket, and an excavated channel to direct the water back to the natural river channel. A plan and sections of the spillway are presented in the reference[(65)].

The approach channel will be 52 m wide and will be excavated to El.75. The channel will be straight and approximately 150 m long. The uncontrolled ogee section will consist of three bays with a total opening of 50 m. Two piers will support an 8-m wide bridge to connect the dam crest to the right abutment access road.

The chute will be 180 m long from the downstream end of the control structure to the beginning of the flip bucket. The width of the spillway chute will taper from 52 m to 12 m at the upstream end of the flip bucket. An aeration ramp will be installed about two-thirds of the way down the chute. The chute is sloped at about 33% to facilitate founding the entire structure on competent rock. At this slope the discharge will be supercritical. The maximum water depth will vary from 4.0 m at the crest to 1.5 m at the upstream end of the chute to 1.7 m at the upstream end of the flip bucket. A constant wall height of 3.0 m has been selected.

The flip bucket is located so that the plunge pool will not impact on any of the proposed project structures. The lip of the bucket will be 14 m wide and will be at El. 14 m about 1.0 m above the anticipated tailwater elevation under PMF conditions. The plunge pool will be formed in pre-excavated competent rock. A reinforced concrete slab about 8.0 m long will extend downstream from the bucket to provide foundation protection for small discharges.

Diversion During Construction

The facilities for the diversion of the Rio Indio during the construction consist of cofferdams upstream and downstream from the dam site and a tunnel in the right abutment. The river diversion facilities plan, profile, sections, and details are presented in[65]. The tunnel will serve to:

- Pass the 50-year flood;
- Control the rate of initial reservoir filling, and;
- Assist in the evacuation of the reservoir.

The diversion tunnel will be a 4.0-m diameter, modified horseshoe tunnel with vertical sides and a 635-meter long horizontal invert. Under the 50-year flood event, the tunnel will discharge about 113m^3/s with the upstream water surface at El. 21.6 and the downstream water surface at El. 7.8.

An approach channel 250-meter long will lead to the intake portal. The approach channel will be horizontal and approximately at El. 5. The upstream portal will be excavated into a rock face to provide cover of about 10 m at the beginning of the tunnel. The excavation will be at a slope of 1H:5V in the rock and 2H:1V in the overburden. Rockbolts and shotcrete will be applied as needed. A 120-m long discharge channel will extend from the downstream portal to the river channel. It will be formed as a part of the spillway discharge channel.

The diversion tunnel will be excavated in tuffaceous sandstone, which should be of moderate strength and unweathered over most of the tunnel length. Drill and blast methods will be used

for excavation, and the tunnel support will vary from steel sets at the portals to shotcrete in the better sections.

The upstream and downstream cofferdams will be 18-m high and 3.0-m high respectively. The upstream and downstream slopes of the cofferdams will be 2.5H:1V and 2H:1V respectively (the upstream slope of the downstream cofferdam is on the downstream side). Although not yet designed, the upstream section is expected to be relatively finer impervious material and the downstream shell will be courser material. A chimney and blanket filter will be provided. The total volume of both cofferdams will be about 107,500 m^3.

A low-level intake structure will be constructed at the intake portal and a gate shaft will be constructed at about the mid-point of the tunnel to facilitate its use as a low level outlet for reservoir evacuation. The intake structure will be constructed to El. 12 to permit continuous operation over the life of the project without interference from sediment buildup. The gate shaft will house a 4-m wide by 4-m high wheel gate and a bulkhead gate with similar size. The diversion tunnel opening in the low-level intake will be plugged when the gate shaft is completed. Water can then rise to El. 12 and flow through the low-level intake and be controlled at the gate shaft.

Minimum Release Facilities

A minimum release facility is required to maintain flow in Rio Indio downstream of the project. The minimum release has been assumed to be equal to 10% of the average flow or about 2.6m^3/s. Computer modeling studies of the water quality expected in the Rio Indio Reservoir have been performed[(78)]. While the studies generally indicate that the quality of water in or released from the Rio Indio Reservoir should not present any problems that require mitigation, the model did predict low dissolved oxygen levels under some operation scenarios at lower reservoir elevations. There are no concerns about the quality of water that will be discharged through the transfer tunnel into Lake Gatun. When making minimum releases downstream of the Rio Indio dam, aeration would likely raise dissolved oxygen levels above minimum acceptable levels. However, to avoid any potential for discharging reservoir water with low levels of dissolved oxygen, the minimum release facility intake will be located at elevations above the projected low oxygen content water, or above El. 30.0.

An intake structure will be located on the face of the CFRD just below El. 40.0, the minimum operating level of the reservoir. The 1.0 m wide x 2.0 m high intake will be equipped with a trash rack and slide gate housed in an inclined structure located on the concrete facing of the dam. Both will be operated from the crest of the CFRD. The intake will connect through the

face of the dam to a penstock, nominal size at 1.0 m, to provide more than sufficient capacity for the assumed minimum release. The penstock will transfer the minimum release flow 150 m through the dam then 100 m down the downstream right abutment back to the Rio Indio. The penstock will be placed in a trench excavated in rock. The trench will be backfilled with concrete under the dam, and conventional granular backfill downstream of the dam. The penstock will terminate at a valve/power house containing a turbine/generator unit and a Howell-Bunger flow regulating valve. Releases will discharge into a channel that directs flow back into the Rio Indio immediately downstream of the dam. A guard valve will be provided upstream of the control valve.

Studies on the use of the minimum release for hydroelectric power generation have been performed. The studies show that the addition of hydroelectric power is currently not warranted. However, a decision was made to include a power plant attached to the minimum release facility to provide electricity to the resettlement area and as the primary source of power for project operation. The unit will consist of a horizontal-shaft Francis turbine directly connected to a synchronous generator. The unit will have a capacity of 1.6 MW and be designed to pass the minimum release at the minimum reservoir operating level (El. 40).

Water Transfer Tunnel

The water transfer tunnel consists of an approach channel, an intake structure, the tunnel, and an outlet structure. The plan and profile, and typical cross sections, are shown in [MWH, 2003]. The approach channel is 100 m long and has its invert at El. 30. The channel is excavated as a trapezoidal section with a bottom width of 20 m and side slopes of 2H:1V. The intake structure is a reinforced concrete structure with an opening of 5 m by 10 m. Trash racks protect the openings. Intake flow velocities at maximum discharge are limited to 1.5 m/s. The invert of the intake is at El. 32 to allow for proper hydraulic conditions at minimum pool operation. The intake structure extends up to El. 85, 1 m above the design flood elevation to provide access to the trash racks.

The intake structure goes beyond the tunnel, which is an 8,350-m long modified horseshoe shaped tunnel with vertical sides and a horizontal invert. The finished diameter of the tunnel is 4.5 m and the capacity is 94 m^3/s and 43 m^3/s at full supply level, El. 80, and minimum pool level, El. 40, respectively.

It was assumed that the tunnel construction would use drill and blast techniques from multiple headings. For the selected alignment, the estimated proportional distributions of the different rock support classes are shown below:

Tunnel Length (%)	Approx. Length (m)	Rock Support Class	
25	2100	Excellent	I
40	3400	Good to fair	II
30	2500	Fair to poor	III
5	400	Poor	IV

It is assumed that the tunnel will be fully lined. The lining is included to prevent erosion and deterioration of the rock in areas of soft or highly fractured rock. The lining will be cast-in-place concrete with a minimum thickness of 0.25 m. Reinforcement, thicker concrete, and steel lining will be included as required. For the cost estimate, it is assumed that the concrete lining will be increased to 0.5 m and nominal reinforcement will be provided where the rock cover is relatively low to provide containment.

A gate shaft and gate will be provided at the upstream end of the tunnel for runoff. It is located at 50 m from the intake structure. The gate will be 3.8 m wide by 4.5 m high. The gate will be raised and lowered by means of a hydraulic cylinder hoist that will be powered and operated from a surface control structure.

At the downstream end of the tunnel, an outlet structure will house two 2.5 m wide by 4.5 m high, bonneted guard gates and bonneted control gates in series. This will provide redundancy for reliable operation and maintenance, and additional flow control. The outlet structure will be founded on solid rock. Power and control equipment will be housed in a small structure adjacent to the gates. A road is provided for a mobile crane to access the gates when maintenance is required.

The outlet will discharge at El. 27, slightly above the maximum water surface elevation for Lake Gatun, onto a concrete sill about 35 m long. The sill ends at El. 20, slightly below the minimum level of Lake Gatun. The sill widens from 9 m wide at the outlet structure to 19 m wide at the downstream channel. The outlet structure discharges into a 240 m long channel. The channel is excavated as a trapezoidal section with a bottom width of 20 m and side slopes of 2H:1V. It directs the flow from the Rio Indio transfer tunnel into Lake Gatun adjacent to Isla Pablon.

Operation Facilities

Operation facilities are required for the Rio Indio Water Supply Project Alternative. Without the addition of hydroelectric power and considering only that the Indio to Gatun transfer tunnel gates requires daily adjustment, the project lends itself to remote operation. Operation facilities will

include a SCADA system for remote monitoring and operation of the project. The system will monitor water levels, flow measurements, gate operation and project safety instrumentation. The new SCADA system will include a communications package. It will be monitored and operated by the ACP Meteorology and Hydrology Division as an extension to their existing system.

Additional project facilities will include security and lighting at the dam and spillway, and intake and outlet of the transfer tunnel. Landscaping and drainage will also be provided at these project features. Minimum maintenance facilities will be retained from the temporary construction facilities.

2.4.3 Investment Costs Estimate

Here follows an estimate of the Project Construction Costs for Option 1, the more expensive of these two options[65]:

Item	Estimated Cost
Land acquisition and resettlement	$26,100,000
General costs, including Construction and Permanent Access	$23,839,000
Diversion	$3,603,000
Main dam	$52,704,000
Spillway	$6,043,000
Low-level outlet	$3,049,000
Saddle Dams	$7,427,000
Inter-basin transfer tunnel	$46,765,000
Minimum release facility	$837,000
Operation facilities	$1,139,000
Subtotal, direct cost	**$171,506,000**
Contingencies	$28,868,000
Direct cost	**$200,374,000**
Engineering and administration	$30,056,000
Construction cost (mid-2001 price levels)	**$230,430,000**

It is estimated that the option will require about 8 years for implementation and 5 years (58 months) for construction. The first 16 months of the 5 year construction period are required to mobilize, complete most of the access roads, and establish the construction camp. Construction of the dam and appurtenant works and water transfer tunnel will require about 42 months[65] Power for construction will be provided by small size diesel generators. Electrical power needs for construction is estimated to be approx. 1.5 MW.

2.4.4 Description of Construction Stages

The construction works for the water options are anticipated to take between 5 and 8 years. A brief description of the main tasks is provided below:

Land Acquisition (5,000 ha). Project implementation would begin with land acquisition. Lands for the project housing and facilities, which include the access roads, would be acquired initially. Lands for the dam site, staging area, disposal area, transmission lines and lake would then be acquired.

Improvement and Construction of Access Roads (45 Km of upgrades and 15 Km of new roads). Access roads would be constructed to the dam site and the inter-basin transfer tunnel inlet and outlet sites.

Camp Construction (8.0 ha). Once highway access to the sites has been established, a camp would be built to house workers during construction, offices and workshops.

Resettlement programs (2,300 people). Socio-economic programs would begin shortly before construction of the dam. The relocation of towns, small settlements, and isolated structures would be carried out. Socio-economic programs to assist those individuals impacted by the construction of the proposed project would continue throughout the construction phase. The details of the resettlement plans have been reviewed by the URS team, and are included as part of the environmental management plan.

Clearing and grubbing (5,000 ha). Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Is expected to take a minimum of two years and will be started from the lower level working towards the higher elevations.

Excavation activities (1.5 MCM of material). Excavation for the inter-basin transfer tunnel, the intake structure, the diversion tunnel and the spillway would follow with work being done simultaneously.

Disposal of the Material. Rock and earth and rockfill materials removed as a result of the required excavation for structures, tunnels or roadways that are unsatisfactory, in excess, or impractical for use in the finished work will be stockpiled in designated areas and sloped to drain so as to provide a stable mass.

Extraction of material from quarries (1.2 MCM of material). Materials will be extracted from two quarries, Cerro La Jota and Cerro Las Ollas, located at about 6.5 km and 3.0 km from the dam site respectively.

Construction of the dam and appurtenants (2 MCM excavated; 3 MCM of fill volume). Once the intake structure and diversion tunnel are completed, the dam construction site will be isolated using upstream and downstream cofferdams, which would eventually become part of the main dam, and the stream would be diverted through the tunnel. The dam foundation would then be excavated and grouted, and the dam constructed.

Lake filling. Upon completion of the dam and inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped and reservoir filling would begin. Upon completion, all facilities would undergo testing followed by commissioning for service.

2.5 Options 3 and 4: Alto Indio 50-40 and 45-40

Location maps for Options 3 and 4 are shown on Figure 2-5 and Figure 2-6. The selected dam site for these two options would be located at a location of approximately 10 km upstream from the Tres Hermanas site. The axis of the dam would be slightly concave downstream and would cross the main channel of the Rio Indio at about the coordinates 991000N, 592000E (UTM Coordinate System).

2.5.1 Project Justification

The water production derived from this Option will be used to augment the existing supply of water to the Canal, provide for increases in municipal and industrial water in and around the Panama Canal Watershed, and adjacent area, and will possible be used as energy source for the local and regional market.

2.5.2 Components Identification and Works Design

The major components of the Alto Indio Water Supply project are:

- A concrete face rockfill dam and appurtenant works.
- A 4.5 m diameter water transfer tunnel, with a length ranging between 8,500 and 9000 m to transfer water from the Alto Indio Reservoir to Lake Gatun.

For Option 3, the dam will impound a reservoir with a gross storage capacity of approximately 90 MCM at El. 50, the full supply level. Live storage between El. 50 and El. 40 will be 60 MCM. For Option 4, the dam will impound a reservoir with a gross storage capacity of 55 MCM at El. 45, the full supply level. Live storage between El. 45 and El. 40 will be 25 MCM. These physical dimensions are summarized on Figure 2-7.

Alto Indio Dam

The proposed Alto Indio Dam will be a concrete-face rockfill dam (CFRD) constructed of durable, free-draining compacted rockfill obtained from the excavation required for the right abutment and from nearby quarries. The slopes of the upstream and downstream faces will be conservatively set at 1.4H:1.0V based on precedent cases for this dam type, foundation, and seismicity at the site. The main body of the dam will be comprised of rockfill and the downstream shell will be coarse rockfill.

The crest of the dam will be at El. 50 and the width of the crest will be 8.0 m. A 5-m high parapet wall will extend 2.0 m above the crest to El. 55. The dam will be about 60 m high from the deepest foundation excavation to the top of the parapet wall.

The reinforced concrete facing will act as the impervious membrane. It will be designed to have low permeability, durability against weathering, and sufficient flexibility to tolerate small expected embankment settling. A 3-m wide zone of filter material and a 3-m wide zone of fine rockfill will underlay the concrete face to provide continuous support. The filter material will be manufactured from igneous quarry material. The average thickness of the concrete face will be 0.4 m. Reinforced steel will be included at a rate of 30 kg/m^3. The facing will be placed in individual up to 15 m wide slabs and horizontal joints will be inserted whenever necessary.

Foundation Treatment

No detailed information about the foundations required for this dam is available and they are consequently assumed to be similar to those described for the Rio Indio Options 1 and 2.

Spillway

An uncontrolled ogee spillway located within the abutment adjacent to the left end of the dam, with a total length of 113.11 m is required. The spillway has been designed to pass the probable maximum flow (PMF) without overtopping the dam (1 in 1000 frequency). The discharge under PMF conditions will be 618m^3/s.

Water Transfer Tunnel

The water transfer tunnel consists of an approach channel, an intake structure, the tunnel, and an outlet structure. The approach channel is 100 m long and has its invert at El. 30. The channel is excavated as a trapezoidal section with a bottom width of 20 m and side slopes of 2H:1V. The intake structure is a reinforced concrete structure with an opening of 5 m by 10 m. Trash racks protect the openings. Intake flow velocities at maximum discharge are limited to 1.5 m/s. The invert of the intake is at El. 32 to allow for proper hydraulic conditions at minimum pool operation. The intake structure extends up to El. 55, to provide access to the trash racks. A trash rake is provided to clean the trash racks.

The intake structure goes beyond the tunnel, which is an 8,500 – 9000 m (see Figure 2.-5 and Figure 2-6 for potential tunnel layouts) long modified horseshoe shaped tunnel with vertical sides and a horizontal invert. It was assumed that the tunnel construction would utilize drill and blast techniques from multiple headings.

2.5.3 Investment Costs Estimate

The cost estimate for the project construction were taken from the USACE Reconnaissance Study, where this dam and reservoir where originally conceptualized in conjunction with the Lower Trinidad Dam and Impoundment. For comparison purposes, these costs were updated on the basis of Options 1 and 2 for Rio Indio, which are in 2001 US Dollars.

2.5.3.1 Description of the Construction Stages

Construction works for the water options are assumed to be similar in nature and time requirements to those described for options 1 and 2 above. General tasks are assumed to include the following:

- Land Acquisition;
- Upgrade and Construction of Access Roads;
- Camp Construction;
- Resettlement programs;
- Clearing and grubbing;
- Excavation activities;
- Disposal of the Material;
- Extraction of material from quarries;
- Construction of the dam and appurtenants; and
- Lake filling.

Item	Estimated Cost
Land acquisition and resettlement	$4,750,000
General costs, including Construction and Permanent Access	$11,138,694
Diversion	$9,565,287
Main dam	$15,226,374
Spillway	$42,070,303
Low-level outlet	$7,701,295
Saddle dams	N/C
Inter-basin transfer tunnel	$27,806,250
Minimum release facility	--
Operation facilities	--
Subtotal, direct cost	**$118,258,203**
Contingencies	$39,835,375
Direct cost	**$158,093,578**
Engineering and administration	$26,556,917
Construction cost	**$184,650,495**

Note: The cost presented in this table was taken from the section 38, page 38-21 from the Panama Canal, Reconnaissance Study, USACE 1999.

2.6 Description of Additional Water Options in the Rio Indio Watershed

This section documents the results of an analysis performed by URS to provide two additional water resources options for storage and delivery of water to the ACP. For the identification and development of these two options at a conceptual level, the URS team used detailed topographic data (DEM 10 x 10 meters) provided by ACP and developed a runoff model for the area under study. This model is described in **Annex 2-B** of this report and was very useful to identify the most significant water producing areas within the area under study.

For processing the surface topographic data provided by the ACP, a geographical processing terrain modeling tool was used. The tool selected for this task was the Watershed Modeling System (WMS v7.0), originally developed by the US Army Corps of Engineers. WMS was used as a graphical modeling environment for the ROCC watershed hydrology. This tool includes automated modeling processes such as watershed delineation, geometric parameter estimation; GIS overlay computations and external data processing such as rainfall depth, runoff coefficients and cross-section extraction from terrain data and phase-area-storage calculations.

WMS was used to analyze several storage-conveyance-renewal configurations in order to define the "additional" water resources options, described in this Section. This involved the following methodological steps:

(a) Basin Delineation: First streams and watershed/sub-basin boundaries based were delineated on the basis of the land surface represented by a digital terrain model provided by the ACP. This procedure is computed automatically from the terrain data provided by the ACP in electronic (DEM) form.

(b) Development of Flooding Contours: The flood depth and extension maps were then generated on the basis of the digital terrain model and water surface data. For this, one or a combination of available options were used: 2D interpolation of flood depths over the surface of the terrain, lateral interpolation of water surface elevations along cross sections, stream center-line interpolation between cross-sections, flood barrier inclusion (buildings, levees, walls, etc.).

(c) Placement of storage structures (dams): Here, different locations for the storage structures were tested and the resulting flood contours were recomputed to determine the impact areas of different flood elevations while maximizing the storage capacity of the each dam.

(d) Storage calculations in resulting reservoirs: A characterization of the elevation-storage-area relationship for the resulting reservoirs was established and presented graphically to provide the operating range of each water resources option.

(e) Comparison with "existing" storage benchmarks: The calculated elevation-storage-area relationships were compared to the benchmarks established by the feasibility studies for the Indio, Caño Sucio and Toabre watersheds, for the purposes of establishing the viability of the given dam configurations.

This procedure was used iteratively until a set of two "additional" water resources options was obtained that would be comparable to the "existing" alternative benchmarks. The identification and selection of the options, and the cost conceptualization are included in Annexes 2-C and 2-D, respectively. Because these two additional options were not subject to a feasibility-level of analysis, the information presented is preliminary but sufficient to allow for these two options to be considered in relative comparison to the other existing options from the water supply capacity and estimated costs points of view.

The option descriptions presented below thus focus on these two aspects of the two proposed additional water supply options for ACP.

2.6.1 Option 11: Teria-Alto Teria

This option consists of a set of two interconnected reservoirs (Teria-1 and Teria-2) in the Rio Teria watershed. The location of these two reservoirs is shown on Figure 2-8. In this option, the Teria-1 reservoir operates at maximum capacity at El.130m, and discharges at an elevation of El. 90m, generating approximately 250 MCM of usable storage. The Teria-2 reservoir operates at maximum capacity at El. 265m, discharging to an elevation of El. 225m and generating 200 MCM of usable storage conveyed directly to Teria-1 through the existing river bed. Thus, the combined usable storage would be 450 MCM replenished every 1.8 years on average, with a maximum total storage of 530 MCM. These physical dimensions are summarized on Figure 2-9.

Water is conveyed from the Teria-1 reservoir to the Canal through a 4-km long inter-basin transfer tunnel into the Rio Ciri which discharges into Lake Gatun.

The dam sites at Rio Teria would cross the main channel of the river at about coordinates 985500N, 596000E for the Teria-1 reservoir and 975525N, 596657E for the Teria-2 reservoir (UTM Coordinate System).

2.6.1.1 Project Justification

The Teria-1 and Teria-2 reservoirs would be connected by the river channel and would be operated as one lake or two modular lakes. The structures for the proposed option would consist of rock fill dams on the two proposed locations in the Rio Teria, inter-basin transfer facilities, and outlet works. An analysis of this option was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project.

A general development plan, showing the location of the dam, the reservoir boundary, and the water transfer alignment for this option is shown on Figure 2-8.

2.6.1.2 Investment Costs Estimate

URS develop a cost estimate for the Project Construction for Option 11 at the conceptual level, and it has been used to compare it to the other alternatives.

Item	Estimated Cost
Land acquisition and resettlement	$ 11,912,100
General costs, including Construction and Permanent Access	$ 6,401,000
Diversion	$ 2,500,300
Main Dams	$ 197,402,700
Spillway	$ 4,193,600
Low-level outlet	$ 3,783,300
Saddle dams	$ 393,500
Inter-basin transfer tunnel	$ 13,898,800
Minimum release facility	$ 1,038,590
Operation facilities	$ 1,413,337
Subtotal, direct cost	**$ 242,937,227**
Contingencies	$ 69,798,922
Direct cost	**$ 312,736,149**
Engineering and administration	$ 37,443,773
Construction cost (2004 price levels)	**$ 350,179,922**

2.6.2 Option 12: Teria-Cabecera Indio

This option is a variant of the previous one so as to reduce costs and increase the annual average discharge through the system. It consists of a set of three interconnected reservoirs (Teria-1, Teria-2 and Cabecera Indio) in the Rio Teria and Rio Indio watersheds. The location of these two reservoirs is shown on Figure 2-10. In this option, the Teria-1 reservoir operates at maximum capacity at El.130m, and discharges at an elevation of El. 90m, generating approximately 250 MCM of usable storage. The Teria-2 operates at maximum capacity at El. 265 m and discharges at an elevation of El. 225, generating 200 MCM of usable storage conveyed directly to Teria-1 through the existing river bed. The Cabecera Indio reservoir is only a diversion structure, and it is estimated that it may transfer approximately 70-80% of the water to the Teria River sub-basin, operating at El. 300 m, with a usable storage of only 30 MCM. The water would be transferred to the Teria River through an approximately 1 km long aqueduct. Thus, the combined usable storage would be 450 MCM replenished every 1.05 years on average, with a maximum total storage of 550 MCM. These physical dimensions are summarized on Figure 2-11.

Water is conveyed from the Teria-1 reservoir to the Canal via a 4-km long inter-basin transfer tunnel into the Rio Ciri which discharges into Lake Gatun. The dam sites at Rio Teria would cross the main channel of the river at about 985500N, 596000E for the Teria-1 reservoir and 968000N, 596000E for the Cabecera Indio reservoir (UTM Coordinate System).

2.6.2.1 Project Justification

The Cabecera Indio reservoir would convey water to the Teria watershed through a 1-km long aqueduct. The structures for the proposed option would consist of rock fill dams on the three proposed locations in the Rio Teria and Rio Indio watersheds, inter-basin transfer facilities, and outlet works. An analysis of this option was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project.

A general development plan, showing the location of the dam, the reservoir boundary, and the water transfer alignment for this option is shown on Figure 2-10.

2.6.2.2 Investment Costs Estimate

URS estimated the costs for the Project Construction under Option 12 at the conceptual level, and was used for comparison with other alternatives.

Item	**Estimated Cost**
Land acquisition and resettlement	$ 13,300,000
General costs, including Construction and Permanent Access	$ 13,721,885
Diversion	$ 6,020,203
Main Dams	$ 195,200,000
Spillway	$ 10,097,165
Low-level outlet	$ 9,147,000
Saddle dams	$ 999,450
Inter-basin transfer tunnel	$ 44,804,790
Canal	$ 900,000
Minimum release facility	$ 2,511,000
Operation facilities	$ 3,417,000
Subtotal, direct cost	**$ 277,350,767**
Contingencies	$ 80,268,590
Direct cost	**$ 357,619,357**
Engineering and administration	$ 43,590,564
Construction cost (2004 price levels)	**$ 401,209,921**

2.7 Summary of Water Options

The water resources required for the future operation and potential expansions currently planned by the ACP require the creation of reservoirs within the corresponding watersheds in order to allow for increased storage capacity. The most up-to-date information on the different water resources options being considered is presented in feasibility studies recently completed. In

addition to this, two additional options are proposed based on an analysis of the topographic and surface runoff generation capabilities of the watersheds within the ROCC.

The key characteristics of the alternatives associated to the Rio Indio watershed are summarized in Tables 2-1 to 2-6.

Table 2-1: Option 1
SIGNIFICANT DATA ON THE PROJECT: INDIO 80-40

Project scenario	Rio Indio watershed; NW of the city of Panama and SW of Colon	
Hydrology		
Average annual rainfall	3078	mm
Average annual flow	25.8	m^3/s
Water storage facilities		
Reservoir		
Drainage area	381	Km^2
Maximum water level	El. 80	MSL
Volume	1,577	MCM
Surface area	45.6	Km^2
Minimum water level	El. 40	MSL
Volume	283	MCM
Surface area	17.7	Km^2
Water transfer facilities		
Tunnel		
Length	8,350	M
Diameter	4.5	M
Estimated project cost		
Construction cost	$230,430,000	
Annual cost	$1,940,000	
Estimated project yield		
Volumetric reliability	99.6	%
Yield lockage/day	15.5	L/d
Yield MCM/year	1,177	MCM/year

Table 2-2: Option 2
SIGNIFICANT DATA ON THE PROJECT: INDIO 45-40

Project scenario	Rio Indio watershed; NW of the city of Panama and SW of Colon	
Hydrology		
Average annual rainfall	3,078	mm
Average annual flow	25.8	m^3/s
Water storage facilities		
Reservoir		
Drainage area	381	Km^2
Maximum water level	El. 45	MSL
Volume	400	MCM
Surface area	22.5	Km^2
Minimum water level	El. 40	MSL
Volume	283	MCM
Surface area	17.7	Km^2
Water transfer facilities		
Tunnel		
Length	8,350	m
Diameter	4.5	m
Estimated project cost		
Construction cost	$185,000,000	
Annual cost	$ 1,390,000	
Estimated project yield		
Volumetric reliability	99.6	%
Yield lockage/day	1.4	L/d
Yield MCM/year	106	MCM/year

Table 2-3: Option 3
SIGNIFICANT DATA ON THE PROJECT: ALTO INDIO 50-40

Project scenario	Rio Indio watershed; NW of the city of Panama and SW of Colon	
Hydrology		
Average annual rainfall	3,078	mm
Average annual flow	25.8	m^3/s
Water storage facilities		
Reservoir		
Drainage area	256	Km^2
Maximum water level	El. 50	MSL
Volume	90	MCM
Surface area	26.5	Km^2
Minimum water level	El. 40	MSL
Volume	30	MCM
Surface area	17.7	Km^2
Water transfer facilities		
Tunnel		
Length	8,500-9,000	m
Diameter	4.5	m
Estimated project cost		
Construction cost	$ 184,650,495	
Annual cost	$ 1,250,000	
Estimated project yield		
Volumetric reliability	99.6	%
Yield lockage/day	0.7	L/d
Yield MCM/year	53	MCM/year

Table 2-4: Option 4
SIGNIFICANT DATA ON THE PROJECT: ALTO INDIO 45-40

Project scenario	Rio Indio watershed; NW of the city of Panama and SW of Colon	
Hydrology		
Average annual rainfall	3,078	mm
Average annual flow	25.8	m^3/s
Water storage facilities		
Reservoir		
Drainage area	256	Km^2
Maximum water level	El. 45	MSL
Volume	55	MCM
Surface area	22.5	Km^2
Minimum water level	El. 40	MSL
Volume	30	MCM
Surface area	17.7	Km^2
Water transfer facilities		
Tunnel		
Length	8,500-9,000	m
Diameter	4.5	m
Estimated project cost		
Construction cost	$145,000,000	
Annual cost	$ 1,250,000	
Estimated project yield		
Volumetric reliability	99.6	%
Yield lockage/day	0.3	L/d
Yield MCM/year	23	MCM/year

Table 2-5: Option 11
SIGNIFICANT DATA ON THE PROJECT: TERIA

Project scenario	**Rio Teria-1 watershed El. 130-90**	**Rio Teria-2 watershed El. 265-225**	
Hydrology			
Average annual rainfall	3,740	4,240	mm
Average annual flow	7.4	3.4	m^3/s
Water storage facilities			
Reservoir			
Drainage area	94	35.6	Km^2
Maximum water level	El. 130	El. 265	MSL
Volume	270	245	MCM
Surface area	11.72	8.25	Km^2
Minimum water level	El. 90	El. 225	MSL
Volume	50	40	MCM
Surface area	-	-	Km^2
Water transfer facilities			
Tunnel	Teria to Ciri	-------	
Length	4,000	-------	m
Diameter	4.5	-------	m
Estimated project cost			
Construction cost	$277,084,262	$ 73,095,659	
Annual cost	$3,980,000		
Estimated project yield			
Volumetric reliability	99.6	99.6	%
Yield lockage/day	5.1		L/d
Yield MCM/year	387		MCM/year

Table 2-6: Option 12
SIGNIFICANT DATA ON THE PROJECT: TERIA-INDIO

Project scenario	**Rio Teria 1 El. 130-90**	**Rio Teria-2 El. 265-225**	**Cabecera R. Indio El. 300-295**	
Hydrology				
Average annual rainfall	3,740	4,240	4,340	mm
Average annual flow	7.4		6.4	m^3/s
Water storage facilities				
Reservoir				
Drainage area	94	35.6	60.9	km^2
Maximum water level	El. 130	El. 265	El. 300	MSL
Volume	270	245	30	MCM
Surface area	7.6	8.25	11	Km^2
Minimum water level	El. 90	El. 225	El. 295	MSL
Volume	50	40	10	MCM
Surface area	-	-	-	Km^2
Water transfer facilities				
Tunnel	Teria to Ciri			
Length	4,000	-------	-------	m
Diameter	4.5	-------	-------	m
Estimated project cost				
Construction cost	$277,084,262	$73,095,659	$51,030,000	
Annual cost		$4,375,000		
Estimated project yield				
Volumetric reliability		99.6		%
Yield lockage/day		5.3		L/d
Yield MCM/year		502		MCM/year

2.8 Legal Framework

The environmental laws, regulations and guidelines applicable to the Environmental Assessment of Water options at the ROCC, include the regulations and laws of the applicable agencies of Panama, the World Bank guidelines and requirements, and the ACP Environmental Assessment Manual. This sections describes the laws, regulations and/or guidelines which may be applicable to the water options. The information relevant to this project has been grouped under the following headings:

- Constitution of the Republic of Panama
- Environmental Management

- Natural Resources
- Water
- Air
- Noise
- Waste and Hazardous Waste
- Safety

It is important to point out that the guidelines related to the World Bank and the ACP Environmental Assessment Manual have been included under Environmental Management.

2.8.1 Constitution of the Republic of Panama from 1972, amended in 1978 and 1983

Chapter VII, Title III, on Individual and Social Rights and Duties, appropriately establishes an Ecological Regime, assigning to the State and to all inhabitants of the country specific functions related to the conservation and use of natural resources.

Said Chapter has four sections which establish the following: Section 114 establishes that it is the duty of the State to guarantee a safe environment free from contamination for the population, where the air, water and food satisfy the requirements of adequate development of human life. Section 115 establishes that the State and all inhabitants of the nation have the duty to promote the social and economic development that will prevent the contamination of the environment, maintain the ecological balance, and avoid the destruction of ecosystems. Section 116 establishes that the State will regulate, supervise, and enforce the necessary measures to guarantee the use and exploitation of the terrestrial, fluvial and marine fauna, as well as of the forests, lands and water in a rational way so as to avoid predation, and ensure the preservation, renewal and permanence. Finally, Section 117 establishes that legislation shall be enacted to regulate the use of non-renewable resources to avoid any resulting social, economic and/or environmental damage.

The analysis of the previously stated sections indicates that the Panama State, in environmental matters, follows the criteria for sustainable development of resources for as long as sustainability is ensured, and extinction prevented.

2.8.2 Environmental Management

Act 41, dated June 1 1998, General Act on the Environment. ANAM

Act 41, dated June 1 1998 empowered the National Environmental Authority (*Autoridad Nacional del Ambiente* or ANAM) to regulate through its Executive body the process of Environmental Impact Assessment. Chapter II, Title IV of the General Act on the Environment refers to the Environmental Impact Assessment Process and establishes that those activities, works, or project, whether private or public, that due to their nature, characteristics, effects, location or resources may generate an environmental risk, require the execution of an Environmental Impact Evaluation prior to the beginning of the work or project. Besides, it states the different stages involved in the assessment process.

Act 30, dated December 30 1994, amending Section 7, Act 1. ANAM

This Act requires the execution of an environmental impact evaluation for every project or human activity that may damage or affect the natural environment. Besides, Section 1 of this Act amends Section 7 of the Forestry Act, which indicated, in general terms, that the EIA had to be performed by skilled professionals trained in the field of sciences related to ecology.

Executive Decree No. 59, dated March 16 2000, Rules for the Environmental Impact Assessment Process. ANAM

These rules establish that the Environmental Impact Assessment Process will be subject to the provisions of Act No. 41, dated June 1 1998, the General Act on the Environment of the Republic of Panama. A said rule include the functions and responsibilities of the ANAM in relation to the environmental impact assessment process, and establishes the responsibilities in the EIA of the initiators.

Section 14, Title II, presents a list of projects that are regulated by the environmental impact assessment process, such as projects for the construction of dams. Besides, Sections 17 and 18, Chapter I, Title III establish the environmental protection criteria to be taken into account to determine the category in which the Environmental Impact Evaluation falls, and Section 19 describes the three EIA categories established by the ANAM. The minimum contents and general terms of reference required for the EIA are provided for under Sections 22, 23, 24, and 25 of said Rules and Sections 26, 27, 28, 29, and 30 refer to citizen participation.

Executive Decree No. 57, dated March 16 2000, "regulating the constitution and operation of the Environmental Advisory Committees" ANAM

This regulation sets forth the provisions of Act No. 41, dated July 1 1998, in matters of Advisory Committees, Mechanisms for Public Consultation, and Claims Procedures. The objectives of the citizen participation process are as follows: to involve the citizens in the State Environmental Management, as actors and active participants therein; reinforce the democratic government system on the basis of the exercise of non-political rights, to facilitate the provision of information and negotiation between private and/or public actors tending to decrease or adequately resolve its development; to increase the State institutional credibility; to facilitate the planning process and a more certain decision making process in environmental matters by government agents, reducing the room for mistakes in public management; to strengthen the civic-environmental educational process of citizens as a whole; and to introduce administrative transparency in environmental management practices.

Executive decree No. 58, dated March 16 2000, "regulating the procedure for the elaboration of environmental quality standards and maximum permitted limits". ANAM

This Decree establishes the procedure to elaborate environmental quality standards and maximum allowable limits referred to in Chapter III, Title IV, Act No. 41, General Act on the Environment, as well as the criteria and procedure to review those standards, which shall be compulsory enforced in all the national territory and, in their development, the applicable authority from the regions, municipalities and organized communities, shall be involved. The Executive body through and executive decree may issue environmental quality standards and established transient maximum permitted limits, notwithstanding the procedure previously provided for in this regulation, so as to recover environmentally critical areas or overcome contingent situations in case of a disaster, as established in Chapter IV, Title III of this regulation, without hereby excluding the approval of other technical standards, parameters, guidelines or directives tending to prevent the environmental damage.

All primary standards shall indicate critical values determining environmental emergency situations; term for their enforcement; divisional organizations in charge of supervising compliance; methodologies for measurement and control of the standard, all of which, if in existence, shall indicate the methodology corresponding to the standard of concern. These values will also be applied to secondary environmental quality standards and their maximum permitted limits. Once the actions are implemented, and the circumstances giving rise to the contingency are overcome, the transient standards for environmental recovery will cease to be in force, and

the environmental quality standards and current maximum permitted limits for environmentally normal situations will be in full force.

Resolution (ANAM) N.° AG-0292-01, dated September 10 2001, Operative Manual for Environmental Impact Assessments. ANAM

The main objective of this Manual is to provide a guideline on the application of the EIA preventive procedure so as to incorporate the environmental dimension into new projects, and the modification of existing ones executed in the Republic of Panama. The Manual contains a *central body* that contains the background and scope of the document and establishes the procedure to be carried out, together with a set of *instruments* the purpose of which is to provide support to the specific procedural applications through qualified information.

ACP Environmental Assessment Manual, January 1999

The ACP Environmental Assessment Manual is a document prepared by the US Army Corps of Engineers, and it specifies procedures to identify and assess possible impacts associated to the activities performed by this organization. The Manual is organized in 25 chapters including topics such as public participation, assessment of effects on the water quality; assessment of growth potential of aquatic plants in reservoirs; assessment of impacts on fishing grounds, assessment of impacts on wetlands; assessment of impact on endangered species; and assessment of socio-economic impacts; among others.

World Bank Environmental Assessment Sourcebook – Volumes I, II and III

The World Bank Environmental Assessment Sourcebook is divided into three volumes including the following: Volume I: Policies, Procedures and Trans-Sectoral Issues; Volume II: Sectoral Guidelines, and Volume III: Guidelines for Environmental Assessment of Electric Power and Industrial Projects. In each one of these documents, there are aspects aimed at guiding or assisting the environmental assessment, ranging from basic principles to the elaboration, assessment, and approval of an environmental assessment. However, Volume II of this Sourcebooks describes the sectoral guidelines for Projects related to Dams and Reservoirs. The guidelines have been grouped under the following categories:

Potential Impacts. It identifies typical impacts which may be generated as part of a project of this nature and it groups them under hydrological and limnological effects; social issues; fishing grounds and wild life; seismic threats; and management of watersheds. For each one of the

possible impacts, the most significant aspects to be taken into consideration during the environmental assessment are presented.

Project Alternatives. It describes a series of alternatives which should or could be considered before the construction of a dam or reservoir. Within these alternatives, the following are described: postponement of works by enforcing savings in water consumption; study of the possibility of locating the project in an already impounded river; location and adjustment of the project height to minimize its impact; and construction of several small dams instead of a large one.

Management and Training. It describes the responsibilities to be assumed by an agency or authority during the management of the works once it has been built. Some of the responsibilities include the collection of data on the watershed; the construction and management of the works; the preparation of a master plan on water use; the approval of permits for the extraction of water from the reservoir; the coordination of the vectors control; and the planning of the municipal water supply and treatment facilities.

Monitoring. A series of factors to be monitored are presented. They include: rainfall, water storage; volume of sediments transported to the reservoir; reservoir water quality, and generation of hydrogen sulfide and methane behind the dam; among others.

Besides the Assessment Manual, there are also Operational Directives for specific issues such as Involuntary Resettlement (OD 4.30); Management of Plagues in Agriculture (OD 4.03), and Native Populations (OD 4.20); among others. The relevant Operational Directives shall be considered during environmental assessments.

2.8.3 Natural Resources

Act 1, dated February 3 1994, Forestry Act. ANAM

This act is a positive legal statement for the national sustainable development of forests. Its aims are the protection, preservation, upgrade, education, study, management, and rational use of the forestry resources of the Republic of Panama.

The Forestry Act is the first law, which considers, under Section 7, Environmental Impact Studies as prerequisites for activities, works, or projects that may damage the environment.

Resolution (ANAM) No. AG-0235-2003, dated June 12 2003, establishes the fees to be paid for ecological compensations, for the issuance of permits for clear-cutting, and elimination of undergrowth, or grass formations.

This resolution establishes the rate to be charged for every development, infrastructure, and construction works involving the clearing of any type of vegetation, which will involve an economic compensation for the damage caused to the environment. Depending on the category of the area, the fees to be charged will be as follows:

- Intervened primary natural forest, or mature secondary forests = B/. 5000/hectare.
- Wetlands (mangroves, *oreysales* and *activales*) = B/. 10000/hectare.
- Secondary forests with intermediate growth = B/. 3000/hectare.
- Young secondary forests = B/. 1000/hectare.
- Undergrowth = 50% of prior figures, depending on the degree of ecological evolution of the forest.
- Grassland (scrubland) formation = B/. 500/hectare.
- When the vegetation clearance or elimination is in protected areas, the amount to be charged will be twice the prior figures.

Finally, that resolution indicates that when it is a unit fraction, considering that a unit is equal to a hectare, the amounts charged will be proportional to the affected surface area.

Act No.44 dated August 30 1999, approving the boundaries of the Panama Canal Watershed. ACP

This act establishes the new boundaries for the Watershed, annexing the watersheds of the Indio, Caño Sucio/Miguel de la Borda and Cocle del Norte watersheds, which have a drainage area towards the Caribbean Sea. With this new demarcation of the Canal Watershed, the area is divided into two regions, the Eastern Region covering the areas located in the traditional watershed, and the Western Region which covers the above-mentioned watersheds and which are distributed among the provinces of Panama, Cocle, and Colon. Both regions cover a total surface area of 552,761 has.

2.8.4 Water

Act No. 35, dated September 22 1966, Act on Use of Water. MIDA

This Act establishes that the waters belong to the State, and are for public use. It regulates the use of the State water - in terms of use, conservation and management - for its exploitation in the interest and for the public and social welfare. It establishes that all fluvial, lacustrine, marine, atmospheric and ground water within the national, continental and insular territory, the subsoil, the submarine continental platform, territorial sea, and air space of the Republic are assets belonging to the State, and are therefore for common free use. Therefore, the property of these waters cannot be assigned to private individuals since they are for public use.

Under the provisions of this act, the use of water for public or social purposes or objectives have priority over private interests since thus, there is more benefit for the public and social interest in matters of public health. The regime for its use contains provisions on health and sanitation and, sanctions are set for lack of compliance. The National Department of Water watersheds (*Direccion Nacional de Cuencas Hidricas*) recommends the set-up of forest reserves, the preservation of the vegetative cover or measures to fight erosion in state or private lands, in the banks of rivers and streams, and in any other area considered convenient for the protection of water watersheds. This office may oblige owners to preserve the vegetative cover or adopt measures against erosion, and ban facilities and uses which may cause any danger as a result of the modifications they may cause in the natural water flow.

Act No. 2, dated January 1997, regulatory and institutional framework for the provision of potable water and sanitation. IDAAN

This act sets the regulatory framework for activities related to the public supply of potable water and for the sanitation network, considered to be for the public good. They should be provided under quality conditions, at low prices, while using the natural resources in a sustainable way and protecting the environment.

The suppliers of potable water and sanitation which in the course of their activity alter the environment, are obliged to mitigate the negative effects through the submittal of environmental studies and proposals before the development of new projects. The quality of the potable water and sewage system must comply with the limits established in the current legislation.

Act 21 dated July 9 1980, regulating contamination of the sea and waterways. MICI

It prohibits the discharge of any pollutant in the waterways and territorial sea of the Republic of Panama from ships, aircrafts, marine and land facilities connected or linked to those waters, and includes the ships under Panamanian flag in international waters. It excludes those discharges for the exceptional situations anticipated in the international conventions to which Panama is a party, exemption extending to aircraft, and land and marine facilities. *All ships with a gross register over three hundred tons* transporting pollutants within the waters of the Republic of Panama or two thousand (2000) tons of bulk hydrocarbons, as cargo must have an insurance or financial guarantee to cover the amount of its liability.

The Ministry of Trade and Industries, through the corresponding office, and with the cooperation of other State agencies, will assess through periodical technical studies the ecological conditions of the waterways, territorial sea and littoral of the country, so as to assess the damage caused by the discharge of pollutants.

Act 16 dated October 23 1975, through which the International Convention related to Intervention on the High Sea in cases of Oil Pollution Casualties. MICI

The Parties to this Convention, may take the necessary measures on the high sea to prevent, mitigate, or eliminate all serious or imminent danger to its littoral area or related interests due to contamination or threat of contamination of the waters by hydrocarbons, as a result of a marine accident or other acts related to that accident considered to have large consequences, being excluded the war ships or other ships the property or use of which correspond to the State and are used exclusively, at that moment for non-commercial government services.

Technical Regulation DGNTI-COPANIT 35-2000 and 39-2000, Water. Direct discharge of liquid effluents in surface bodies or groundwater. MICI

The objectives of these two technical regulations is to prevent the contamination of bodies of surface water or groundwater in the Republic of Panama, through the control of liquid effluents from domestic, commercial or industrial activities, which are discharged into the receiving bodies and sewage in order to maintain the water free from contamination, thus preserving the population's health. These regulations also include some general requirements on the discharge of liquid effluents to receiving bodies (35-2000) and sewage system (39-2000) such as, the banning of discharge of explosive or flammable liquids, chemicals such as pesticides, radioactive elements; waste from medical/health care facilities without adequate treatment; it also bans the

discharge of liquid effluents from domestic, commercial, or industrial activities into the receiving bodies, if they do not comply with the maximum permitted limits. It should be pointed out, that these regulations establish maximum permitted limits that the discharge of liquid effluents from domestic, commercial, or industrial activities must comply with.

Technical Regulation DGNTI-COPANIT 24-99, reuse of treated wastewater. MICI

The objectives of this technical regulation are to safeguard the health of the inhabitants, protect the environment, foster the rational use of resources, and establish regulations for the different uses of wastewater treated in different wastewater treatment plants of Panama. The Technical regulations indicate that the treatment plants must control by themselves the parameters established by this regulation, depending on the use to be assigned to the treated water, notwithstanding the controls which may be performed by the applicable authorities. The samples must be taken by trained personnel of an accredited laboratory, and they shall be taken at each one of the discharge or outlet points of the plants for the treatment of wastewater, being that the responsibility of the plant operator. The controls by the applicable authority will be performed without prior notice, and they will involve the sampling and determination of the characteristics of the effluents from the treatment plant.

Resolution AG-0026/2002. Characterization and adjustment of technical rules for the discharge of wastewater DGNTI-COPANIT 35-2000 and DGNTI-COPANIT 39-2000. ANAM

The discharge of wastewater from commercial, domestic, or industrial activities established after August 10, 2000, must comply with the Technical Regulations DGNTI-COPANIT 35-2000 and DGNTI-COPANIT 39-2000, once in operation. Those established before August 10, 2000 and that discharge liquid effluents directly into bodies of surface water or groundwater, or the wastewater collection systems must comply with the Technical Regulations DGNTI-COPANIT 35–2000 and DGNTI-COPANIT 39-2000 under the schedule for compliance established in these regulations. Those individuals or corporations discharging wastewater are obliged to characterize the discharges to determine the monthly and daily average, as established under the Technical Regulations DGNTI – COPANIT 35-2000 and DGNTI – COPANIT 39-2000. All facilities discharging liquid effluents directly into bodies of surface water or groundwater must submit to the National Authority on the Environment, a quarterly report with the analysis made.

Resolution AG-0466-2002, establishing the requirements for the application for permits for the discharge of used water or wastewater. ANAM

The facilities discharging used water/wastewater must characterize the effluents under the provisions of Technical Regulation DGNTI-COPANIT 35-2000, and must submit the results of the characterization as specified in the Registry for the Characterization of the Discharge of Liquid Effluents, which will be available at the National Office for the Protection of Environmental Quality (*Direccion Nacional de Proteccion de la Calidad Ambiental*) of the National Authority on the Environment.

Technical regulation DGNTI-COPANIT 22-394-99 Sample Taking for Biological Analysis. MICI

The objective of this regulation is to establish the methodology to be followed in order to obtain a representative sample of water on the basis of which the sanitary biological quality of the potable water supply facilities will be determined. The sample taking must take into account the microbial composition of the water collected. This regulation will be applied to all types of water, whichever its origin, whether taps, wells, deposits, lakes, rivers, springs, and others. This regulation establishes the type of sample, necessary material, sampling techniques, volume of the sample, identification and labeling, as well as conditioning and preservation of the sample.

2.8.5 Air

Act 36, dated May 17 1996, Control of Air Contamination. MICI

This Act establishes the control of the air contamination as a result of the use of fuel and lead, particularly, originating in the use of internal combustion engines. It bans, as of January 1, 1997, the manufacture or import of paints, veneers, dyes, and by-products with content higher than that allowed by the Ministry of Health. Its also indicates that "as of January 1, 1999 the gas vehicles imported to the Republic of Panama must have a system for the control of emissions in order to comply with the permitted levels established by the Ministry of Health so as to reduce contamination".

As regards the use of leaded gas, it specifies that as of 2002, only the sale of unleaded gas will be allowed. In order to monitor the level of air contamination, this law sets up the national measurement and analysis network, and it assigns the *Instituto Especializado de Analisis* of the Univeristy of Panama the resources necessary to set up and maintain the monitoring network.

Ozone Layer

Act No. 46 dated July 05 1996, approving the Amendment to the Montreal Protocol related to substances depleting the ozone layer, adopted in the VI Meeting of State Parties, held in Copenhagen on November 25, 1992. ANAM
Act No. 25 dated December 10, 1990, approving the Amendment to the Montreal Protocol related to substances depleting the ozone layer, adopted on June 29, 1990 (London Amendment)

It corresponds to an amendment to Act No. 7 dated January 3, 2989, which approves the Montreal Protocol related to substances depleting the ozone layer. In both cases, the amendments involve the incorporation of substances and control measures for the use of substances depleting the ozone layer. Both changes were adopted and/or included in Executive decree No. 225 dated November 16 1998, regulating Act 7 related to the protection of the ozone layer. In conclusion Executive decree No. 225 presents all changes and incorporations made to Acts No. 46 and No.25.

Act No. 7 dated January 03 1989, approving the Montreal Protocol related to substances depleting the ozone layer. ANAM

The Legislature approves this since it is: "determined to protect the ozone layer through the adoption of preventive measures to fairly control the total world emissions of substances depleting the ozone layer, with the final objective of eliminating them, on the basis of the advances in science and taking into account economic and technical considerations", as indicated by the Montreal Protocol related to substances depleting the ozone layer signed by the Parties to this Protocol. The Parties will "see that the estimated level of consumption of the substances controlled listed under Group I of Annex A do not exceed the estimated level of consumption for 1986. Each Party producing one or more substances will ensure that the estimated level of production of these substances does not exceed the 1986 production level, with the exception that that level cannot increase more than 10% in relation to 1986. Said increase will only be allowed to satisfy basic internal needs of the Parties to this Protocol under Section 5 and in order to promote industrial rationalization among the parties".

Executive decree No. 225 dated November 16 1998, regulating Act 7, dated January 3 1989 related to the protection of the ozone layer. ANAM

It prohibits the manufacture and deliberate emission into the air of ozone depleting substances, whether in pure or mixed form, in accordance with the substances listed in Annexes A, B,C and E. Consequently, all individuals or companies responsible for the import, recycling, and destruction of said substances, must perform all operations in a environmentally friendly and safe manner, while submitting to the Ministry of Health, every six months, the data related to the amount imported, recycled and destroyed.

Act No. 2 dated January 03 1989, approving the Vienna Convention for the Protection of the Ozone Layer. ANAM

The State (referenced to as "Party") engages itself to taking the necessary measures to "protect human health and the environment against the resulting adverse effects or the effects which may result from human activities which modify or may modify the ozone layer". To this end, the Parties will cooperate in the implementation of measures, procedures, and standards, and will cooperate with the international applicable organizations so as to comply with the execution of this Agreement. Scientific research and assessments will be undertaken taking into account the national legislations and the on-going relevant activities, which will enable the promotion or fostering of joint or complementary programs for the systematic observation of the state of the ozone layer and other relevant parameters.

The Parties also engage themselves to cooperating with the international relevant organizations to guarantee the gathering, validation and dissemination of observational and research data through adequate world data centers.

2.8.6 Noise

Executive decree N.° 306, dated September 4 2002, establishing maximum permitted noise levels. ANAM

Sections 1 and 2 of this Decree prohibit the production of noise which due to its nature or inopportuneness disturb the health, rest or quiet of the members of the communities, or which may cause material or psychological damage. Therefore, this Decree considers that all work or activity must be performed in a way that will reduce the noise generated by them, particularly those generated by loose, or excessively worn out equipment, transmission belts in poor

conditions, or compressed vapor or air exhaust systems, as well as unnecessary noise which may be avoided.

Sections 7, 12, and 14 of the Decree refer to the standards and controls to be applied to (1) the noise produced by neighboring industries and stores to residential areas or housing areas, (2) noise in residential or housing areas, (3) public spaces, (4) workplace, and (5) noise generated by temporary activities. The maximum permitted continuous noise levels for the above-mentioned areas are in the range of 50 to 85 decibels.

2.8.7 Waste and Hazardous Waste

Executive decree No. 111, dated June 23 1999, APRA Regulation for the management and handling of waste from health care facilities. MINSA

This act regulates all that is related to the management and handling of solid waste generated in public or private animal or human health care centers in order to protect the health of people and the environment. The health care centers include: hospitals, clinics, small clinics, medical centers, dental centers, policlinics, and psychiatric homes, old people's homes or clinics and other specialties of the public and private sector; autonomous institutes related to health; clinical laboratories, public or private biochemical and biotechnological laboratories; departments of pathology, morgues, and undertakers, and cremation centers; medical offices, veterinarian hospitals, clinics and laboratories, center of research on biomedicine, biotechnology, and genetics, companies engaged in the collection, transport, treatment and final disposal of waste, and any other facilities to be established by the Ministry of Health.

Act No. 8 dated June 7, 1991, banning the import of toxic waste or pollutants to the territory of the Republic of Panama. MICI

This Act bans the import, in any form of toxic waste or pollutants into the National territory. It establishes that sanctions shall be applied to those infringing this act and involved in illegal traffic as defined by the Basel Convention. Any violation of this act involves sanctions punishable with one to three years in jail, and fines of five thousand to twenty thousand balboas, without detriment of any compensation that may correspond and the duty to return the toxic waste or pollutants to the country of origin. Toxic waste or pollutants are considered to be all substances, whether radioactive or not, or elements of immediate or delayed effect, which may cause any disturbance to human health, or any type of animal or plant life, or capable of producing harmful effects on the ecological balance of the country.

Act No. 2 dated March 20 1986, establishing the national system for the measurement of characteristics and components of agricultural supplies. It prohibits the use of chemical products in Panama if their use has been prohibited in other countries due to their toxicity to human beings. MIDA

This act bans, in the national territory, the use of those chemical products used in agrarian production, if their use has been banned in other countries due to their toxicity, which under the prior analysis made by the Department of Plant Health and Agrarian Quarantine (*Direccion de Sanidad Vegetal y Cuarentena Agropecuaria*), are harmful to the human health. It sets special areas for the development of agribusiness (Bocas del Toro, Darien and the Districts of Sona and Chepo, which have special benefits under the benefits granted to the national industry and exports.

Act 28 dated December 26 1990, modifying section 9of Act 2, dated March 1986, on the regulation of the use of pesticides. MIDA

The amendment of Section 9, Act 2, dated March 20, 1986, determines that the "Ministry of Agrarian Development, unless otherwise provided for by the health legislation, at its own initiative or under the recommendation of an Inter-Institutional Technical Committee, made up by the Ministry of Agrarian Development, Ministry of Health, and *Instituto de Investigacion Agropecuaria sobre Agroquimicos*, shall prohibit, restrict, limit, and regulate the import, manufacture, transport, distribution, sale and use of agrochemicals in the agrarian activity in the Republic of Panama".

Resolution No. 50, from the Ministry of Health, dated July 23 1999, Sanitary Rules for the Handling, Storage, and Transport of Asbestos in the Republic of Panama.

This act establishes the hygiene-sanitary guidelines regulating the handling, transport, and storage of asbestos in all the national territory. Asbestos is considered to be the group of silicate minerals, in general magnesium, with fibrous characteristics, used in industry due to its yield strength, acid and fire strength, as well as its flexibility. It aims at preventing the risk of exposure to this substance in the workplace and its harmful effect on the health of workers. It prohibits the use of any variety of asbestos in operations using projection methods.

Executive decree No. 197 dated August 19 1996, creating the national network of solid waste. MINSA

This act creates the national network of solid waste involving the following institutions: Ministry of Health (appointed as chair), Ministry of Education, Home Ministry and Ministry of Justice, Ministry of Economic Planning and Policy, Ministry of Housing, *Direccion Metropolitana de Aseo, Instituto de Acueductos y Alcantarillados Nacionales, Comision Nacional de Medio Ambiente* (National Committee on the Environment), *Instituto de Recursos Naturales Renovables*, Ministry of Trade and Industry, University of Panama, a representative of Private Universities, Association of Municipalities of Panama, a representative of each Environmental NGO and the Association of Private Companies, which have expressed their interest in participating in this network.

A summary of the functions of these institutions is as follows: achieve the exchange, and dissemination of, and permanent contribution with, knowledge and experience in the environmental management of waste; to stimulate and contribute to the environmental management of waste; to coordinate the efforts for a joint operation between the Controller (Government), the generators of waste (industries, public sector and communities) and institutions related to the management of waste: guide the research on the management of waste that would promote the execution of projects; coordinate and promote information systems and services related to this topic in particular; support formal and informal educational activities on the topic; to make an annual budget for the Network activities; approve its regulations; and other functions that the Ministry of Health may expressly determine.

Act No. 13 dated April 21 1995, approving the Regional Agreement on the Trans-Boundary Movement of Hazardous Waste. MICI

Hazardous waste is defined as all the substances included in any category of Annex I or with the characteristics of Annex II, of this agreement, as well as the substances considered to be such under the laws of the Exporting, Importing or Transit States, and the hazardous substances prohibited, or with registration records that have been rejected or cancelled by government regulations. Trans-Boundary movement refers to be the movement of hazardous waste from an area under the national jurisdiction of any State towards or through an area under the jurisdiction of another state, or towards or through an area which is not under the national jurisdiction of another State, as long as the movement involves at least two States.

This act prohibits the import of Hazardous Waste, under an Agreement signed by the Central American countries, which will take the necessary legal, administrative measures or otherwise, to prohibit within the areas under their jurisdiction the import and transit of hazardous waste towards Central America from countries which are not a party to this Agreement. Also, the Parties to this Agreement will not allow the export of those waste to States which have banned their import, under their internal legislation or international agreements signed to that end or if they consider that there will not be an environmentally friendly management of those waste, as established by the United Nations Program for the Environment (UNPE).

Act No. 32 dated May 28 1998, approving the amendment to the Basel convention on the control of Trans-Boundary Movement of hazardous waste. MICI

This act has a new paragraph, which reads "acknowledging that the trans-boundary movement of hazardous waste, particularly to developing countries, entails a high risk since there might not be the rational and efficient environmental management of hazardous waste sought under this Convention". It also indicates that each one of the parties listed in Annex VII shall prohibit all trans-boundary movement of hazardous waste the purpose of which are the operations anticipated in Annex IV A, to the States not listed in Annex VII. Each one of the parties shall gradually interrupt up to December 31, 1997, and prohibit thereafter all trans-boundary movement of hazardous waste under the provisions of paragraph a) subparagraph i) of Section 1 of the Convention which are to be used for the operations anticipated in Annex IV B to the States only listed in Annex VII. That trans-boundary movement will only be banned if the waste in question has been characterized as hazardous under the provisions of the Convention. Annex VII includes Parties and other States member of the OCDE and EC, and Liechtenstein".

2.8.8 Safety

Act 48, dated January 31 1963, amended by Act 21, dated October 18, 1982 creating the Office of Safety attached to the Fire Department of Panama

This office is in charge and responsible for supervising and guaranteeing that all types of facilities and constructions (residential, commercial, industrial, ports, etc.) are built under the existing safety standards. This institution grants the corresponding permits, once the applicant has fulfilled the safety standards prior to the development of the project of concern.

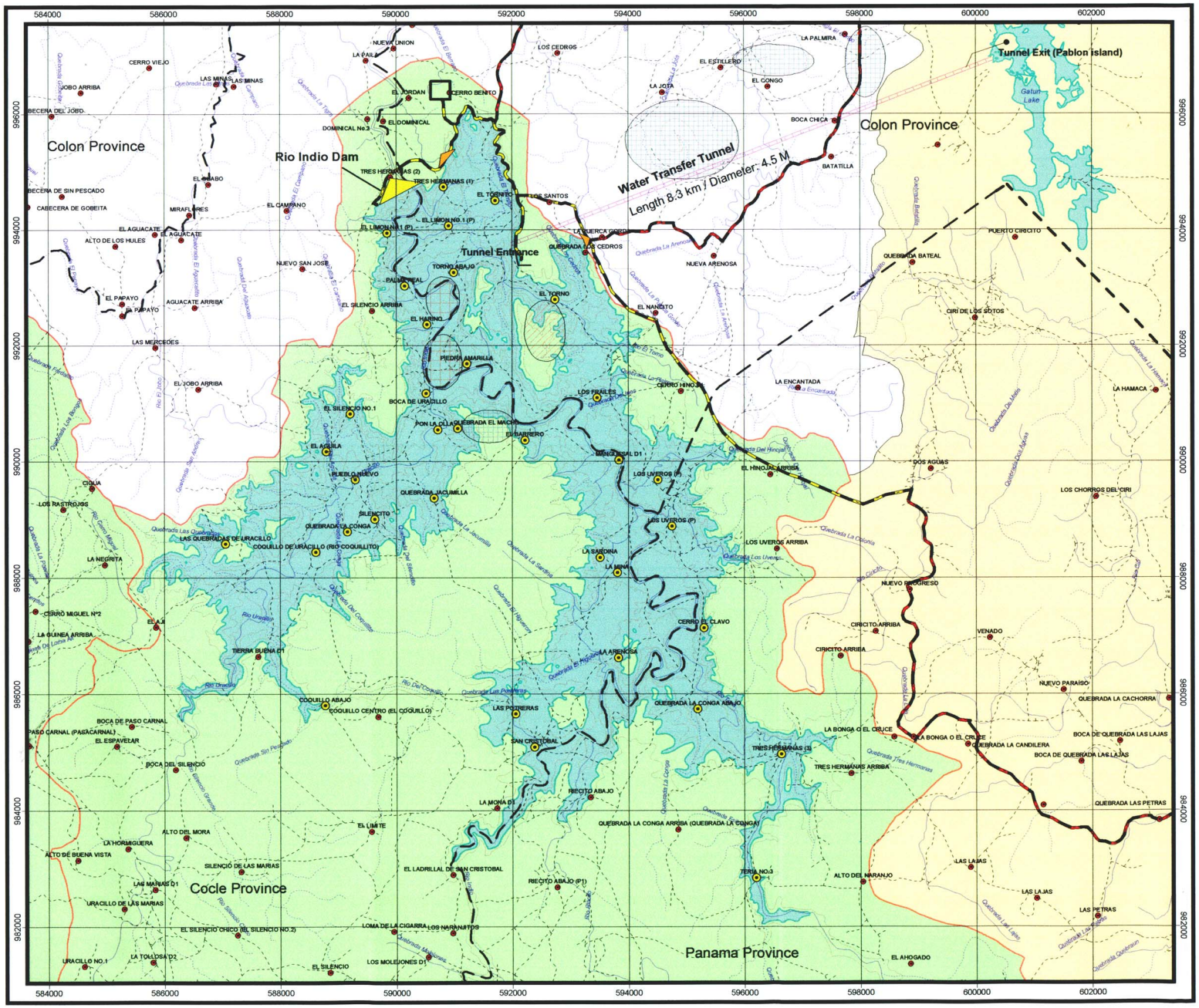
Technical regulation DGNTI-COPANIT 44-2000, Safety and Hygiene. Health and safety conditions in the workplace where noise is generated. MICI

This regulation establishes the measures to improve the safety and hygiene in the workplaces where noise is generated, and which due to the noise characteristics; levels and times of exposure may alter the workers' health and the maximum permitted time limits of exposure per work day. This regulation is applicable to all individuals and companies, public or private, in which noises capable of harming the workers' health is generated or transmitted.

Section 3 indicates that the owners of the facilities must comply with the measures set forth by the Ministry of Health to avoid and correct adverse effects and nuisances caused by exposure to noise. It also indicates that exposure to noise exceeding 130 decibels will not be permitted unless workers have adequate protection equipment. Section 4, on the other hand, refers to the employer's duties in relation to the health damage originating from the noise, the noise characteristics, and frequency components. It also establishes they must provide the workers with personal protection equipment at no cost and to update the record of noise levels to be shown to the authorities of the Ministry of Health, if they so require it.

Technical regulation DGNTI-COPANIT 45-2000 "Industrial Safety and Hygiene. Health and Safety in the Workplace where vibrations are generated". MICI

This regulation establishes measures to protect the workers' health and improve safety and hygiene in the workplace where vibrations that due to their transmission level and time of exposure are capable of altering the workers' health are generated or transmitted. It also establishes the correlations between maximum permitted levels of vibration and maximum permitted time of exposure per workday. The owners of those facilities must follow and adopt, in the timeframe established by the Ministry of Health and applicable authority, the necessary measures to correct adverse effects and nuisance caused by exposure to vibrations in the workplace. The construction, installation, import and maintenance of equipment, tools and machines for work will comply with the provisions of this regulation.



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 1: RIO INDIO 80-40
PROJECT DESCRIPTION

ACP PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Saddle Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer tunnel Rio Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Existing Roads
- Main and Secondary Rivers
- Creeks
- Contours levels
- ROCC Subbasin Boundaries
- Indio 80-40 Reservoirs
- Alluvial Deposits
- Borrow Area
- Sandstone Quarry
- Occidental Basin
- Oriental Basin

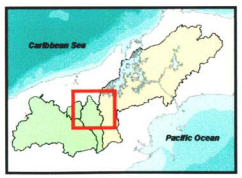
Source: Panama Canal Authority (ACP), Contraloría General de la República, IGN "Tommy Guardia", and URS Holding.

N
W E
S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

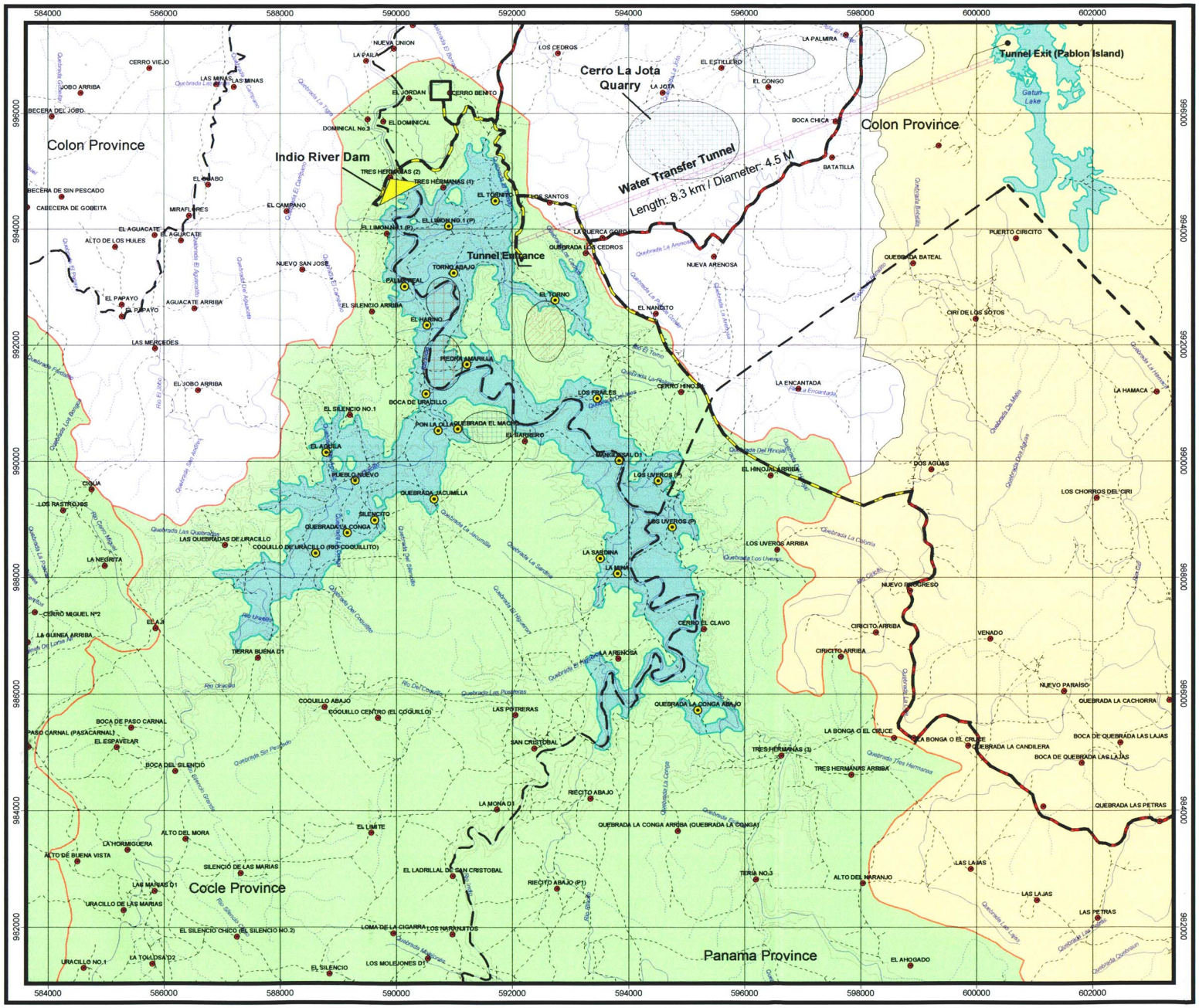
2 0 2 Km

REGIONAL LOCATION



SCALE: 1:65,000

Figure N° 2-1



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 2: RIO INDIO 45-40 PROJECT DESCRIPTION

ACP PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Camping
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer tunnel Rio Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Existing Roads
- Main and Secondary Rivers
- Creeks
- Contours levels
- ROCC Subbasin Boundaries
- Indio 45-40 Reservoirs
- Alluvial Deposits
- Borrow Area
- Sandstone Quarry
- Occidental Basin
- Oriental Basin

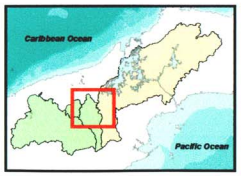
Source: Panama Canal Authority (ACP), Contraloria General de la República, IGN "Tommy Guardia", and URS Holding.

N W E S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

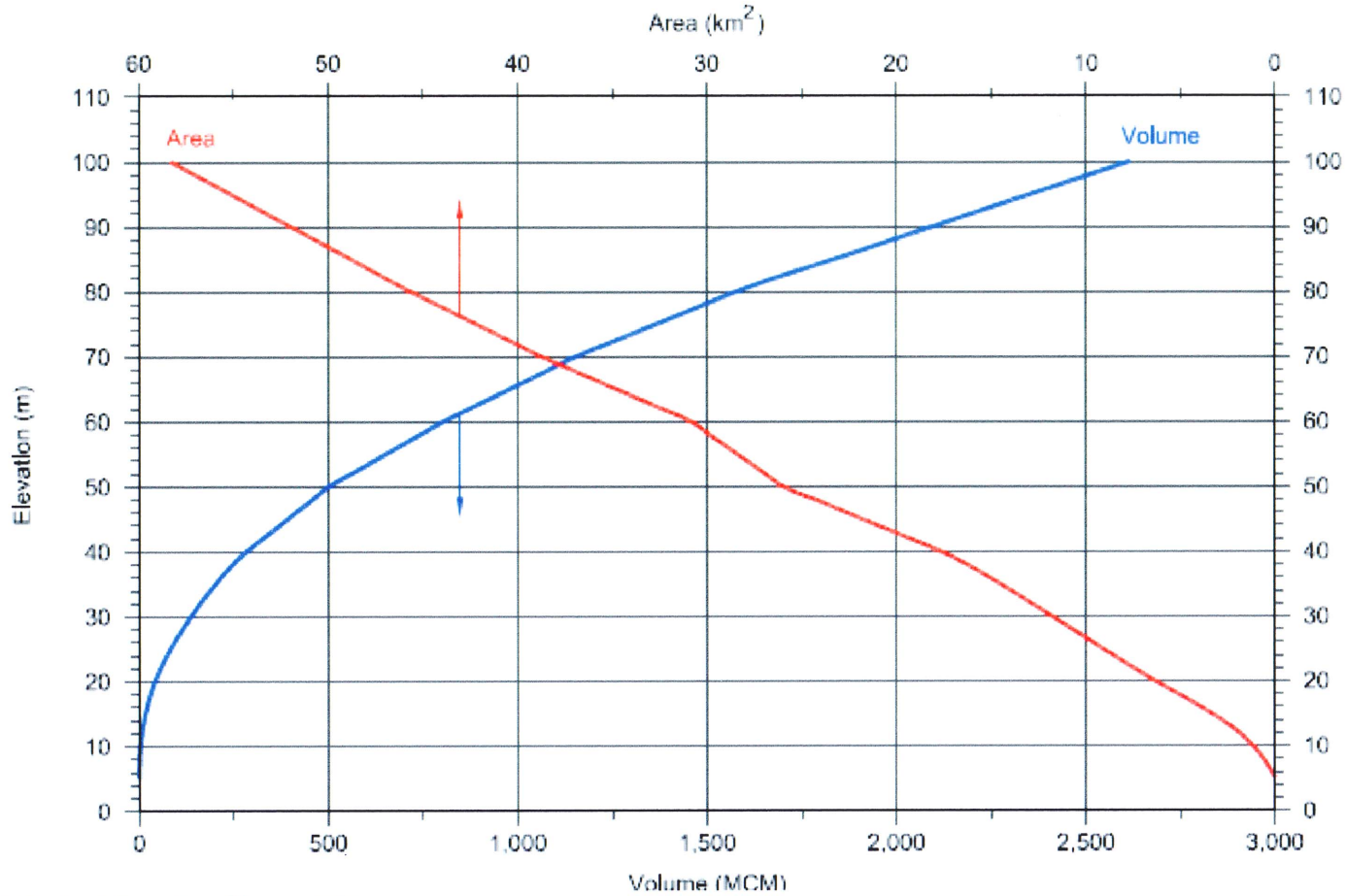
2 0 2 Km

REGIONAL LOCATION



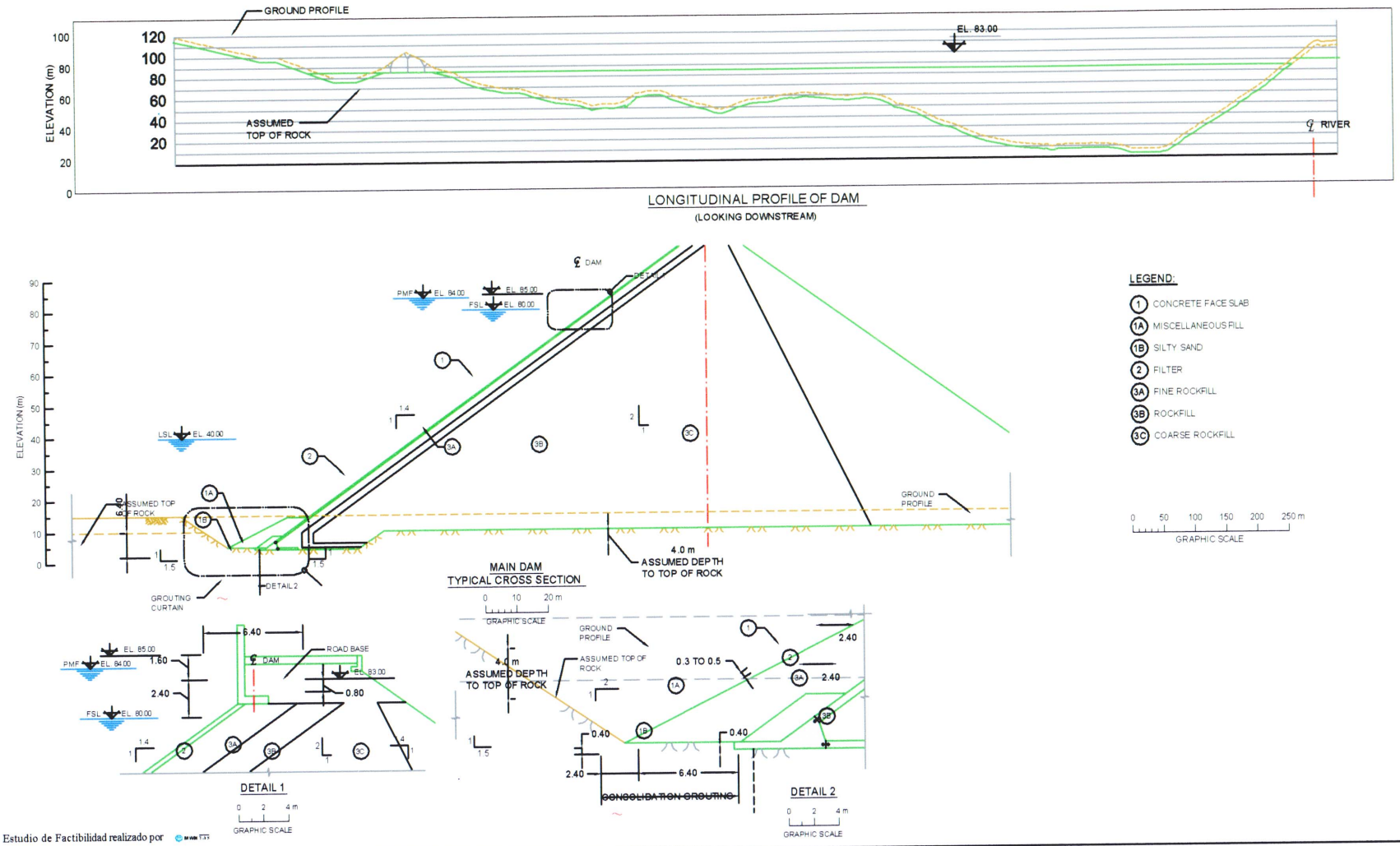
SCALE. 1:65,000

Figure N° 2-2



Source: Factibility Study Done By MWH TAMS

Environmental Evaluation of Water Resources Options for Indio, Caño Sucio and Toabre Rivers	URS	**Figure 2-3** **ELEVATION / AREA / VOLUME CURVE RIO INDIO RESERVOIR**

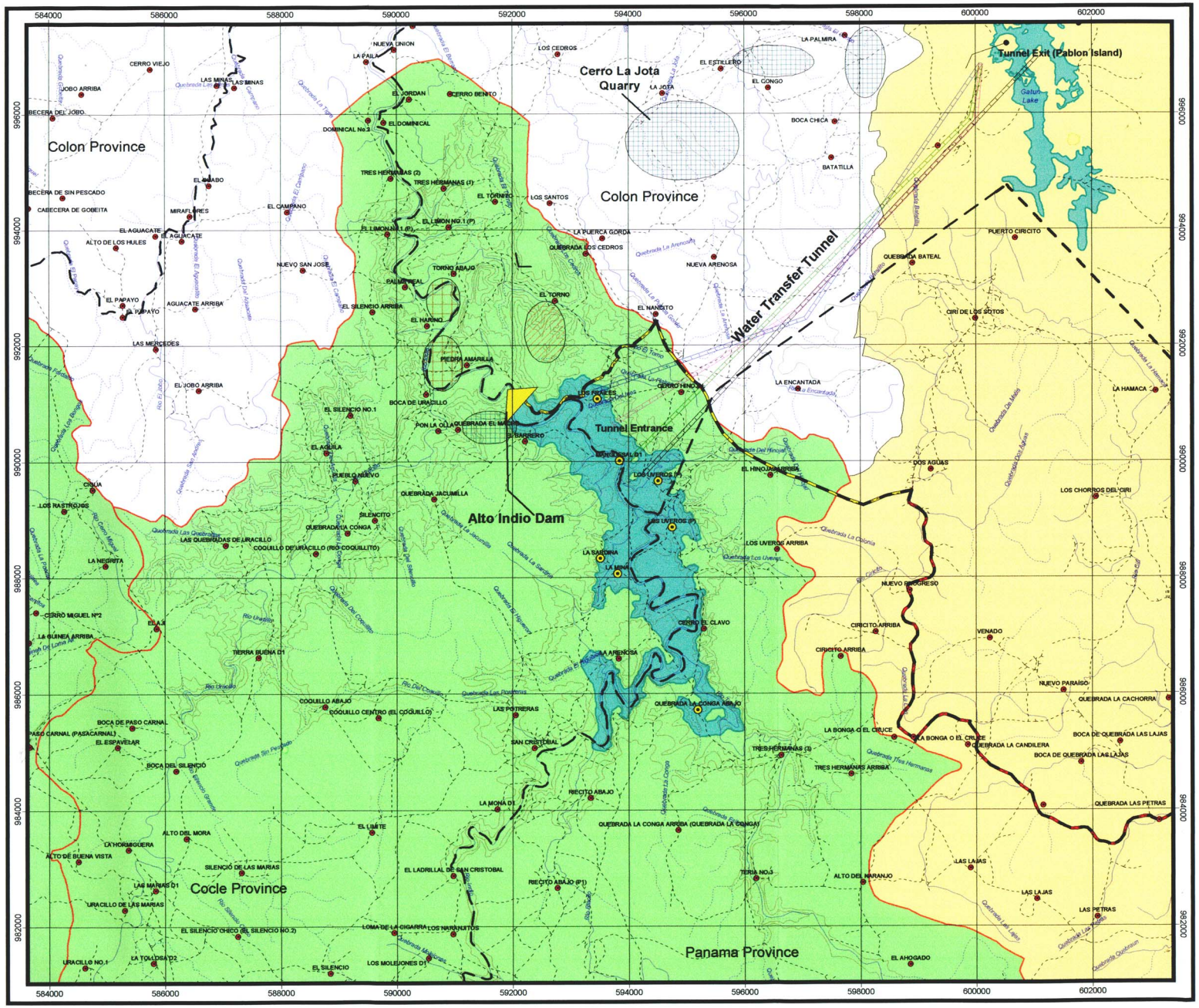


Fuente: Estudio de Factibilidad realizado por

Environmental Evaluation of Water Resources Options for Indio, Caño Sucio and Toabre Rivers

URS

Figure 2-4
Longitudinal Profile and Typical Cross Sections Rio Indio Dam



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 3: ALTO INDIO 50-40

PROJECT DESCRIPTION

ACP PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Tunnel Options Alto Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase Main and Secondary Rivers
- Existing Roads
- Main and Secondary Rivers
- Creeks
- Contours levels
- ROCC Subbasin Boundaries
- Indio50-40 Reservoirs
- Alluvial Deposits
- Borrow Area
- Sandstone Quarry
- Occidental Basin
- Oriental Basin

Source: Panama Canal Authority (ACP), Contraloría General de la República, IGN "Tommy Guardia", and URS Holding.

N W E S

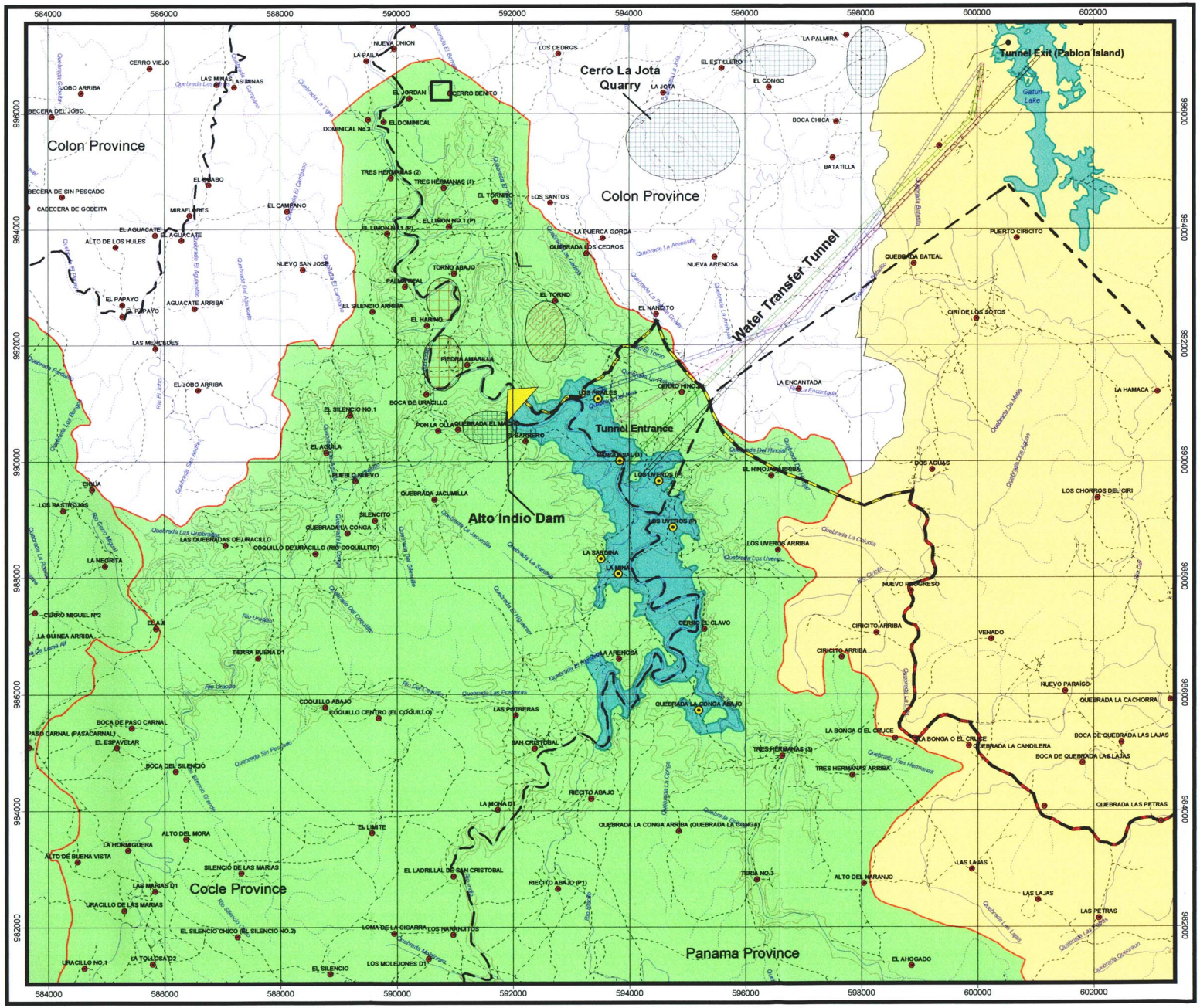
Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

2 0 2 Km

REGIONAL LOCATION

SCALE: 1:65,000

Figure N° 2-5



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 4: ALTO INDIO 45-40

PROJECT DESCRIPTION

ACP

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Tunnel Options Alto Indio - Lago Gatun
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase Main and Secondary Rivers
- Existing Roads
- Main and Secondary Rivers
- Creeks
- Contours level
- ROCC Subbasin Boundaries
- Alto Indio 45-40 Reservoirs
- Alluvial Deposits
- Borrow Area
- Sandstone Quarry
- Occidental Basin
- Oriental Basin

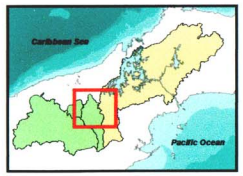
Source: Panama Canal Authority (ACP), Contraloría General de la República, IGN "Tommy Guardia", and URS Holding.

N
W E
S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

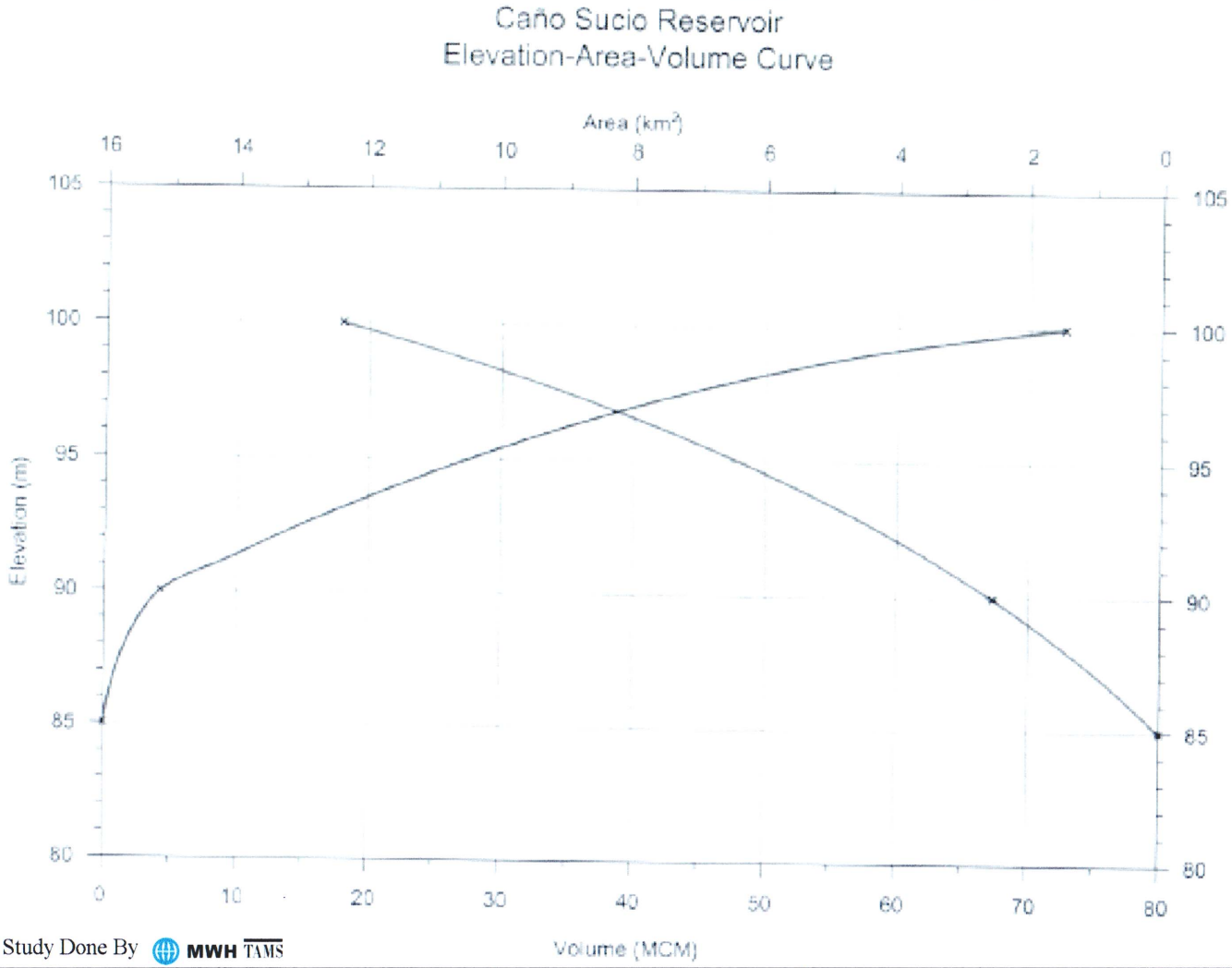
2 0 2 Km

REGIONAL LOCATION



SCALE 1:65,000

Figure N° 2-6



Source: Factibiliy Study Done By MWH TAMS

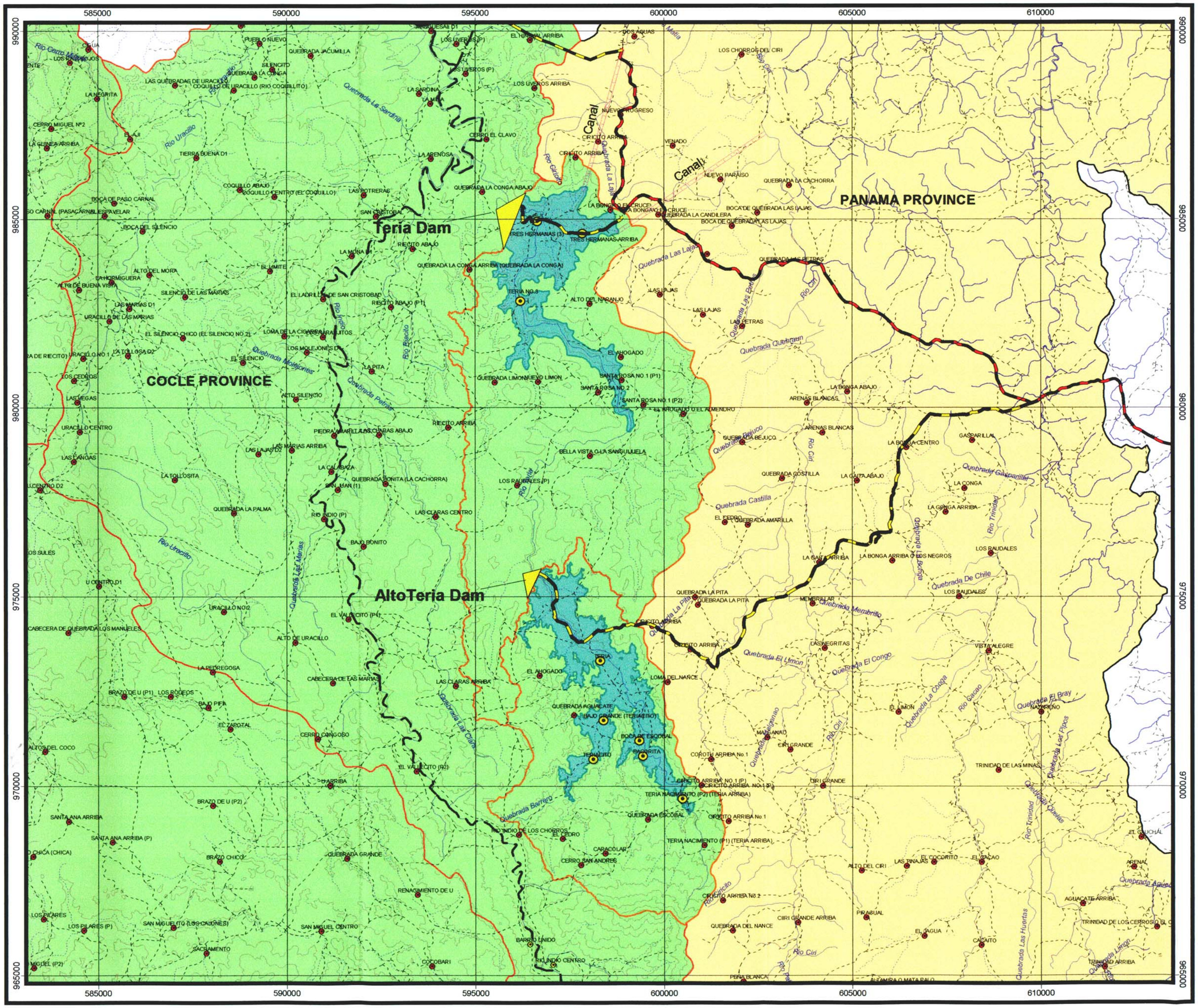
Environmental Evaluation of Water Resources Options for Indio, Caño Sucio and Toabre Rivers	URS	**Figure 2-7** **TYPICAL CROSS SECTION RIO TOABRE DAM**

ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 11: RIO TERIA BASIN

PROJECT DESCRIPTION

PANAMA CANAL AUTHORITY(ACP)



LEGEND

- Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer tunnel
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase Main and Secondary Rivers
- Existing Roads
- Main and Secondary Rivers
- Contours levels
- ROCC Subbasin Boundaries
- Teria and Alto Teria Reservoirs
- Alluvial Deposits
- Occidental Basin
- Oriental Basin

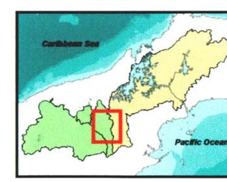
Source: Panama Canal Authority (ACP), Contraloria General de la República, IGN "Tommy Guardia", and URS Holding.

N W E S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

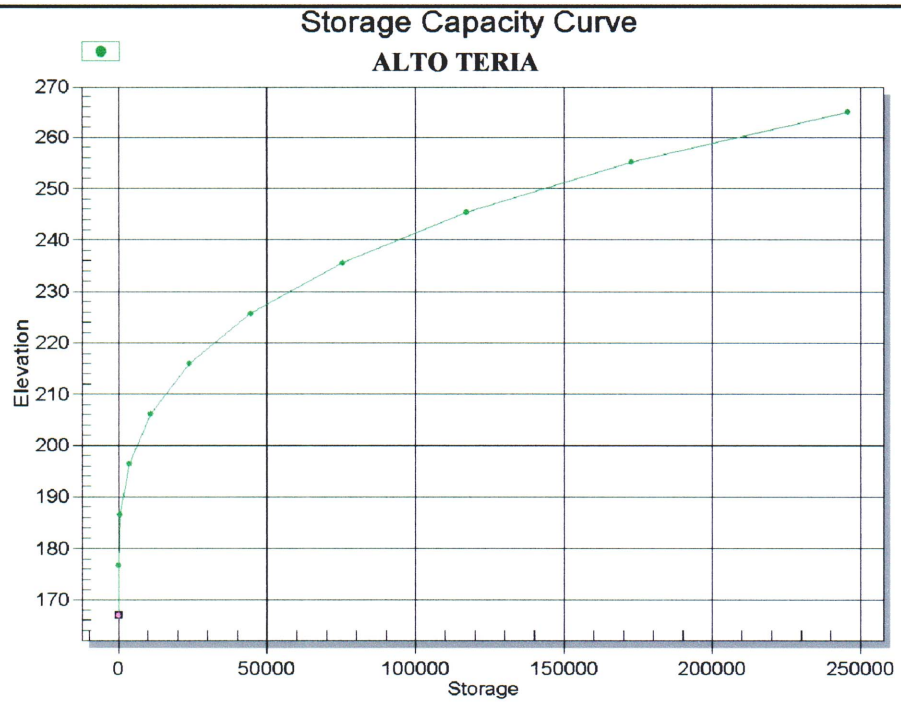
2 0 2 Kilometers

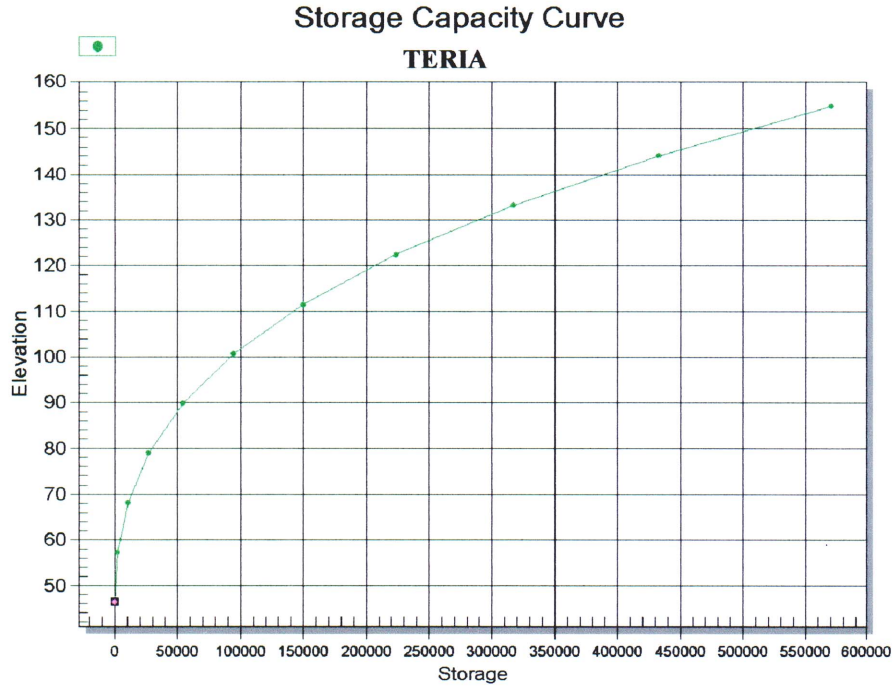
REGIONAL LOCATION



SCALE: 1:100,000

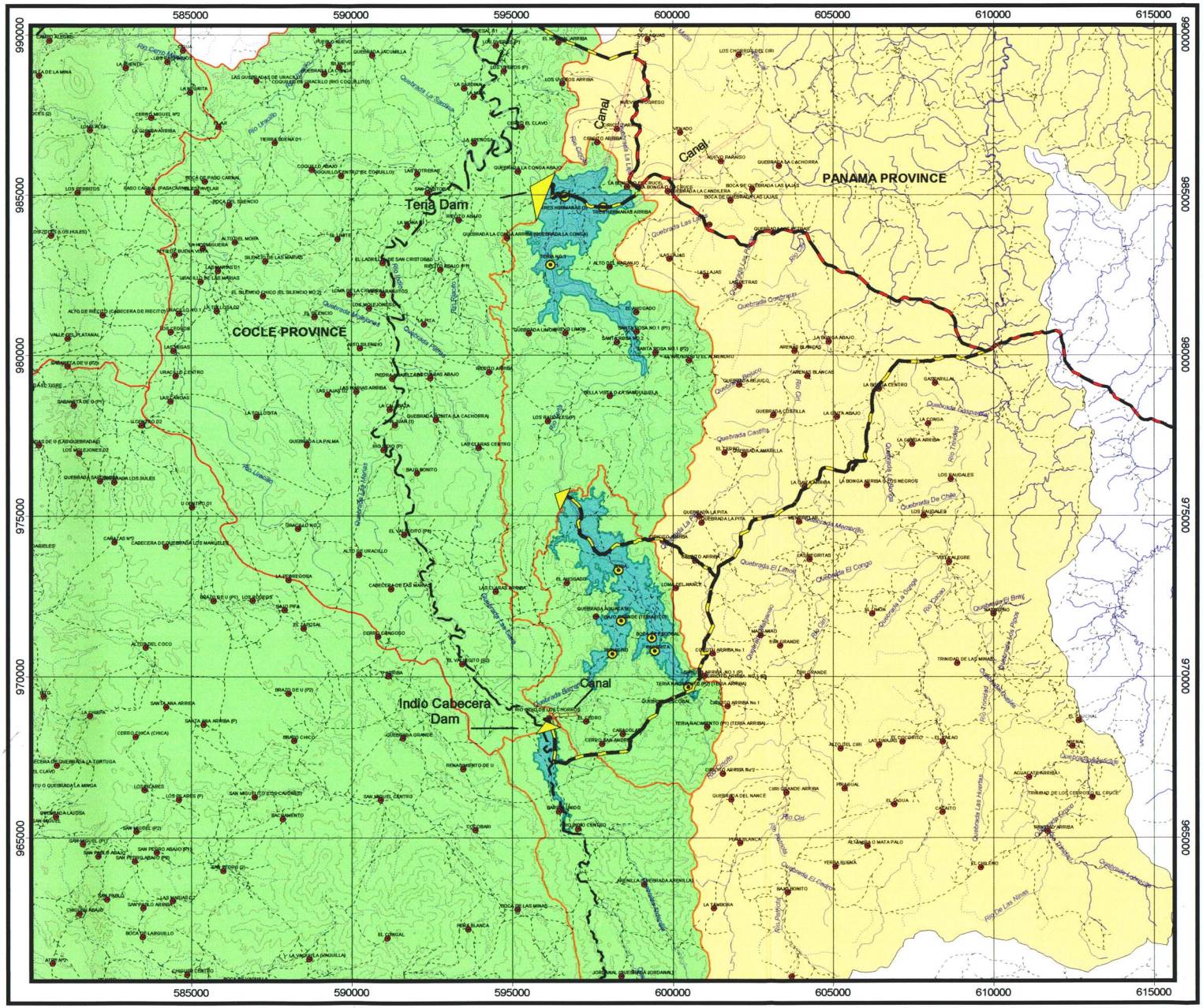
Figure N° 2-8





Source: URS Holding inc.

Environmental Evaluation of Water Resources Options for Indio, Caño Sucio and Toabre Rivers	URS	**Figure 2-9** **STORAGE CAPACITY CURVE TERIA RIVER**



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 12: INDIO CABECERA, ALTO TERIA AND TERIA RIVERS BASIN

PROJECT DESCRIPTION

PANAMA CANAL AUTHORITY(ACP)

LEGEND

- Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer tunnel
- Transfer tunnel
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase Main and Secondary Rivers
- Existing Roads
- Main and Secondary Rivers
- Creeks
- Contours levels
- ROCC Subbasin Boundaries
- Indio Cabecera and Teria and Alto Teria Reservoirs
- Teria, Alto Teria and Indio Cabecera Rivers Basin
- Occidental Basin
- Oriental Basin

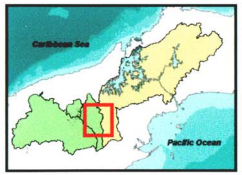
Source: Panama Canal Authority (ACP), Contraloría General de la República, IGN "Tommy Guardia", and URS Holding.

N
W E
S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

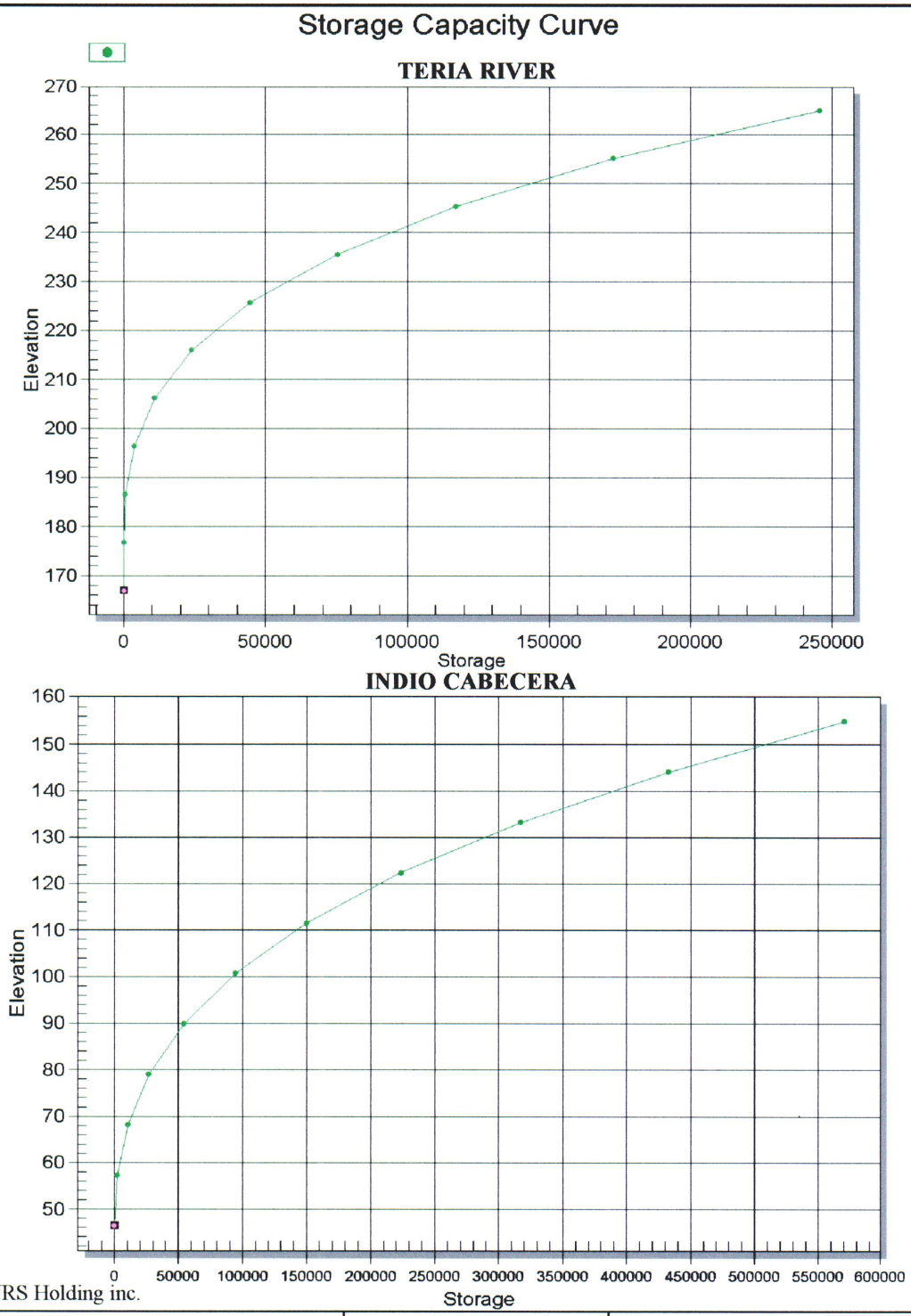
2 0 2 Km

REGIONAL LOCATION



SCALE: 1:120,000

Figure N° 2-10



Source: URS Holding inc.

Environmental Evaluation of Water Resources Options for Indio, Caño Sucio and Toabre Rivers	URS	**Figure 2-11** **STORAGE CAPACITY CURVE** **TERIA RIVER - INDIO CABECERA**

3.0 CONDITIONS AT THE RIO INDIO WATERSHED

An adequate characterization of the existing environmental, social, cultural, and economic conditions, as well as of the trends present in these characteristics is essential for the environmental assessment process described in the introduction to this report. Therefore, in this chapter, a summary is presented of the conditions existing in the Rio Indio watershed and adjacent areas, which may be influenced by the development of the option or options that may be selected if the ACP actually executes the project. This characterization emphasizes the assessment of environmental goods and services (water, soil, biological diversity, air, rainfall, topography, surface runoff, temperature, and geological basement, among others), and of the nature of interaction that the local communities have had or currently have with them since these interactions constitute agents for change within the landscape of the area under study.

It is important to clarify that little fieldwork was performed in this study and, therefore, the characterization herein presented is mainly based on the review, interpretation, and analysis of data from secondary sources of information. Among these sources, the main one is the set of studies aimed at gathering environmental, socioeconomic and cultural information promoted recently by the ACP, which began at the end of the year 2000 and finished in 2002.

3.1 General Aspects

The Rio Indio watershed is a hydrographic system immediately adjacent to the West of the Ciri Grande River. Out of the main tributaries of Lake Gatun, the Ciri Grande River is the one located more to the West (Figure 3-1). The Rio Indio drainage area (watershed) covers a total surface area of approximately 565 Km^2, and its main watercourse is approximately 98 km long. However, the Rio Indio watershed that is part of the ROCC only covers 386.6 Km^2 that is approximately 68% of the total surface area. In terms of average flow rate, the stretch of the river within the ROCC drains an area, which produces a greater runoff, and contributes with approximately 72% of the total average flow rate ($32.4m^3/s$).

The area of greatest interest, which is the watershed upstream from the proposed dam site for Option 1: Rio Indio 80-40 and the areas adjacent to the river main watercourse downstream from the dam, up to the river mouth in the Caribbean Sea, includes the territories of three provinces of the Republic of Panama (Cocle, Colon and Panama), five Districts (Penonome, El Valle, Chagres, Capira and Donoso) 11 departments (Rio Indio de Penonome), Chirigui Arriba, El Valle, La Encantada, Ciri Grande, Ciri de los Sotos, El Cacao, Santa Rosa, Gobea, Rio Indio de Donoso and Salud).

Geologically, the upper and mid watershed area originated as a result of the volcanic activity during the Tertiary period and the low watershed areas due to sediment deposition derived from this in more recent eras. The topography is mostly undulated and uneven with a rocky basement and outcrops. The region is hot and rainy, particularly the highlands, leading to the lixiviation of the soils, which are poor and with many restrictions for traditional agriculture and cattle raising activities.

In their natural state, the native ecosystems were mainly evergreen tropical forests with significant vertical growth and biomass. The estimates based on the climatic and edaphic conditions and on specific observations suggest that the upper canopy of the primary forest of this region of Panama must have reached a height of 50-52 meters, that its structure was complex, and that there were up to four tree layers, apart from the understory.

However, it should be pointed out that due to the high rainfall and temperature conditions, these ecosystems must be considered as fragile since the biogeochemical cycle of the nutrients stores much more in the biomass than in the soil and waters, and consequently when burning or clearing the biomass or when their quality or diversity is lost, the nutrients are lost or removed at an accelerated pace and the natural fertility falls abruptly. This is a very closed cycle of nutrients with very few inputs of additional nutrients from the outside and very little export of nutrients, in its climax state. Since the high rainfall and temperature tend to rapidly remove the nutrients, which are not part of the living matter, the evolution strategy of the system involves the minimization of the time the nutrients remain in a soluble inorganic form.

The fragility of the systems to deforestation is very high because when vegetation is eliminated, most of the nutrients are also eliminated. Under this scenario, the renewability of some natural goods and services such as the replacement of nutrients, the forest structure, and the diversity of the flora and fauna species is slow. That is why, this is a region with forest vocation and to be used for natural tourism purposes, with low productivity for agricultural and cattle raising activities, which should be primarily used for projects and activities related to the production of water with good quality for the national or regional benefit, or other production purposes, such as conservation, tourism, recreation, and selective use and management of the biological diversity, within a program of natural protection and social upgrade.

However, the situation is at present quite different and most of the forest (78%) has been cleared. The spontaneous colonization, the fragility of the ecosystems and "shifting cultivation" through schemes involving clearing, cutting and burning have impoverished the ecosystems to the extent that they have been turned into pastures used mostly for extensive cattle raising activities, which

are even unsustainable in the mid-term. This process of natural impoverishment leads to a socioeconomic and cultural impoverishment accelerated when the mining of natural goods and services increases, particularly when there is a high incidence of forest fires in this region.

It is important to observe that along with the ecosystems, the residents of local communities also become impoverished. This situation has been typical of other parts of the Latin American and Panamanian tropical rain forest, when landless farmers move to humid areas in search of lands for their agricultural activities. Consequently, the population of the Rio Indio watershed, as it also happens in the rest of the ROCC, is very poor, with an average income lower than the third of the national average, and migrates towards other regions of the country in search of opportunities for better living conditions.

As expected in this situation, the infrastructure for basic services and utilities is very limited and access itself to most communities is difficult and costly. The colonization of the area has not been planned but was rather disorderly and spontaneous and has come about differently from the North and from the South. From the North, the process depended mostly on the access through the Rio Indio main watercourse and its largest tributaries mainly during the rainy season; while from the South the colonization took place primarily during the dry season through penetration roads coming from the Pan-American Highway and other secondary roads.

In brief, the historical process of a spontaneous, non-planned colonization of the natural goods and services of the region has led to a disorganized and inarticulate occupation of the territory. The existing landscapes in the basin show the effects of this colonization process, resulting in part from the lack of security in landholding and other political and socioeconomic factors, which gave rise to the current situation where there is high level of environmental and social impoverishment. The trend to a deepening of the environmental and social impoverishment of the Rio Indio Watershed constitutes a risk for the stability of the water alternatives in case one or more of these options is executed.

3.2 Characteristics of the Physical Environment

As it has been previously stated, emphasis will be given to the description of the existing conditions for those aspects particularly relevant to the development of the water alternatives and their environmental assessment. In this sense, the geological, geomorphological and climatic aspects, the nature and potential use of the soils and the way they are used are important because they determine the quantity and quality of water discharged, and also because they determine the

stability of the civil works necessary for the use of the water resources, a natural asset, of high interest for the ACP. The most relevant characteristics of these aspects are indicated below.

3.2.1 Geology and Geomorphology

As previously stated, the oldest areas of the basin date from the Tertiary period, about 15 million years ago and correspond to the upper and mid portions. On the other hand, the lower area is of Quaternary origin (approximately 3 million years ago), and it was formed as a result of the sedimentation of particles coming from the highlands (Coates, 2002).

3.2.1.1 Geological Formations

As it happens in most part of the ROCC, the Rio Indio Watershed is situated on lithological formations from the Lower – Upper and Undifferentiated Tertiary period, characterized by the presence of rocks of sedimentary and volcanic origin. Taking into account the different altitudes, it is possible to specify, on the basis of the Geological Map of Panama, the following formations in the Rio Indio watershed:

A. The lower sector, closest to the sea with heights ranging between 20 and 49 meters above the sea level – masl – is distinguished by the sedimentary formations, Gatun and Chagres , which were formed mainly during the Lower and Upper Tertiary Period. The prevailing rocks consist of sandstone, tuffaceous sandstone, massive sandstone, shales, tuffs, conglomerates and sandy clay stone.

B. The mid sector, where the elevations range between 50 and 200 masl, is dominated by the Gatun sedimentary formation and the typical rocks include tuffaceous sandstone, tuffaceous shale, tuff and foraminifer limestone.

C. Finally, in the upper sector, with elevations above 200 masl, there are two formations with a clear volcanic origin:
    - The Tucue formation of the Cañazas Group made up of andesite, basalts, lavas, breccias, tuffs and "plug"; and
    - The Cerro Viejo formation made up of basalts, andesite, vitreous amygdaloids and post-ignimbrite basalts

On the basis of the geological information available, it was possible to determine the geological formations in the areas of the dams and reservoirs. The conditions in the prospective areas of the

reservoirs include sedimentary rocks of the Rio Hato and Caimito formation, as well as the volcanic rocks of the Tucue and C. El Encanto formations. The volcanic formation make up many of the steep hills and high plains observed in the area. The sedimentary and volcanic rocks are interspersed and in some areas there are intrusions of volcanic rock dikes and flows in the sedimentary deposits. It is necessary to emphasize that in the "poblado" La Mina there is a mine of natural Coal and studies realized in 1956 [(76a)] in this area determined that this material was immature for its development and in the actuality these deposits can remain flooded for any reservoir options

Table No. 3-1 below presents the approximate distribution of the types of geological formations to be expected within the boundaries of the reservoirs for each option. It is estimated, on the basis of this information, that approximately 80-90 per cent of the bedrock in the areas to be flooded in Options 1 and 2 (Indio) will mainly consist of material of sedimentary origin. In the case of Alto Indio (Options 3 and 4), the proportion of sedimentary rocks in the area to be flooded is lower, about 70 per cent; i.e., a higher percentage of volcanic formations are expected in the upper areas of the river. This situation is even more marked in options 11 and 12, involving the Teria River and the upper Rio Indio area. Most of the rocks in the area of the project are covered with colluviums and residual soils with a moderate to high thickness, which contain a relatively high clayey component. The few field studies performed up to this date indicate that there are no large alluvial deposits of sand and gravel along the river.

According to the feasibility study, the dam site in the option considered in the study (which corresponds to Options 1 and 2) include bedrock consisting primarily of sedimentary material including sandstone and tuffaceous siltstones, conglomerates and agglomerates, which are thought to belong to the Caimito formation or another similar formation of the same period.

Some areas are suspected to have volcanic materials, specifically lava, interspersed with sedimentary deposits. The surface soils in the dam site consist mainly of talus deposits, colluviums, residual soils in the valley slopes and alluvial deposits in the river bed. In the case of Alto Indio (Options 3 and 4), although there is no specific field information, on the basis of the geological map, it is possible to estimate that the dam site includes a sedimentary bedrock of the Rio Hato formation.

Table 3-1
Geological Formations in the Direct Area of Influence of the Water Alternatives at the Rio Indio Watershed

		OPTION / RESERVOIR								
		1	2	3	4	Reservoir	Reservoir	Reservoir	11	12
FORMATION	**DESCRIPTION**	**INDIO 80-40**	**INDIO 45-40**	**ALTO INDIO 50-40**	**ALTO INDIO 45-40**	**TERIA (130)**	**ALTO TERIA (255)**	**INDIO CABECERA (300 masl)**		
Caimito (Sedimentary)	Tuffaceous sandstone, tuffaceous shale, tuff, foraminifer limestone. Quebrancha Member	2,846	1,523	244	236	0	0	0	0	0
Rio Hato (Sedimentary)	Conglomerate, sandstone, shales, tuffs, non-consolidated sandstone, pumice.	810	349	365	326	0	0	0	0	0
Tucue (Volcanic)	Andesites/basalts, lava, breccias, tuffs and plugs.	754	219	238	219	559	66	110	625	735
C. El Encanto (Volcanic)	Dacite, rhyodacite, ignimbrite, sub-intrusive, tuffs and lava.	122	3	5	3	0	238	0	238	238
C. Picacho (Volcanic)	Basalts/andesite, conglomerates, alluvium, colluviums, lodolite.	6	0	0	0	240	0	0	140	140
Cerro Viejo (Volcanic)	Basalts/andesite, vitreous amygdaloids. Post-ignimbrites Basalts	0	0	0	0	61	520	0	581	581
	Total Hectares	4,538	2,094	852	784	760	824	110	1,584	1,695

The Rio Indio options include a tunnel to transfer water from the new reservoir to Lake Gatun, with a length estimated at 8.3 km , and a diameter of 4.5 meters. Up to this date, there is no specific information on the geological conditions along the alternate routes for the tunnel. On the basis of the limited information available, it is estimated that the tunnel will mainly cross sedimentary rocks of the Caimito formation towards the side of the new reservoir and very hard volcanic rocks, such as andesite and basalt in the area close to Lake Gatun.

The site proposed for the Rio Indio dam is located at 31.2 km from the mouth; Alto Indio is at 7.5 km upstream from the Indio dam. On the other hand, the site proposed for the Teria dam (T.1) is about 3 km upstream from the site where the Teria river drains into the Indio river, 14 km upstream from the Alto Indio dam (52.7 km from the mouth); Alto Teria is 13.8 km upstream from the Teria dam (66.5 km from the mouth); finally the Indio Cabecera dam is at 85.2 km from the mouth.

The topographic map of the region indicates that the Teria reservoir is in the mid area of the Rio Rio Indio Watershed, where the elevations range between approximately 100 and 300 masl. According to the geological map of the region, the bedrock within the limits of the dam is estimated to consist of volcanic deposits of the Tucue formation, from the Tertiary period and the Quaternary Cerro Viejo and C. Picacho formations. The main rocks in these formations include andesite and basalt. However, the proposed dam site is close to an area where the geological map identifies the presence of sedimentary rocks of the Rio Hato formation including conglomerates, sandstone, shales and tuffs.

The Alto Teria dam is in the high area of this sub-watershed, where the altitude in the river banks range between approximately 300 and 400 masl. The area is estimated to basically consist of volcanic rocks from the Cerro Viejo, C. El Encanto and Tucue formations (Table No. 3-1). The water transfer tunnel from the Teria reservoir to Rio Ciri or Rio Ciricito is estimated to cross rocks that are mostly hard volcanic rocks (for example, andesites and basalts), although there might be sedimentary rocks such as conglomerates, sandstone, and shales depending on the selected route.

To this date, there is no field information to allow for an estimate of the thickness and nature of the soils or other geological, geomorphological and geotechnical conditions in the areas of these dams. Considering the limited information available, it is assumed that the soil thickness in the Teria reservoir area ranges from small to moderate (maybe less than two to three meters), depending on the location, and is even less in the relatively highlands of the Alto Teria reservoir and dam.

Option 12, proposed by URS, includes the same Teria reservoir included in Option 11 as well as a reservoir in the highlands of the Rio Indio Watershed with elevations above 300 to 400 masl. An open canal of about 1-2 km will transfer water from the Cabecera Indio reservoir to the high Teria river watershed, and from there, the water would drain through the natural watercourse up to the Teria reservoir.

According to the geological map of the region, the Cabecera Indio reservoir would be in an area mainly constituted by the volcanic rock of Tucue formation, with a small area of sedimentary rocks from the Rio Hato formation. The depth of the soils over the bedrock is estimated to be very low, maybe less than one to two meters, depending on the location.

3.2.1.2 Geomorphology

According to the National Atlas of the Republic of Panama (1988 edition) the evolution of the earth crust in the Rio Indio watershed has given rise to five differentiated geomorphological structures:

- **Low coastal and littoral plains, below 20 masl.** Most of this sector is characterized by the presence of volcanic rocks and sediments from the Miocene of the Tertiary age. This is the region of most recent deposition in which the geomorphological processes have created beaches, dunes, deltas, alluvial and flood coastal plains, and some mangroves, which show an active erosion/sedimentation process in the watershed, which may increase due to deforestation.

- **Low hills and hillocks.** A wide complex of low hills and hillocks is distinguished in the region. Their elevations range between approximately 20 to 200 masl. Most of these hills and hillocks have a molded topography with slightly steep slopes, they are lands belonging to the Lower-Upper and Undifferentiated Tertiary period.

- **Low and medium-high mountains.** Made up of mountains originating during the Undifferentiated Tertiary Period, with heights ranging between approximately 200 and 400 masl and with slopes varying between moderately to strongly steep slopes.

- **High mountains.** This section of the basin was formed during the Undifferentiated Tertiary period, and is characterized by mountains with an altitude ranging between approximately 400 and 600 masl.

- **Peaks and summits of the high mountains.** These are the areas presenting the more erosion and weathering resistant rocks, also formed during the Undifferentiated Tertiary Period. The most noteworthy elevation of this group is the Gaital Mountain.

3.2.1.3 Seismicity and Tectonism

The tectonic activity in the south of Central America is predominantly determined by the interaction between the Nazca, Cocos, Central and South American Plates. Volcanism and seismicity are strongly influenced by the plates' relative movement. Although the country is located in the Southeast border of the Caribbean Plate, Panama itself is located on the micro-plate known as Panama Block.

The region is not considered to be seismically active; however, there are a few seismic events on records:

- 1882 in Rio Indio, an earthquake was felt which produced a tsunami hitting Miguel de la Borda and destroying houses in Rio Indio and Gobea.

- 1935, an earthquake was felt, that had minimal impact on the departments of Cocle del Norte and San Jose del General

- 1971, an earthquake was felt in the departments of Donoso and Gobea, district Donoso, with high impact.

According to the Geological Map of Panama (1988 edition), two tectonic faulting type structures are prominent in the region, one in the E-W direction, and the other with a N-S direction.

3.2.2 Topography and Relief

In the Rio Indio watershed several distinctive ground elevations levels may be distinguished, and their topographic and edaphic characteristics are described below:

- Relative altitude < 20 masl: these are areas formed by low coastal and littoral plains in which the slopes vary from slightly steep to flat. The most significant limitations on the flat terrains are related to salinity (marshes) and frequent floods (alluvial plains). The sectors with mild slopes have land use limitations, while those with moderate slopes have severe land use limitations.

- Relative altitude ranging between 20 to 49 masl: in this sector, there are hills and plains with slight to moderately inclined slopes and soils with low nutrient content.

- Relative altitude ranging between 50 to 99 m: at this altitude there are low hills and hillocks with moderately to strongly inclined slopes, good internal drainage and low agricultural capacity.

- Relative altitude ranging between 100 to 199 masl: these areas are characterized by the presence of low mountains and high hills in which drainage is good to excellent, and the soils have low agricultural capacity.

- Altitude ranging between 200 to 399 masl: this sector is characterized by the presence of low and medium-high mountains in which the mountain slope is very strong. Furthermore, they have good internal drainage and the agricultural capacity of the soil ranges between good and excellent.

- Altitude ranging between 400 to 599 masl: This level is represented by high mountains in which strong slopes prevail; the soils are thin and have low agricultural capacity.

- Altitude ranging between 600 masl and over: formed by high mountains summits and peaks characterized by abrupt slopes, thin soils with good to excessive internal drainage.

3.2.3 Soils

The soils of the Rio Indio basin have developed under conditions which favor strong weathering and lixiviation effects as a result of the high temperatures and heavy rainfall. Under these conditions, the soils tend to be poor with different types of restrictions, and generally with low natural fertility. The oldest terrains have originated from a series of volcanic formations dacites, rhyodacites, sub-intrusive material, tuffs and lava.

3.2.3.1 Agricultural Capacity

According to the system for the classification of the agricultural capacity of soils of the Department of Agriculture of the United States, most of the soils in the highlands of Rio Indio belong to Class VI, VII and VIII soils, which are soils with severe land use limitations, where in some cases it is possible to develop cattle raising activities and plantations with permanent

production and protection of soils (VI soils), but in cases where the terrain is very steep, they should be used for recreation, reserves or water supply.

The mid part of the region was formed out of andesites, basalt, lava and tuffs. Most of the soils of this section are classified as class VI and VII, and therefore are not considered to be good arable land and have severe land use limitations. The use of the soils is recommended for pasture, in some cases, and in other as forest cover, for protection or for lumber production. In this sector, there are small sectors with soils belonging to class II, III and IV. These soils represent arable land and have limitations of a different sort in the choosing of the plants which may be used for the purpose of protection.

In the lower part of the region, originating mainly from sedimentary material made of tuffaceous sandstone, tuffaceous shale, tuff and limestone material, the soils are class III, IV, VI and VII, which, as stated above, have limitations for use.

3.2.3.2 Potential Land Use

The potential land use defines the maximum use the land may be assigned to, normally under a common management program for the area, without losing its quality as natural asset in the long run. In other words, it defines the maximum sustainable land use. To determine the potential use of the land of several areas of the Rio Indio Watershed, the information on Life Zones, Slopes and Agricultural Capacity was combined, and thus five (5) categories of potential land use were identified, which were used to classify the land:

- **Agricultural**: The lands which have an agricultural potential are first agriculturally classified within Classes II and III of the classification of the Soils Service of the Department of Agriculture of the United States of America and Dr. Reinmar Tejeira's map.

- **Agricultural-Livestock Use:** It involves different agricultural classes, II-III and IV. The latter are located in strips toward the area of San Jose del General, La Pintada, Sonadora and Tambo, Ciri de Los Sotos – La Encantada, Ciri Grande and El Cacao. They require careful management due to the danger of erosion. Consequently, the cattle raising activities to be carried out must be of low intensity and the crops shall be annual and permanent and managed with techniques for soil and water conservation.

- **Cattle Raising Activities:** This corresponds to soils Class V, and also includes a potential for permanent crops which may produce a cover similar to the forests. Although class V soils undergo the risk of erosion, they are appropriate mainly for pastures and forests. They are scarce in the area under study since they are only located in two small sectors: in the South end of La Pintada, in La Encantada, Pajonal and in the Caribbean Littoral area.

- **Forests and Commercial Forests:** these are lands with very severe limitations, mainly used for forests and reserve lands. The ones with greatest development correspond mainly to Class VI and VII (from Class II to Class V); they are towards the inland of the region from the North to the Center and from East to West. They are mainly located in the departments of El Cacao, Chiguiri Arriba, Ciri Grande, Rio Indio, Gobea, El Harino and Cocle Del Norte.

- **Protection:** they correspond to a potential for protected wild areas or wild areas to be protected, necessary for environmental education, ecotourism, scientific research and landscaping. The limitations they have exclude all agricultural and cattle raising activities, even the production of commercial plants.

The relative significance of each one of the categories for potential land use for the Rio Indio Watershed are included in the table below:

Table 3-2
Distribution of Potential Land Use in the Rio Indio Watershed (Has)

Category of Potential Use	Total	% Total
Agricultural	346.9	0.90
Agricultural and Cattle-Raising	5.2	0.01
Cattle Raising	-	-
Forest and Forest Crops	38,170.6	98.73
Protection	137.6	0.36
TOTAL	**38,660.00**	**100.00**

Source: Geographical Information System, URS Holdings, Inc.

When contrasting potential and actual use of the land, it is possible to observe that in the area there is conflict between over-exploitation of the land, in which the lands are being used beyond their sustainable capacity, and sub-exploitation of lands which might be used with greater

intensity as long as adequate conservation measures are followed. The most common case is overgrazing in areas where the potential use is for forests – commercial forests.

3.2.4 Climate

The climate in the watershed, as well as in the ROCC, corresponds, under Köppen climate classification to a Tropical moist climate characterized by:

- Annual precipitation greater than 2500 mm
- One or more months with precipitations under 60 mm
- Mean temperature in the coolest month > 18°C
- Difference between the mean temperature of the hottest and coldest month of < 5°C

3.2.4.1 Rainfall

The information on rainfall comes from records of monthly rainfall average in the period from 1991-2000 from 3 rain gauging stations (Table 3-3) as well as from an isohyetal map supplied by the ACP for the ROCC and adjacent area. This isohyetal map was converted into a raster image with a spatial resolution of 10 x 10 m with the help of the ERDAS IMAGINE software for topographical analysis and the information of a digital land model with 10 x 10 m pixels, thus creating a three dimensional surface on the bases of the lines with equal rainfall (Figure 3-2). This information suggests that the rainfall in the area of the Rio Indio Watershed fluctuates between 2.700 – 4.700 mm/year.

Table 3-3
Monthly Mean Rainfall (mm) in the Rio Indio Watershed and Adjacent Area

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Chiguiri Arriba	155	66	64	151	537	528	445	548	506	459	509	337	4,285
Boca de Uracillo	112	78	91	176	301	347	220	236	298	322	339	288	2,807
El Valle	51	20	27	62	338	421	283	391	478	469	316	73	2,927

Source: ETESA

The highest monthly averages were recorded in the months of June and August in the Chiguiri Arriba station, while the lowest averages were recorded in the months of February and March in the stations of El Valle and Boca de Uracillo.

3.2.4.2 Temperature

The temperature information at the level of the Rio Indio Watershed comes from the monthly average of the same weather stations at Chirigui Arriba, Boca de Uracillo and El Valle (Table 3-4). As it may be observed, the monthly mean temperatures in the watershed and adjacent area ranges between 23.2° C y 27.6 °C; corresponding to the Chirigui Arriba and Boca de Uracillo stations, the highest mean monthly temperature (26.6 and 27.6 °C) and to El Valle the lowest (23.2 °C) . The highest annual average (26.8 °C) was recorded in the station of Boca de Uracillo and the lowest average was recorded in the station of El Valle (23.7 °C), recording a temperature gradient to the North, which coincides with that described in the ARI Regional Plan (1996).

A raster image, similar to that described for rainfall, was also prepared for the temperature with the aid of the ERDAS IMAGINE software and the digital land model with 10x10 meters pixels. The value for the mean annual temperature (in Celsius, °C), of the surface air was computed with the aid of the **thermal equations,** developed by the old department of Hydrometeorology of the IRHE (*Instituto de Recursos Hidraulicos y Electrificacion*) known today as ETESA.

Table 3-4
Mean Monthly Temperatures (°C) in the Rio Indio Watershed and Adjacent Area

Station	Lat.	Long.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Aver.
Chiguiri Arriba	8°40'	80°11'	25.4	25.9	26.5	26.6	26.3	25.8	25.9	25.9	25.7	25.6	25.6	25.6	25.9
El Valle	8° 36'	80° 08'	23.2	23.5	24.2	24.3	24.1	23.8	23.8	23.8	23.5	23.4	23.4	23.3	23.7
Boca de Uracillo	8° 58'	80°11'	26.4	26.9	27.4	27.6	27.2	26.7	26.8	26.8	26.5	26.4	26.4	26.5	26.8

Source: ETESA; TLBG/UP/STRI Consortium

The thermal formula used to calculate temperature was:

(1) $\mathbf{T = 26.9006 - 0.0055(H).}$

Where **H** is the elevation of the area expressed in meters above mean sea level. The coefficients used (26.9006 and 0.0055) correspond to the mean value of the monthly adjusted formulas calculated by the IRHE.

When applying this ratio to each one of the 10 x 10 meter pixels, a temperature raster image was generated (Figure 3-3). The temperature image (T) was generated by applying the already mentioned coefficients on the image of the digital land model (H), that is why the resulting temperature image maintains the geometrical characteristics of spatial resolution and projection

of the digital land model, i.e., a 10 x 10 pixel size and provides an excellent graphic representation of the annual mean temperature in the Indio Watershed and all the ROCC area.

3.2.4.3 Evapotranspiration and Runoff

On the basis of the data on monthly temperature and rainfall, the annual water balance was estimated; using Thornthwaite and Holdridge methodology for the calculation of the evapotranspiration potential (ETP) and mean annual runoff for those stations (Table 3-5).

Furthermore, with the assistance of the same digital land model and the ERDAS IMAGINE software, the annual water balance was estimated for each 10 x 10 m pixel, and it was possible to generate a runoff map (Figure 3-4), which predicts 99.64% of the runoff measured in the ROCC rivers, under study, and even includes the variations caused by the alterations in the original vegetation cover.

Table 3-5
Evapotranspiration Potential and Runoff for the Rio Indio Watershed

Station	ETP Thornthwaite mm / year	ETP Holdridge mm / year	Runoff Thornthwaite mm / year	Runoff Holdridge mm / year
Chiguiri Arriba	1403	1406	2882	2879
Boca de Uracillo	1567	1468	1240	1339
El Valle	950	1049	1978	1878

Source TLB/UP/STRI Consortium

3.2.5 Hydrology - Hydrography

The hydrography is the result of the combination of several factors, among them, geology, climate, relief and soils. As it may be observed in Figure 3-5, in the case of the river Indio, there are three well differentiated slope stretches. The levels in increasing altitude are:

a) High: Between the headwaters and an altitude of 350 masl, where there is an inflection of the main watercourse.

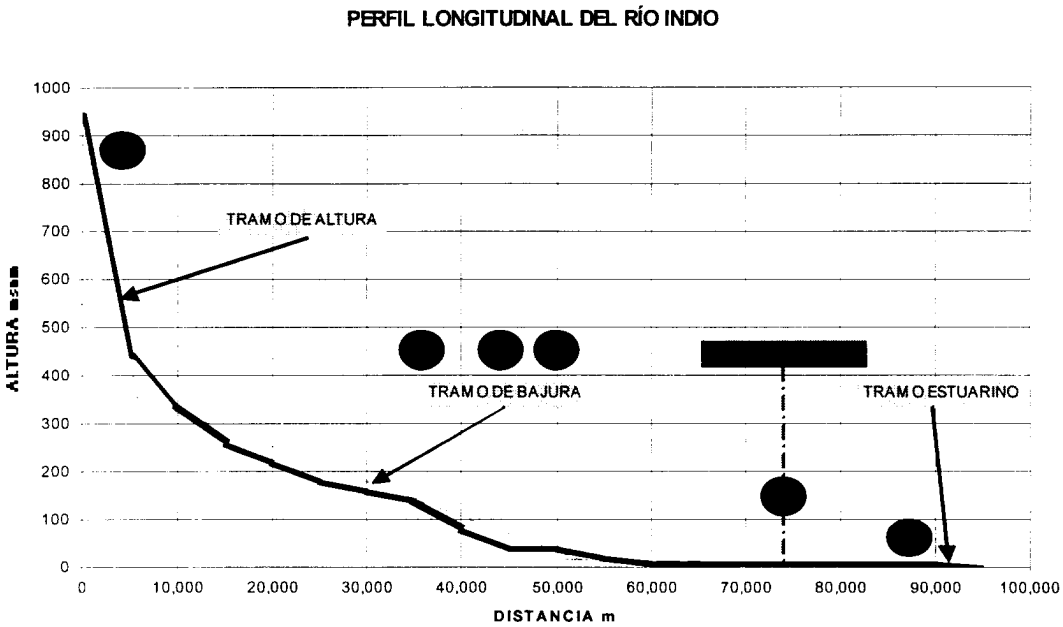
b) Intermediate: it develops between the previous one and the estuarine system; and

c) Estuarine: it develops between an elevation of 10 masl and the river mouth into the sea. In the case of this sub-basin, given the extensive development of the estuarine systems, special

attention should be paid to the ecological flow rate to be discharged downstream from the reservoirs for their preservation.

In the section within the ROCC, the Rio Indio Watershed drains through three main watercourses. The Rio Indio main watercourse drains approximately 49% of the area located in the central part of the basin, including the headwaters, and its two main tributaries; they drain areas more or less equal on both sides of the main watercourse. These tributaries are the Teria river, which drains about 95 Km^2 (25%) of the Eastern part of the watershed and the Uracillo river, which drains approximately 99 km^2 (26%) of the Westernmost section of the watershed.

Figure 3-5
Longitudinal Profile of Rio Indio



Source: Report elaborated by the LBI/UP/STRI Consortium

3.2.5.1 Flows

The surface water discharge of the Rio Indio Watershed (flow rates) has been measured by ETESA, throughout time, at two specific control points, Limon station since 1958 until 1980 and Boca de Uracillo since 1979 up to this date. The latter are shown in Table 3-6.

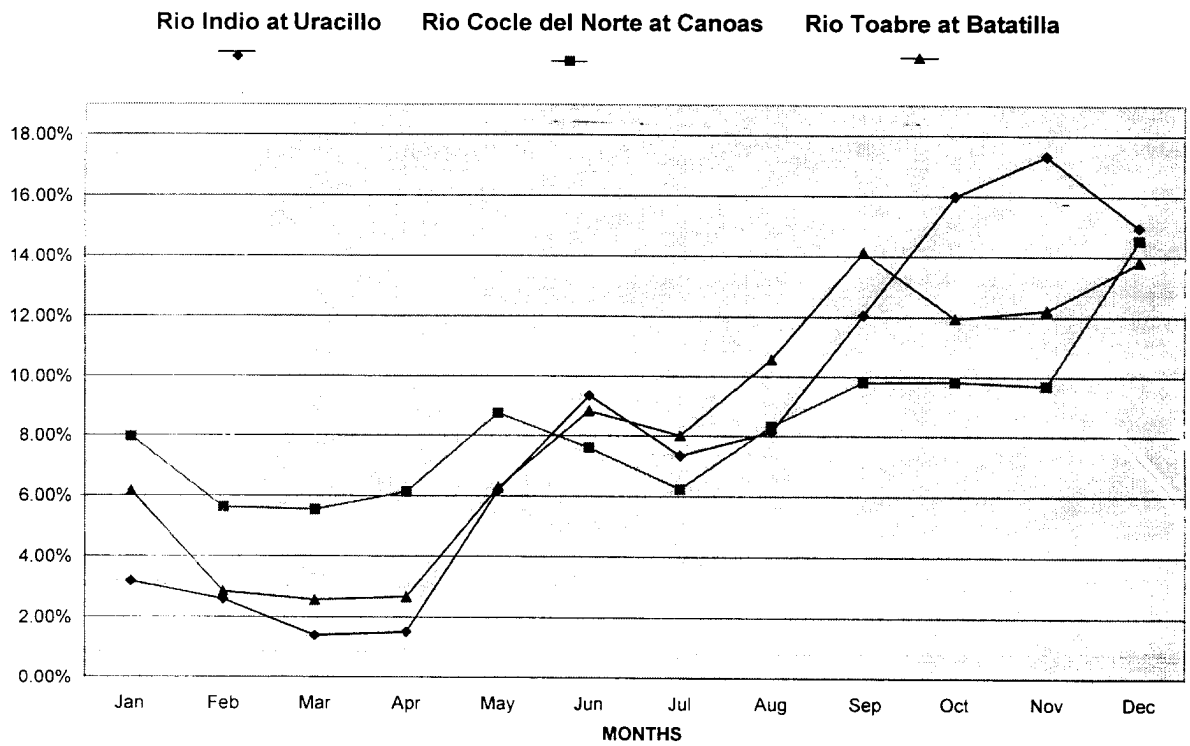
Table 3-6
Average Flow Rate (m^3/s)

Watershed/Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE.
Indio/Boca de Uracillo	10.5	8.53	4.61	5	20.4	30.8	24.2	26.8	39.7	52.7	57.1	49.3	27.6

Source: ETESA; MWH.

The comparison of the behavior of these flow rates with those observed at other points of the ROCC suggests that the seasonality phenomenon is more marked in the Rio Indio Watershed than in those of Cocle Del Norte and Toabre (Figure 3-6). Although the seasonality of the flow rates, in the ROCC is not as significant as in other areas of the country, it is possible that in the case of Rio Indio. deforestation may be intensifying the impact of the dry season in the River flow. It should be pointed out that the Rio Indio Watershed has the least vegetation cover in all the ROCC, with only 26.2% of the forests that once existed, remaining. In this graph, the monthly average flow rate of the three rivers is expressed in percentages to facilitate the visualization of their behavior. It is notable that the greatest percentage of discharge of Rio Indio is in the most humid season during the months of October and November. Also the low values of the discharge in the dry season are notable, particularly in January, March, and April.

Figure 3-6: Seasonality of the ROCC Flow Rate



Monthly mean flow rate expressed in percentages of the annual mean rate

3.2.5.2 Groundwater

The information on the groundwater in the region is scarce; that is due to its limited water supply, compared to the large surface water resources available. As a result of the information gathered, the conclusion may be drawn that the groundwater does not constitute a massively exploitable resources due to its relative scarce presence, mainly in the fissures and cracks of fractures rocks.

Given the little information on groundwater, the only variable that may be used to determine if there is any saltwater intrusion in the areas closer to the estuary are biological indicators. However, the observations of the LBI consortium in the report of environmental and cultural data[53] did not indicate the presence of any plants already adapted to a saline environment which shows that, at present, the area close to the Atlantic sector is lixiviated by the heavy rainfall, and at least on the surface, does not show the presence of salts.

3.3 Characteristics of the Biotic Environment

As previously stated, under natural conditions, the area of the Rio Indio watershed and adjacent area would be covered by evergreen tropical forests with large structural development and habitat diversity, which drain the surplus of the abundant rainfall through rivers and ravines which are also anticipated to have a significant habitat and associated species diversity. The study and documentation of the conditions actually prevailing in the biotic component of the ecosystem are important because their condition largely determines the water quality, erosion control, risk of eutrophication and other environmental services which are essential for the success of the execution and operation of the water alternatives for the quality of life of the inhabitants of local communities.

The paragraphs below present a brief description of the condition of the vegetation cover, the health of the aquatic ecosystems, and the status of the biological diversity in the watershed. The area has been reported to have species of special interest, both related to the flora and fauna, which are included in the subsections specifically dealing with them. The reasons to include the species in this list are varied and include their significance from the food, medical, and economic point of view or their conservation status or risk of extinction.

3.3.1 Vegetation Cover

As previously mentioned, the Rio Indio Watershed has been most severely affected by deforestation caused by man. As it may be observed in Figure 3.7 and Table 3.7, only a small fraction of the original forests remain in the basin (26.2%). Since the forest in the low lands is the most abundant and the one where the conditions are less restrictive for human settlements, it is this forest the one most affected by human intervention in the Rio Indio Watershed, there remaining only 23% of the original cover.

The vegetation cover in the Rio Indio watershed has suffered significant changes during the last 15-20 years (Figure 3-8). Although by the mid 80's, the watershed had already undergone strong intervention and the extension of underbrush and scrub was significant, they were mainly located in the North and South of the watershed, reflecting the disorderly colonization process coming from both fronts. At this time, it was still possible to observe dense forests in the central sector of the watershed (Santa Rosa and Ciri Grande), secondary/intervened forests in all the sub-basin and particularly in the South of Ciri Grande.

Table 3-7
Habitat Categories in the Rio Indio Watershed

Type of Habitat	ORIGINAL CONDITION		CURRENT CONDITION	
	Hectares	%	Hectares	%
Pasture	0	0	5,723	14.8
Stubble	0	0	20,782	53.8
Forests	38,660	100.0	12,155	31.4
Lowland tropical evergreen broadleaf wet forest	34,059	87.7	9,466	24.5(27.8)[1]
Sub-montane tropical evergreen broadleaf wet forest	4,527	11.7	2,599	6.7(57.4)[1]
Montane tropical evergreen broadleaf wet forest	228	0.6	89	0.2(39.0)[1]
TOTAL	38,660		38,660	

Modified from the report by the Louis Berger/Consortium.
1/The figure in parenthesis indicates the percentage in each forest category in comparison to the original cover.

By the year 2000, dense forests had almost completely disappeared, and there was a significant reduction of secondary/intervened forests, surviving mainly in the area of the mid basin (central

area of the Santa Rosa department). In most cases, the forest areas were substituted by underbrush/scrub and pasture mainly used for extensive cattle raising activities.

Here follows a description of each of the categories of existing vegetation according to the quality of habitat they represent for the conservation of the biological diversity of plants and animals as well as of other environmental goods and services.

3.3.1.1 Lowland Tropical Evergreen Broadleaved Wet forest

This type of habitat presents dense trees, with a canopy that has leaves all year long. The plants are distributed vertically in at least four stories: emerging, dominant, dominated and floor of the forest understory. In the undergrowth, there is natural regeneration of the canopy species, and there are also shrubs, grass, and epiphytes. This type of forest is under the 500 masl elevation.

This habitat has a total surface area of 7,877 ha in the watershed. The areas where it was originally located have been strongly intervened, and therefore it has almost disappeared. The existing remains are distributed throughout the watershed in a fragmented fashion, which thus minimizes its value as refugee for the wild life populations which once existed there.

A forest with a canopy dominates the landscape, which is about 25 m high. Among the trees dominating the canopy, there is a varied mix of species, where the major ones are: *Inga spectabilis, Vochysia ferruginea, Pterocarpus officinalis, Licania arborea, Couma macrocarpa, Socratea exorrhiza, Welfia regia, Lonchocarpus pentaphyllus, Cordia lucidula* and *Terminalia amazonia*, among others. Below the canopy, there is a tree stratum represented by species like: *Hirtella racemosa, Miconia affinis, Siparuna cuspidata, Palicourea guianensis, Inga heterophylla* and *Gustavia superba*. At the under story level, there is a stratum of grass and bushes. That stratum has species like: *Anthurium pentaphyllum, Anthurium trisectum, Chamaedorea pinnatifrons, Geonoma epetiolata* and *Asplenium maxonii*. The presence of bryophyte is significant, among them there are moss species like: *Callicostella pallida, C. depressa, Calymperes levyanum y Syrropodon parasiticus*. Besides, among hepaticae species, the following are observed: *Ceratolejeunea coarina, Leptolejeunea elliptica* and *Odontolejeunea lunulat.*

3.3.1.2 Submontane Tropical Evergreen Broadleaved Wet forest

The submontane forest is located in lands at an elevation ranging between 500 and 1,000 masl, and is classified as vulnerable. This habitat currently has a total surface area of 2,163 ha, which

represents 47.8% of its original extension. The tree vegetation is dense; the dominant canopy reaches a height of 25 m and presents two lower stories. In this habitat, there is great abundance of epiphyte due to the high relative humidity prevailing there. In the Rio Indio Watershed, this type of habitat is located in the south and has been strongly intervened by human activities.

In the canopy, the following species may be found: *Licania jefensi, Pterocarpus officinalis, Sterculia apetala, Byrsonima spicata, Swartzia simplex, Marila laxiflora, Hyeronima oblonga* and *Jacaranda copaia*, among others. Under the canopy, there are tree species such as: *Otoba latiolata, Quiina amazonica, Ocotea cernua, Amaioua corymbosa* and *Hirtella tubiflora*, among others. The under story stratum is made up of grass and bushes, where species like: *Anthurium bakeri, Anthurium vallense, Calyptrogyne allenii, Geonoma deversa, Synechanthus warcewiczianus, Aechmea allenii* and *Guzmania musaica,* among others, may be found. The bryophytes are particularly abundant on the ground or on the trees. Among the bryophytes, it is possible to find moss species like: *Acroporium pungens, A. longirostre, Pireella angustifolia, Pyrrhobryun spiniforme.* Among the hepatic plants, it is possible to observe *Ceratojeunea coarina, Cuclolejeunea convexistipa, Diplasiolejeunea pellucida and Leptolejeunea elliptica.*

3.3.1.3 Montane Tropical Evergreen Broadleaved Wet forest

The conditions for the proliferation of the montane forest in the Rio Indio Watershed are even more restricted than for the submontane forest. This type of ecosystem is located above an elevation of 1000 masl and is dominated by forest vegetation. The forest canopy is in average 13 m high; below, several stories are observed. This habitat occupies a surface of 74 hectares, representing 32.4% of its original extension, and is located in the South of the watershed, coinciding with the land with higher elevation.

Among the species observed in the canopy are the following: *Zanthoxyllum melanostictum, Albizzia niopoide, Macrolobium colombianum, Magnolia sororum, Virola sebifera, Zinowiewia costaricensis* and *Billia colombianum, among others.* In this type of habitat, the typical genus of mature forests of the highlands is found, such as *Magnolia sp.*, *Talauma sp.*, *Quercus sp.* and *Alfaroa sp.* Under the canopy, stratums of tree species like: *Marila laxiflora, Richeria obovata, Elaeagia nitifolia, Amaioua corymbosa, Phoebe brenesii* and *Erythroxylum macrophyllum*, among others, may be found. Besides, there is a stratum made up of grass and bushes, such as: *Anthurium pittieri, Aphelandra dolicantha, Stenospermation spruceanum, Clidemia folsomii and Miconia curvipetiolata, among others.* Among the bryophyte, it is possible to observe moss species like: *Leucobryum giganteum, Macromitrium fusco-aureum, Orthostichella pentastichia and Phyllogonium viscosum.* Among hepatic species, it is possible to observe: *Lophocolea*

muricata, Scoparia portoricensis, Metzeria spp., Monoclea gottschei and Symphyogyna brongniartii. The Anthoceros group is represented by *Leiosporoceros dussii, Megaceros vicentianus and Phaeoceros sp,* among others.

3.3.1.4 Pastures

Among the habitat modified or altered by human activities, the pastures prevail. The type of habitat that has received the greatest pressure and alteration in the process of establishment of grazing lands has been the lowland tropical evergreen broadleaved wet forest. This is probably due to the fact that it is usually located on flat land, with less relief than other types of forest, thus facilitating access and handling.

The pastures total surface area is 7,723 ha, which represent 14.8% of the basin. The herbaceous vegetation, with an average height of 30-90 cm remains green all year long due to the rainfall conditions prevailing in the area. In this category, grasses, mainly of the Poaceae family, dominate the landscape. The species used for the establishment of pastures is *Ischaemum timorense*, known as Lucuntu grass, which is an exotic species introduced many years ago in the region. When the pastures are not taken care of, new grass species establish themselves, mainly indigenous grass, considered to be weeds. The species considered to be weeds in the pastures are several; among the most common ones are the following: *Scleria melaleuca, Desmodium axillare, Lantana camara, Solanum jamaicense, Rhynchospora nervosa, Panicum pilosum and Sida rhombifolia*

Pastures undergo constant anthropogenic intervention; with a frequency of clearing of shrubs (weed) occurring three to four times a year. This eliminates the possibility of recovery of the natural habitat.

3.3.1.5 Stubbles

The fallow land or stubble is distributed all over the area, independently of the elevation, relief or climate. This type of vegetation occupies 22,822 ha, which represents approximately 59% of the total watershed area. In the region, it is possible to observe stubble of different ages. The generalized practice is to leave the land in fallout for a maximum of six years. However, during the environmental data collection study, land that had been left in fallow up to eight years or more was observed, with a dominance of tree vegetation that is quite similar to that of secondary forests.

3.3.2 Biological Diversity

As a result of the impoverishment previously mentioned, which is the consequence of deforestation and the substitution of forest mainly by pastures, there is in Rio Indio a decrease in the primary production rate and a reduction of the biological diversity at all levels of the ecosystem in the watershed. This decrease in habitat adequate for the wild life species affects mainly the abundance of species in the upper trophic levels, but is also manifest itself in all the strata of the food chain, including producers (plants) and herbivores. Here follows a description of the status of the biological diversity in the main groups of organisms that constitute the biological community of the watershed area. Some of the organisms are called of special interest due to several reasons as indicated below.

3.3.2.1 Special Interest Species

As previously stated, some of the animal and plant species are of special of interest for one or more groups of the society for a series of reasons. In order to offer a general vision, the special interest categories are described in this section, and the numbers of species are included in each taxonomic group within each category (Table 3-8). The common and scientific names of each species are listed in Annex 3, and are described in each of the groups described in the text.

The flora and fauna species included in the list of special interest species are found in one of the following categories.

- Species of Medical Interest/Interest for Food.- It refers to the species which are vectors of diseases, hosts of vectors, dangerous species for man, and wild species useful as food for local communities.

- Local Protection.- This category includes the species protected by the national legislation. In this case, the most common designation used are: vulnerable (VU), endangered (EN), in critical risk (CR), endemic, threatened or with restricted distribution.

- Species included in the CITES Convention. It refers to the species included in the appendixes of the Convention on International Trade in Endangered Species of the Wild Fauna and Flora. Three appendices of the convention are significant from the point of view of protection of biological diversity:

- Appendix I: It includes all species threatened with extinction. Trade in specimens of these species requires a special permit, and is only authorized in exceptional circumstances.
- Appendix II: It includes the species which although are not necessarily threatened now with extinction, but may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with their survival.
- Appendix III: It contains the species which are protected at least in one country, which has requested assistance from other members of the CITES to control its trade.

- List of the International Union for the Conservation of Nature (IUCN). This list is known as the Red Book of Threatened Species and includes the denomination included below:
  - Extinct (EX): A taxon or species considered to be extinct when there is no reasonable doubt that the last individual of this taxon has died.
  - Extinct in the Wild (EX/E): It refers to species extinct as wild life and only known in captivity or outside its natural range.
  - Endangered (EN): A taxon is in danger of extinction when there is evidence indicating that the size of the population showed a reduction of more than 50% in the last 10 years.
  - Vulnerable (VU): This denomination applies to species whose population has undergone a 30 to 50% reduction or a significant reduction in its geographical range in the last 10 years or with an estimated population of less than 10,000 mature individuals.
  - Rare (R): A species is considered to be rare when its population is low and the specimens are not common in field collections.
  - Low Risk (LR): It refers to a taxon which does not fit any of the prior denominations, but it may qualify in the near future, and must therefore be monitored.
  - Deficient Data (DD): It refers to a taxon with inadequate information for a direct or indirect classification of its risk of extinction based on its distribution or population status.
  - Undetermined (I): a taxon is considered to be undetermined when it has not been assessed under any criterion.

Table 3-8: Special Interest Species in the Indio, Caño Sucio and Toabre Watersheds

	R. Indio	C. Sucio	Toabre		R. Indio	C. Sucio	Toabre
A.- Medical-Food- Economic				**Vulnerable**			
Vector insects	23	23	23	Plants	38	6	15
Plague insects	3	3	3	Amphibious and Reptiles	7	6	6
Poisonous Amphibious and Reptiles	3	5	5	Birds	10	8	30
Mammals hosts of diseases	5	1	4	Mammals	9	6	6
Edible fish	23	23	23	**Rare**			
Edible shrimp	3	3	3	Plants	1	1	1
Aquatic Weeds	4	4	4	Amphibious and Reptiles			
B.- Locally Protected				Birds	4		17
Plants	1			Mammals	2		5
Amphibious and Reptiles		12	13	**Low Risk**			
Birds	9	5	13	Plants	4		2
Mammals	12	9	10	**TNC[1] List**			
C. CITES Listing				**Restricted Dist. N2** - Birds	32		10
Appendix I – Mammals	3	1	5	**Restricted Dist. N3** - Birds	2		46
Appendix II				**F. Others**			
Amphibious and Reptiles	4	6	9	**Migratory** - Birds	31		
Birds	32	31	46	**Endemic**			
Mammals	2		2	Plants	5		1
Appendix III – Birds	3	2	6	Amphibious and Reptiles	5	3	6
D. UICN List				Mammals	1		
Endangered				**Scientific Interest**			
Plants	8	1	5	Fish	4	4	4
Amphibious and Reptiles	11	6	8				
Birds			1				
Mammals	5	3	7				

[1] The Nature Conservancy

- TNC List – (The Nature Conservancy): This list includes species which have a habitat with restricted distribution and present a distribution range as indicated below:
  - Range N2: refers to species which due to the restricted national habitat may be severely threatened due to loss of habitat or hunting.
  - Range N3: refers to vulnerable species in the country, whether because they are rare or not common, or because they are found in a restricted range.

- Species of Scientific Interest: They are special interest species with a taxonomic classification or geographical distribution that is not clear. It often occurs when there is a report of the presence of a species where it has not been previously reported or species that is new for science.

3.3.2.2 Biological Diversity of the Flora

Panama's flora is the result of the migration of species from South and Central America. With the formation of the Panama Isthmus, there were migratory movements in both direction of the North-South axis. This contributed to the establishment of a mixture of species in Panama. Some of the recorded species have as boundary of their geographical distribution, the Panama Isthmus. The number of species with restricted geographical distribution, limited by the area formed by Costa Rica, Panama and Colombian (Chocoana species) is remarkable. Considering the form of geographical distribution, there is a certain degree of endemism possibly due to those migrations, and the subsequent isolation of the populations. However, the number of species documented is less than the incidence potential due to the environmental impoverishment effect previously stated.

The results of the sampling of the flora of the Rio Indio Watershed indicate the presence of 579 species distributed in 146 families and 367 genera. The diversity of the species in the area is closely related to the situation of the different types of habitat, since where the conditions are natural or slightly altered, the number of species is greater than in the habitats strongly altered or modified by human activities. The most abundant group belongs to the angiosperms with 375 species. The numbers of species recorded represent a 5.8% of the total estimated number for Panama (more than 10,000 species in all).

The report on environmental and cultural data collection[53] presents the inventory made, grouping the species recorded according to the main types of plants recorded:

- Magnoliophyta with 375 species;
- Pteridophyta and allied with 39;
- Moss, 92;
- Hepaticae and Anthocerophyta with 73; and
- One species of lichen.

The best represented families are Lejeuneaceae, with 20 genera and 32 species, Rubiaceae with 19 genera and 38 species, Melastomataceae with 7 genera and 26 species. Besides, there are other well represented families, if one considers the number of genera present, among which the following may be mentioned Pilotrichaceae (14 genus) and Fabaceae (9 genus). The Piperaceae family, although it has only 2 genera, has a total of 26 species. On the other hand, the Poaceae family, although it is represented by 7 genera and 9 species, is the dominant family in the landscape, particularly in the mid and lower basin. At present, the mid and lower basin is being used for cattle raising activities, which explains the dominance by the Poaceae family, particularly with the presence of the species *Ischaemum timorense* (Lucuntu grass).

In the Rio Indio Watershed, 44 special interest species were documented, 12 of them being endemic, among them *Dioscorea standleyi,* of the Dioscoreaceae family, considered to be rare by the IUCN and *Chrysothemis friedchsthaliana,* considered to be endangered by the ANAM.

3.3.2.3 Aquatic Plants

The macroscopic aquatic plants constitute a special interest category because depending on their growth habits and when the conditions are ideal for development they may cause serious problems in the execution, and particularly the operation of the water alternatives being considered. The species documented in the environmental data collection study are mainly those within the lotic type habitat, or of flowing waters, where the constant water flow, the water – land exchange and the oxygen stress are the most outstanding physical characteristics. The total number of aquatic plants recorded was of 15 species in the Rio Indio Watershed (Table 3-9).

Table 3-9
Aquatic Macrophyta per growth habits and collection site at the Rio Indio Watershed

FAMILY	GENERA	SPECIES	COMMON NAME	HABIT	RIO INDIO						
					01	02	03	04	05	06	
Alismataceae	*Sagittaria*	*platyphylla*	Delta Arrow head	Hi	X						1
Apiaceae	*Hydrocotyle*	*bonariensis*	Large leaf pennywort	Hi						X	1
Araceae	*Montrichardia*	*arborescens*	Mocou mocou	Hi-Ab	X	X					3
Araceae	*Pistia*	*stratiotes*	Water Lettuce	Hi	X						1
Araceae	*Spatiphyllum*	*friedrichsthalii*	Peace Lily	Hi	X	X					3
Araceae	*Spatiphyllum*	*quindiuense*		Hi	X			X	X	X	6
Araceae	*Spatiphyllum*	*sp.*		Hi							1
Brassicaceae	*Nasturtium*	*officinale*	Watercress	Hi						X	4
Cyclantaceae	*Dicranopigyum*	*crinitum*		Hi				X		X	1
Hydrocharitaceae	*Hydromystria*	*laevigata*	Sponge plant	Hi						X	2
Nymplaeaceae	*Nymphaea*	*blanda*	Water lily	Hi	X						2
Onagraceae	*Ludwigia*	*helminthorrhiza*	Water primrose	Hi	X						1
Podostemaceae	*Marathrum*	*allenii*		Hi						X	1
Pontederiaceae	*Eichhornia*	*crassipes*	Rose mallow	Hi	X	X					42
Pontederiaceae	*Heteranthera*	*reniformis*	Mud plantain	Hi						X	2
Pontederiaceae	*Pontederia*	*rotundifolia*	Pickérel weed	Hi	X	X					11
											0
TOTAL SPECIES PER SITE					9	4	0	2	1	7	

Source: Consortium TLBG/UP/STRI, 2003.

Sampling sites 01- RIO MEMBRILLAR 02- QDA. JOBITO 03- QDA. LOS UVEROS 04- RIO LAS MARIAS 05- QDA. LA CONGA 06- RIO INDIO ARRIBA
Hi = Grass; Ab = Bush

Although it is not as expected, the upper Rio Indio watershed has sections with low velocity streams, which favor the establishment and development of aquatic plants, and a total of seven species has been reported in this area of the watershed (Table 3-10). The mid and lower watershed sections are inhabited by the largest number of aquatic plant species. The best represented species was *Spathiphyllum quindiuense* Engl., recorded in three sections of Rio Indio (lower, mid and upper watershed).

Under the special interest category, the *Eichhornia crassipes*, *Pistia stratiotes*, *Pontederia rotundifolia* species may be identified. They are known for their behavior as aquatic weeds due to their easy dispersion capacity. They also constitute a restrictive factor for the effective management and administration of water, and they also hinder the operational activities related to the dam, and present an additional special interest due to their potential for generation of problems for human health, since they facilitate the reproduction of vectors of diseases. Under appropriate conditions for strong growth, these species may form almost continuous layers over the water, which has a direct effect on the development of plant and animal organisms at the bottom of dams since they intercept light and restrict the availability of dissolved oxygen in the water column.

3.3.2.4 Diversity of the Main Groups of Fauna

The available information on diversity of animal species also comes primarily from the environmental and cultural data collection study[53]. Again, it should be pointed out that emphasis has been placed in the main groups considering their significance due to their function in the ecosystem, the status of the population at regional and national level, or because they may be important from another point of view, for example, medical/epidemiological. The groups are described below.

3.3.2.4.1 Insects

Among insects, the environmental data collection study[53] focused on two different groups, those with aquatic habits and those normally occurring outside water, at least, during most of their life cycle. Among them, seven families with a total of 56 species were documented (Table 3-10). The families with largest number of species were Tabanidae, Culicidae, and Psychodidae (see Table 1, Annex 3).

Table 3-10
Number of Species of Insects per Family in the Rio Indio Watershed

Family	No. of species
Tabanidae	20
Culicidae	12
Psychodidae	12
Ceratopogonidos	2
Simulidae	5
Triatominae	4
Oestridae	1
Total	**56**

Source: LBI Consortium, Environmental and Cultural Data Collection Study, 2003.

Six of the documented species are known by being hematophagous insects, some of which are of medical significance, which is why they were included in the category for Special Interest. These species may affect man and domestic animals, among them are the vectors of the pathogen agent of Leishmaniasis (*Lutzomyia panamensis. L. Gomezi, L. sanguinaria y L. trapidoi*). With the exception of the "torsalo" or human bot fly which produces miasis, they feed on blood (are hematophagous) and include insects such as: mosquitoes, chigger fleas, gnats, horsefly, and bedbugs. (Table No.1, Annex 3)

Among *aquatic* insects, the samples collected during the inventory of the Rio Indio Watershed, documented a total of 41 families. The result of the sampling in sites with high accumulation of litter collected at Rio Indio (Table 3-11) presented the most abundant and rich fauna in terms of species and families represented.

Table 3-11
Abundance of Aquatic Insect Individuals, per family, found in sites of accumulation of litter in the Indio River and its tributaries

Family	Individuals per Family	
	Rainy Season	Dry Season
Baetidae	196	181
Chironomidae	1,505	1,497
Hydropsychidae	276	1,337
Leptohyphlebiidae	334	191
Leptohyphidae	326	2,537
Perlidae	50	193
Philopotamidae	436	438
Simuliidae	710	1,547
Subtotal /Basin	**3,833**	**7,921**
Total/Basin	**11,754**	

Source: LBI Consortium, Environmental and Cultural Data Collection Study, 2003.

Out of these families, the ones with greatest numerical representation were in general:

- Leptohyphidae
- Simuliidae
- Chironomidae
- Hydropsychidae
- Philopotamidae
- Elmidae
- Leptophlebiidae.

The distribution of aquatic insects is determined by several physical (temperature, discharge), chemical, and biological (life cycle, availability of food, competition, and depredation) factors. In the case of insects associated to the litter, it should be pointed out that there are different relationships between them and the substratum; some may use it as food, others as refugee.

Several groups of aquatic insects are considered to be of interest due to several reasons (See Table 1, Annex 3). Most are of interest as a source of food for other organisms while others are indicators of environmental quality. The most notable ones are briefly listed below:

- Bloodworms (red worms) have a significant role in the determination of several ecological parameters, such as trophic level of lakes, secondary production of the aquatic environments, and as source of food for fish. Besides, they are used to detect contamination due to the presence of cadmium, copper, lead, and to determine the effect of the application of herbicides in fast-flowing waters.

- Simuliidae (black-flies, buffalo gnats) have medical and veterinary significance since they transmit diseases to animals such as filaria to horses, avian malaria, myxomatosis to rabbits and Eastern Equine Encephalitis. (see Table 1, Annex 3)

- The Leptohyphidae and Hydropsychidae families have been included under the category of special concern (Table 1, Annex 3), since they are an important food source for aquatic organisms, mainly fish.

The large dominance of bloodworms in this study may be reflecting relatively extreme environmental conditions, particularly the little availability of oxygen, since this is a group known to be tolerant to this. In this context, in the watershed under study, the influence of the seasons in the distribution of this group is well marked. Although they were dominant during both seasons, in the dry season there was a marked increase in abundance. This may indicate that the micro-environmental conditions where they were developed vary between both seasons.

Multiple factors (physical, chemical, biological) are determining the distribution of this group tolerant to extreme environmental conditions.

3.3.2.4.2 Aquatic Mollusks

The lake and river mollusks belong to the classes Gastropoda and Pelecipoda. Both are characterized by the development of strategies for survival in these media, where the water may be scarce during part of the year. During the inventory made to document the existing environmental conditions[53], most of the organisms were caught during the rainy season, probably due to the fact that the conditions were optimal for their development.

During the rainy season, 34% of the individuals collected and 68% of the biomass came from the lower area, where slow current flows prevail, being the dominant adult individuals to the *Melanoides tuberculata species*. This snail was the most abundant gastropod in the collections at the Rio Indio Watershed.

On the contrary, in the dry season, the number of individuals and their biomass increased drastically in the upper watershed systems. This phenomenon may be explained by the better hydrological condition, and therefore greater capacity to retain water in the upper watershed, since the water availability in this period, favors the survival of mollusks. On the other hand, during the dry season, in the estuarine section of the Indio hydrological system, a significant reduction was observed in their abundance, diversity and biomass, which may be associated to the decrease of the river flow and the entry of a saline wedge. Among the species of aquatic mollusks found in the Rio Indio Watershed, the following may be mentioned:

- *Anadara sp.*
- *Corbicula fluminea*
- *Tellina sp.*
- *Acmaea sp.*
- *Calliostoma sp.*
- *Nerita sp.*
- *Pomacea sp.*
- *Melanoides tuberculata* Müller
- *Oliva sp.*
- *Monilispira sp.*

Among the mollusks, two species of special interest were identified: the Asian clam *Corbicula fluminea*, due to the deposition of shells and displacement of indigenous species, and the *Melanoides tuberculata*, a gastropod carrier of the flat worm (planaria) which attacks the eyes of several types of birds, leading to severe blindness.

3.3.2.4.3 Crustacean

There are approximately 10,000 species of decapods (shrimp, lobsters, crabs) described in the world, 46 of which have spread outside their natural distribution areas. Out of them, 39 come from marine – estuarine environments and 7 from fresh water – estuarine environments. The cause of this dispersion has been: accidental, due to migration through the navigation canals and due to voluntary introduction for harvesting[72a]. The table below presents a taxonomic classification and list of species of freshwater crustaceans collected in the Rio Indio watershed.

Table 3-12
List and Total Number of Crustacean Species in the Rio Indio Watershed

	Shrimp Species	Relative Abundance
Sub Order: Natantia		
Family: Palaemonidae	*Macrobrachium carcinus*	263 (44.0%)
	Macrobrachium crenulatum	57(9.5%)
	Macrobrachium acanthurus	54(9.0%)
Family: Atyidae	*Atya scabra*	218(36.5%)
	Potimirim glabra	5(0.8%)
	Crab Species	
Sub Order: Reptantia		
Family: Pseudothelphusidae	*Pseudothelphusa americana*	19 (90.4%)
Family: Grapsidae	*Sesarma sp.*	2(9.6%)
	TOTAL	**618**

Source: LBI Consortium, Environmental and Cultural Data Collection Study, 2003.

The number of species reported in the study indicates that the crustacean fauna is relatively poor compared to that of other regions, this may be verified with the richness of species reported, existing a dominance of shrimp of the *Macrobrachium* genus, with three species, the *M. carcinus* the most abundant during the collection period.

Among the crustaceans, three species of river shrimps (*M. carcinus, M. crenulatum* and *M. acanthurus*), are considered to be of special interest. The communities in the region, due to their size, use them as food. Although there is no tradition in the region the freshwater shrimp aquiculture is shown to be increasingly accepted as a viable economic activity.

3.3.2.4.4 Fish

Due to the difficulty of access to the Rio Indio Watershed, the diversity of the fish in its areas has not been deeply studied. During the inventory made by the environmental and cultural data collection study[53], a total of 1,638 individuals distributed in 35 species were identified. Out of the 35 species collected (Table 3-13); the species with greatest representation were *Sicydium sp.* with 325 individuals (19.8 % out of the total number), *Bryconamericus emperador* with 236 individuals (14.4% out of the total number) and *Brachyrhaphis cascajalensis,* with 160 individuals (9.8% of the total collected).

When comparing the richness of the fish species with the preferred habitat for each one of them, a total of 35 species is found in this watershed, 22 species in the low areas, where the flow is slow, 17 species in the upper watershed and 19 species in the areas closer to the estuary (See Table No.2 in Annex 3). The results show that, in spite of the fact that more individuals are collected in some habitats; the fish richness is not greater there.

Out of the species recorded in the Rio Indio Watershed, 25 are considered to be of special interest (Table 3-14), due to the following reasons:

- 21 are species of interest as food;
- 2 are new species belonging to the Aplocheilidae (*Rivulus sp.*) and Characidae (*Roeboides sp.*) families.
- 1 rare species of the Gobiidae family (*Gobionellus sp.*) and
- 1 new record for the area of the Engraulidae family (*Anchoviella elongata*),

3.3.2.4.5 Amphibians and Reptiles

Always taking from the basis of the information from the study of the collection of environmental and cultural data[53], a total of 27 species of amphibious and 16 species of reptiles (See Table No. 3, Annex 3) are reported in the Rio Indio Watershed. The amphibious represent 38% and reptiles 15% of the population of amphibious and reptiles present in the Republic of Panama.

Table 3-13
Families, Genus, Species and Number of Individuals Collected
Rio Indio Watershed

Family	Genus	Species	Number of collected individuals
Aplocheilidae	*Rivulus*	*sp.*	61
Atherinidae	*Atherinella*	*chagresi*	79
Characidae	*Astyanax*	*aeneus*	82
Characidae	*Brycon*	*chagrensis*	3
Characidae	*Brycon*	*obscurus*	31
Characidae	*Bryconamericus*	*emperador*	236
Characidae	*Compsura*	*mitoptera*	25
Characidae	*Gephyrocharax*	*intermedius*	3
Characidae	*Hyphessobrycon*	*panamensis*	60
Characidae	*Roeboides*	*guatemalensis*	20
Characidae	*Roeboides*	*sp. nov.*	2
Cichlidae	*Aequidens*	*coeruleopunctatus*	70
Cichlidae	*Vieja*	*maculicauda*	5
Eleotridae	*Eleotris*	*amblyopsis*	4
Eleotridae	*Eleotris*	*pisonis*	36
Eleotridae	*Gobiomorus*	*dormitor*	13
Gobiidae	*Awaous*	*banana*	2
Gobiidae	*Gobionellus*	*sp.*	1
Gobiidae	*Sicydium*	*altum*	325
Haemulidae	*Pomadasys*	*crocro*	3
Lebiasinidae	*Piabucina*	*panamensis*	9
Loricariidae	*Leptoancistrus*	*canensis*	53
Loricariidae	*Rineloricaria*	*uracantha*	3
Mugilidae	*Agonostomus*	*monticola*	32
Pimelodidae	*Rhamdia*	*quelen*	3
Pimelodidae	*Rhamdia*	*laticauda*	3
Poeciliidae	*Brachyrhaphis*	*cascajalensis*	160
Poeciliidae	*Brachyrhaphis*	*episcopi*	3
Poeciliidae	*Brachyrhaphis*	*roswithae*	118
Poeciliidae	*Poecilia*	*gillii*	70
Rhamphichthyidae	*Brachyhypopomus*	*occidentalis*	21
Synbranchidae	*Synbranchus*	*marmoratus*	3
Syngnathidae	*Microphis*	*brachyurus*	7
Syngnathidae	*Pseudophallus*	*mindii*	2
Trichomycteridae	*Trichomycterus*	*striatus*	90
TOTAL			**1638**

Source: LBI Consortium, Environmental and Cultural Data Collection Study,2003.

Twelve species of amphibians and three of reptiles were found in all the sites under study in the watershed, and it is possible to assert they are the most common species. They include: cane toad *Bufo marinus*, South American toad *Bufo typhonius*, Tink frog *Eleutherodactylus diastema*, three neotropical frogs (*Eleutherodactylus fitzingeri*, *E. taeniatus* and *E. ridens*), two glass frogs (*Hyalinobatrachium fleischmanni* y *H. pulveratum*), white-lipped frog *Leptodactylus labialis*, smokey jungle frog *Leptodactylus pentadactylus*, Tungara frog *Physalaemus pustulosus*,

neotropical tree frog *Smilisca sila*, basilisk *Basiliscus basiliscus*, lancehead *Bothrops asper*, and green lizard *Iguana iguana*. However, only the *Bufo marinus*, *Eleutherodactylus diastema* and *Physalaemus pustulosus* are considered to be the most common species in all sites.

Table 3-14
List of Special Interest Species in the Rio Indio Watershed

Family	Genus	Species	Remarks
Aplocheilidae	*Rivulus*	*sp.*	New undetermined species
Characidae	*Roeboides*	*sp. Nov.*	New species to be determined
Cichlidae	*Aequidens*	*coeruleopunctatus*	Important as food
Mugilidae	*Agonostomus*	*monticola*	Important as food
Loricariidae	*Ancistrus*	*chagresi*	Important as food
Gobiidae	*Awaous*	*banana*	Important as food
Rhamphichthyidae	*Brachyhypopomus*	*occidentales*	Important as food
Characidae	*Brycon*	*chagrensis*	Important as food
Characidae	*Brycon*	*obscurus*	Important as food
Characidae	*Brycon*	*sp.*	Important as food
Characidae	*Bryconamericus*	*emperador*	Important as food
Carangidae	*Caranx*	*latus*	Important as food
Eleotridae	*Eleotris*	*amblyopsis*	Important as food
Eleotridae	*Eleotris*	*pisonis*	Important as food
Eleotridae	*Gobiomorus*	*dormitor*	Important as food
Mugilidae	*Joturus*	*pichardi*	Important as food
Lebiasinidae	*Piabucina*	*panamensis*	Important as food
Poeciliidae	*Poecilia*	*gillii*	Important as food
Haemulidae	*Pomadasys*	*crocro*	Important as food
Pimelodidae	*Rhamdia*	*quelen*	Important as food
Gobiidae	*Sicydium*	*altum*	Important as food.
Synbranchidae	*Synbranchus*	*marmoratus*	Important as food
Cichlidae	*Vieja*	*maculicauda*	Important as food
Engraulidae	*Anchoviella*	*elongata*	New report for the area
Gobiidae	*Gobionellus*	*sp.*	Rare

Source: LBI Consortium, Environmental and Cultural Data Collection Study,2003.

Among the amphibians, twelve species are considered to be of special interest due to the reasons that follow: two species are endemic (see table No. 4, Annex 3); four species may be potentially used as food (*Bufo marinus, Leptodactylus insularum, L. pentadactylus and Rana vaillanti*); and six species have significance as ecological indicators of environmental quality, among them, the glass frogs of the Centrolenidae family, such as: *Centronele ilex, C. prosoblepon, Cochranella albomaculata, C. granulosa, C. spinosa, Hyalinobatrachium pulveratum and H. vireovittatum.*

On the other hand, among reptiles, seven species may be mentioned that can be considered of special interest due to several reasons. Two species (*Caiman crocodrilus and Iguana iguana*) are

protected by Panamanian laws; one species; basilisk (*Basiliscus basiliscus*), is used as food; and four species represent danger to man. The latter are the poisonous serpents species of the Elapidae and Viperidae family: *Bothrops asper* (lancehead), *Lachesis stenophrys* (Central American bushmaster), *Micrurus stewarti* (bicolor coral snake) and *M. mipartitus* (bicolor color snake).

3.3.2.4.6 Birds

In the assessment of the avifauna of the sub-basin, 237 bird species were recorded[53]; i.e., the birds of this basin represent close to 25% of the species reported in Panama. The total of these species are distributed in 44 families and 13 orders.

The bird families with greatest species representation correspond to Tyrannidae with 39 species, Thraupidae with 23 species, Trochilidae with 17 species, Parulidae with 15. Ten species protected under the Panamanian law were reported in the area under study. Among these species, are large birds like the great tinamou (*Tinamus major*), little tinamou (*Crypturellus soui*), grey headed Chachalaca (*Ortalis cinereiceps*); black guan (*Chamaepetes unicolor*); two pigeons, scaled pigeon (*Columba speciosa*), short-billed pigeon (*Columba nigrirostris)* and the yellow-crowned parrot (*Amazona ochrocephala*).

The most abundant species corresponded to rufous breasted hermit (*Glaucis hirsuta*), long-tailed hermit (*Phaethornis superciliosus*), green hermit (*Phaethornis guy*), wedge-billed woodcreeper (*Glyphorynchus spirurus*), cocoa woodcreeper (Glyphorhynchus susurrans), ochre-bellied flycatcher (*Mionectes olegineus*), olivaceous flycatcher (*Mionectes olivaceus*), brownish flycatcher (*Cnipodectes subbrunneus),* Pacific flatbill (*Rhynchocyclus olivaceus*), golden-collared manakin (*Manacus vitellinus*), blue-crowned manakin (*Pipra coronata*) and tangara.

In relation to the migratory species, 26 species were reported; the most abundant ones in the area were chestnut-sided warbler (*Dendroica pensylvanica*), bay-breasted warbler (*Dendroica castanea*), Tennessee warbler (*Vermivora peregrina*), Swainson's thrush (*Catharus ustulatus*), northern water thrush (*Seiurus noveboracensis*) and red-eyed vireo (*Vireo olivaceo*) (See table No. 5, Annex 3).

Among the birds, ten wild species are protected by the law, and four are rare species. The migratory bird species recorded are also considered to be of special interest since they are subject to international treaties and conventions to ensure their survival since they require a large geographical extension to complete their life cycles.

3.3.2.4.7 Mammals

In the Rio Indio watershed, 49 species of mammals were recorded[53]; among them, one marsupial, 3 xenarthros (armadillo, ant bears and sloths), 24 bats, 2 primates, 12 rodents, one rabbit, 4 carnivores, one peccary and one deer. The largest number of species was obtained from the group of bats, 22 of which correspond to the Phyllostomidae family. The communities with more species were Rio Indio Nacimiento and La Mina.

Out of the 22 species of Phyllostomidae, most correspond to the trophic group of frugivorous and the minority to insectivores. The second group of mammals better represented in Rio Indio were the rodents, being the squirrels and mice represented by three species. Out of the carnivores, four species were recorded, the Mustelidae family including the river otter (*Lutra longicaudis*) and the Amazonian skunk (*Conepatus semistriatus*). The largest mammals in Rio Indio were ocelot (*Leopardus pardalis*), capybara (*Hydrochaeris hydrochaeris*), collared peccary (*Tayassu tajacu*) and white-tailed deer (*Odocoileus virginianus*). The rest of the mammals in the region are relatively smaller (less than 12 kg.), whit the paca (*Agouti paca*) being one of the largest.

Out of the 49 species of mammals documented in this study, 18 are included in the categories of special interest species (see Table No. 7, Annex 3), mainly because they are considered to be endangered, because they are protected by the ANAM, or because they are considered rare.

3.4 Socioeconomic Aspects of the Rio Indio Watershed

The information on the prevailing socioeconomic conditions of the Rio Indio watershed comes mainly from the Socioeconomic Data Collection Study[77]. During this effort, information was obtained from the Population and Housing National Census and the Agricultural and Livestock Census, from LANDSAT satellite images, aerial photographs, cartographic information of the ACP as well as information from different ministries (MINSA, MOP, MEDUC, and MIDA). Said information was supplemented with additional field surveys.

This information made it possible to adequately establish, for the purposes of the environmental analysis, the characteristics of the population inhabiting the region of the Rio Indio Watershed and its adjacent area. Special emphasis has been given to aspects, which will enable the assessment of the vulnerability of the population to the activities associated with the development of one or more water options which could be selected for execution.

It is important to point out that in general terms, the Rio Indio Watershed, as it happens in the rest of the ROCC, is an extremely poor region with an average income representing less than the third part of the national average, with very little social infrastructure and services. Economically, the region is not self sufficient and the regional GDP represents less than half of the total income, which is subsidized through transfers and remittances from abroad. Therefore, life expectancy and other indicators of the quality of life are low, and the population, particularly young women, tend to migrate to urban centers in search of better living conditions.

3.4.1 Characteristics of the Population

The Rio Indio watershed covers approximately the third part of the territory of eight departments, belonging to the Provinces of Cocle (three departments), Colon (one department) and Panama (four departments). In the area of the watershed, 7,641 people were registered in the 2000 Census, in a total of 135 populated communities.

3.4.1.1 Demography

According to the information on the population and housing census of the year 2000, the Rio Indio Watershed has a population density of 20 inhab./km2, representing the watershed with highest population density within the ROCC. Among the departments constituting this area, the one with highest population density is that of El Valle (40 inhab./km2), followed by those of La Encantada (31 inhab./km2) and Ciri de los Sotos (22 inhab./km2). However, for the purpose of comparison, it is important to point out that the national population density is of 38 inhab./km^2, in the Province of Panama is of 116 inhab./km^2, in Colon 42 inhab./km^2 and in Cocle (41 inhab./Km^2).

In the Rio Indio sub-basin, more than half (59%) of the populated areas have less than 50 inhabitants; where only 25% of the population of the area live. On the other hand, it is also important to point out that 45% of the Rio Indio residents live in communities of 100 inhabitants and more, which indicates that the Rio Indio watershed has the second largest concentration of population in the Western Region, after Cocle Del Norte.

3.4.1.1.1 Population Growth

The comparison of the population data from the 2000 census with the 1960 census suggests that the population, in the watershed, tripled during these 40 years, since the 1960 census reported a total of 2,172 inhabitants for the same area. However, this growth has not been uniform during

this period, and it shows a greater population increase in the 60's and 80's; a little less in the 70's, and it reached its lowest level in the 90's. In the last reported decade (1990-2000), the growth rate is of only 0.1%, much lower than the total growth for the country, which reached a 2% annual rate in the same decade.

The fertility rate in the Rio Indio watershed (6.4 children per woman) is more than double the national average (3 children per women). Infant mortality is also high (42 per thousand live births) in comparison to the national mean (23 per thousand) and even when compared with the average for all the ROCC (34 per thousand). On the other hand, when comparing general mortality for the year 2000 with 1990, there is a significant increase in Life Expectancy at birth, which varies from 65 to 68.5 years; therefore, there was a gain of a little over 3 years of life in a 10 year period. However, it continues to be below the national average of 74 years of age.

When natural population growth for Rio Indio (birth minus deaths) at 29 per 1,000 inhabitants (2.9%), is compared to the net growth (0.1%), a differential is found which can only be explained by the existence of a high migratory flow towards other regions of the country. This phenomenon explains the negative growth observed in three of the departments, with significant territories within the watershed, in the 1990-2000 decade. These departments are: La Encantada (-2.9%), El Cacao (-5.1%) and Ciri Grande (-0.3%).

There are also internal migratory flows. According to the 2000 Census, the percentage of people born in a district different from that of registration ranges between 29% in Chagres to 9% in Penonome. Therefore, Donoso (26%), Anton (22%) and Chagres, appear to be the largest receptors of foreign population, being this incidence lower in Capira, La Pintada and Penonome.

In brief, it is possible to say that in the Rio Indio watershed, in the districts of Anton and Penonome, there is a negative migratory balance (-18%), while in Donoso, Chagres and Capira, the number of people entering and leaving the district are set off, yielding a very low net migratory balance.

3.4.1.1.2 Population Composition

In the Rio Indio watershed, the male to female ratio is 1.2 (120 males per 100 females), the highest in all the ROCC, which suggests that most migrants are women moving to urban areas where they work mainly as maids. On the other hand, the age structure in Rio Indio is similar to other areas of the ROCC (45% under 15 years of age), but shows a higher proportion of youth than the national average (32% under 15 years of age).

3.4.1.1.3 Education and Schooling

The main educational characteristics indicate an elementary educational level, with high school dropout rates.

a) *Literacy.* The illiteracy rate in the Rio Indio watershed is of 10%, being the Province of Cocle the one with the lowest levels (4 to 6% of illiteracy rate), and the District of Capira, with the highest rate (12 to 14%). These results reflect that formal education does not exceed 5 years.

b) *Instruction Level.* Less than 4% of the Rio Indio population attended high school, and none attended higher education.

c) *School attendance.* According to the 2001 survey, school absenteeism is greater in Rio Indio (37% of absenteeism). In the population between 6-15 years of age, a fifth of the school age population does not attend school.

3.4.1.1.4 Economic Characteristics

A total of 2,641 people of the population of Rio Indio, age 10 or over, were classified as economically active population (EAP). This reflects a high rate, (51%) of participation of the population in the economic activity, which is associated with the low unemployment rate (4.6%). Here follows a description of the type of activities, categories of employment and level of income generated by the EAP.

a) *Economic Activities.* The Rio Indio sub-basin is characterized by being one of the most dependent on agriculture and livestock (90% of the population employed). In general, the activities are similar to the rest of the ROCC. Men and women are mainly engaged in agricultural and cattle raising activities: between 84 and 92% of males and 33 to 41% of females. For men, all other activities lose significance, while this is not the case for females, who show a significant participation in manufacturing and housekeeping services.

b) *Category of employment.* In Rio Indio, the structure per category of workers' occupation is also similar to that observed in the rest of the ROCC. Most people (70% of males and 35% of females) are self-employed. For comparison purposes, at national level only 40% of males and 16% of women are self-employed.

c) *Income level.* The Rio Indio watershed bears the lowest income levels in all the ROCC. The monthly mean income of males is B. /68 and for women B. / 91. For comparison purposes, the median monthly income at national level is of B. /271 per month (B. /268 for males and B. /278 for females). At Provincial level, the median monthly income in Cocle is of B. /173, in Colon of B. /277 and in Panama B. /337. All are figures for the year 2000.

3.4.1.1.5 Housing Characteristics

According to the analysis of the information of the 2000 Census in the Rio Indio watershed, there were up to that date a total of 1,464 houses. The main characteristics are presented in the paragraphs below.

From the point of view of ownership and year of construction, 95% of the total numbers of private homes occupied are considered to be "owned" and approximately half of them were built between 1990 and 2000. On the other hand, from the point of view of the functional characteristics, it is possible to say that 6% of the houses do not have sanitation service, 32% do not have potable water, 72% have a dirt floor and 98% do not have electric power. In 93% of the houses, firewood is used for cooking, which explains the high rates of deforestation prevailing in the area. Finally, from the point of view of communications, 78% of the houses have radio, 9% television, but none has a home phone.

3.4.1.1.6 Future Evolution Perspective of the Population

If no engineering works enabling the use of the water resources of the Canal Watershed are executed, it is possible to assume that the population will follow the historical growth trend. In 20 years, the population of the Western Region would reach 46,000 inhabitants, 9,000 of which would live in the Rio Indio watershed (20%).

In regards to age structure, the 2020 population would be a little younger than at present, assuming an increase of the population in the economically active ages (15-64 years of age) and in those of 65 and over, which would slightly favor the economic development of the area. The child population of under 5 years of age, would reach almost 1,300 and of school age (5-14) would be a little less than 2,250. In regards to the economically active population (15 – 64), they would add up to a little over 4,800 people.

3.4.1.2 Epidemiology and Public Health

In the Rio Indio watershed, the existing physical structure related to medical care for the population consists of 16 low complexity health posts/stations, 14 of which were in operation. These facilities provide services to approximately 20% of the population who actually have access to these health facilities. The remaining 80% must look for health services in more distant sites. The least accessible area is Jobo, Rio Indio.

In regards to the general mortality rate, the lowest rate is in the District of Capira: 2.9/1,000 inhabitants in 1996 and 2.3/1,000 inhabitants in 2000. In the Department of Donoso, the reported mortality during this same period had a negative behavior, going from 2.4 to 2.9/1,000 inhabitants. In the latter district, the population of the department of Rio Indio is the one recording the highest vulnerability index, including deaths of children due to diarrhea and neonatal diseases associated to the deficient basic sanitation conditions.

The morbidity is constant in all area, characterized by preventable infectious diseases (diarrhea, parasitosis, pyodermitis and leishmaniasis) associated to poor hygiene habits in the community. The chronic disease with highest prevalence in all areas is high blood pressure.

Among the diseases produced by vectors, leishmaniasis is the most important one; constituting a public health problem, which seems to increase in this watershed, which appears to be the reservoir's natural habitat.

3.4.2 Characteristics of the Economic Activity in the Watershed

The total economic activity of the watershed amounts to approximately B/. 4.96 million; out of this, B/.1.03 millions correspond to that generated in goods and services within the region and the remaining one outside the basin. The region receives a high level of external transfers: 52.3% of the total consumption value. In fact, the region is not self-sufficient since it receives in transfers the equivalent to two and a half time its GDP. The per capita income is of B/. 649.00 per year and the average income corresponds to B/. 54.00 a month.

Agriculture and livestock represent 64.5% of the economic production, while services contribute 33% of the total internal production of the Watershed. Within agriculture and livestock, agriculture has much greater economic importance than livestock. Although the latter occupies 39% of the watershed surface area, it only contributes 20.5% of the basin GDP.

Within agricultural activities, the ones which contribute more to the watershed GDP are permanent crops and subsistence agriculture, with vegetables representing only 0.2% of the total GDP. Grains (rice, corn) and tubers contribute with 33% of the local GDP. The most significant area and the one that generates the monetary surplus for the exchange with the outside is permanent agriculture, being the main crops coffee, plantains, bananas, oranges, and pixbae, among others. This activity is undoubtedly the most efficient one since it represents 36% of the regional GDP, while it only uses 9% of the total surface.

3.4.2.1 Land Use

The main land uses (Table 3.-15) correspond to the description of the agricultural and cattle raising activities previously mentioned, with the dominant categories being underbrush and stubble, pasture for extensive cattle raising activities, and intervened / secondary forests.

Table 3-15
Land Use in the Area under Study per Category

CATEGORY	1998 – 2000	
	Surface (ha)	**%**
Dense forest with little intervention of high lands	90.10	**0.23**
Dense forest with little intervention, low lands	1,104.67	**2.86**
Secondary /Intervened Forest	10,959.93	**28.35**
Underbrush and Stubble	16,244.54	**42.02**
Livestock area	9,288.89	**24.03**
Annual crops	926.33	**2.40**
Water	45.54	**0.12**
Total	38,660.00	**100.00**

Source: URS-Dames & Moore, SIG.

The Rio Indio watereshed contains a large extension of underbrush and stubble; crops of mixed/shifting agriculture use 1.77% of the surface area. The secondary /intervened forest areas are located mainly in the "Corregimiento" of Rio Indio. The Rio Indio watershed is the one presenting the least dense forests both for high as well as low lands (2.985) in the ROCC. The few relicts tend to concentrate in the central and southeast sectors of the watershed, although there are some small areas of dense lowlands forests in the drainage area. The areas occupied by gallery forests represent 0.8%.

The projected trend based on the results obtained in the socioeconomic data collection study is that in the future, secondary forests will be reduced even more as they are used for pastures, particularly in the "corregimientos" of Santa Rosa and Rio Indio.

It is also possible to assert that if no water alternative is executed, the land is expected to be used more intensely for mining activity. At present, there are 27 areas under the category Mining Applications and Concessions, some of them located fully within the watershed. The areas classified under the category Applications and Concessions of metal minerals in all the ROCC and immediately adjacent area, amount to a total of 280,167 hectares. Out of them, 12% are within the boundaries of the Rio Indio watershed.

3.4.2.2 Landholding Patterns

In the Rio Indio watershed there are 1,426 agricultural-livestock lands occupying 24,246 ha. Within the occupied surface area, most of the farms range between 20 to 50 ha, which occupy 36% of the above-mentioned surface area.

Although the land ownership situation in the Rio Indio watershed does not reach optimal level, there is a greater interest of farmers to legalize their land holdings when compared to other areas of the ROCC. Thus, of the total existing farms in the Rio Indio watershed, 33% of all farms are legally held with title deed or under possession rights. These production units represent 39% of the occupied lands, which have already been legalized.

3.4.2.3 Land Value

There are no land cadastral values within the basin since they are determined at the request of the interested parties. In the Rio Indio watershed, the land has a value of B/.200 per hectare for agricultural lands. Among the identified values, there are some ranging between B/.30 and B/.50 per hectare corresponding to potential use for forest or forest harvests which are located at less than 5 km from permanent and semi-permanent roads. The values of land for agriculture and livestock range between the following categories: B/.50.00 – 80.00 from B/. 100.00 to 120.00/ha and from B/.100.00 to 200.00/ha.

Table No. 3-16
Distribution of Land Value in the Rio Indio Watershed

Value Category	Indio	%
Low	12288.9	31.8
Medium	3840.3	9.9
Relatively high	20085.0	52.0
High values	2421.1	6.3
Total	**38635.2**	**100**

Source: Geographical Information System, URS-Dames & Moore

The higher values are located to the East of the study area in the "Corregimientos" of Santa Rosa and Ciri Grande. They are lands with greater agricultural - livestock potential and are located at approximately one kilometer or less from the river.

The lands with medium value correspond to spots or isolated stretches of land with potential use for cattle raising, located at one kilometer or less from the rivers or areas with potential for combined agricultural – livestock use which are at five kilometers or less from the rivers in the "Corregimientos" of Ciri Grande and La Encantada.

The lands with higher value are outside of the area and are concentrated in the proximities of the communities close to the upgraded road network. They are in La Pintada, El Valle and El Cacao. Also, close to Rio Indio, to the east of Santa Rosa and in the "Corregimientos"of Rio Indio and Salud.

In the Rio Indio watershed, there are relatively high values (52%) and low (34.18%). The first ones are found in the central portion of the watershed (Santa Rosa and Rio Indio), while the second ones are to the north and south.

3.4.3 Community and Public Service Infrastructure

The study for the compilation of socioeconomic data made it possible to know the type, quality and economic significance of the existing infrastructure in the Western Region, including the Rio Indio basin. This is briefly described in nine categories indicated below:

- **Roads and Bridges**: The information obtained indicates that in the Rio Indio watershed there are 521 lineal kilometers of roads. Out of this, 92% correspond to horse tracks, 5% to dry weather roads, and the remaining 3% to permanent roads. In regards to bridges, there are a total of 7 within the basin.

- **Electric Power**: In the Rio Indio watershed, no significant electrical power infrastructures were detected. However, according to the inventory in the region there are power lines and 32 power line poles.

- **Potable Water**: There are two water intakes for the supply of surface water in the "Corregimientos" of Ciri de los Sotos and Capira. The other water intakes for water supply are excavated wells, with a depth ranging from one to seven. There were a total of 27 structures for water storage for human consumption in Rio Indio (23 tanks and 4 non-specified structures). Eleven rural aqueducts, using PVC tubing with two inches in diameter, operated by MINSA were also identified.

- **Wastewater Management:** There are no sewage networks, plants for the treatment of wastewater or community septic tanks. According to the records of the Ministry of Health in the region, there are eleven septic tanks recorded in the Rio Indio basin.

- **Communications:** According to the study for the compilation of socioeconomic data, there are six telecommunications elements in the Rio Indio Watershed, including four public telephones, one antenna, and one non-identified element. All this equipment uses solar paneling for the supply of the necessary electric power for its operation.

- **Schools:** In the Rio Indio basin, there are 34 schools documented. Among them, 22 have 3 or more classrooms, 8 have two classrooms and the others only one classroom. Most of them include primary school, up to sixth grade.

- **Health:** The health infrastructures involve the buildings operating as health posts/stations, health sub-centers, and health care centers. These infrastructures have already been described.

- **Other infrastructure:** This category groups other social infrastructures, such as government or municipal buildings (including police stations and fire stations), recreational and sports facilities, cemeteries, churches, dump sites, stands and bus stop.

  In regards to institutional infrastructures (state, municipal or local administrative offices), there are 38 facilities in the Rio Indio watershed. Among them, 7 are institutional structures, 8 recreational structures, 8 cemeteries and 15 churches.

3.5 Archeological Resources in the Rio Indio Watershed

Archaeologically, Panama is divided into three regions: The Grand Darien (lying mostly to the east of the ROCC, but including Rio Indio); The Grand Cocle (to the west of Rio Indio and encompassing the remainder of the project area; and Grand Chiriqui (to the west of the ROCC area). Although on the basis of current research, these culturally-defined areas correspond to the late phase of the pre-Colombian period, these areas are referred to in the following cultural context.

- ***Paleo-Indian Period.*** Considering the findings at sites such as Monte Verde in Chile, the presence of archaeological sites considered to be prior to 12-14 thousand years ago in Panama is now considered possible. Recent excavations in archaeological sites such as Nieto quarry and Cueva de los Vampiros, the latter in the Rio de Santas Marias water basin, documented the presence of groove points of buried ore deposits[69], which is considered to be a strong evidence in favor of this hypothesis. It is probable that there were populations living in Central Panama 7,000-10,000 years ago, who were small nomad groups, as suggested by the rock shelters available[24].

- ***Pre-ceramic Period (8000 – 2900 BC).*** A series of pre-ceramic sites have been excavated in Panama including rock shelters, open sites and a shell mound[23]. Rock shelter sites appear to have been used during all the pre-ceramic period. The findings at Cerro Mangote dating from 5,000-7,000 years ago show the significance of coastal resource in the pre-ceramic population diet[24].

- ***Early Ceramic Period 2900 BC – 500 BC.*** Monagrillo ceramics appear as of 2400 BC and maize is already in use by around 1500 BC[23]. The transition from pre-ceramic to ceramic in the Cocle region is found on sites such as Cueva de los Ladrones, Aguadulce Shelter, and Cueva de los Vampiros[23]. The diverse collection of fauna (e.g. deer, iguana, birds, fish and shellfish) found on sites of this period is evidence of a continued emphasis on various hunting and gathering practices.

- ***Middle Ceramic Period (500 BC – 750 AD).*** For the period from 300 BC – 500 AD, large permanent maize cultivating villages were established. These villages (e.g., Sitio Serra) of palm-walled thatched houses were occupied by maize cultivators who maintained family cemeteries within the village[23]. Flexed primary burials are typically found in such cemeteries.

- ***Late Ceramic Period (AD 750 – 1500).*** This period witness the consolidation of nucleated village settlements and the elaboration of burial practices. The latter includes the practice of urn burials in artificially constructed mounds. Ceramics began to show greater use of zoomorphic designs and much larger vessels were being constructed, some for use as burial urns. In the last few centuries before the Spanish arrived, nucleated villages persisted in the region but their number decreased. Urn and mound burials became commonplace and ceramic stylistic traditions became even more regionally differentiated. In central Panama, ceramic designs became very stylized with rectilinear designs and overprinted modeled decoration[23] (Table 10.1:271). By the time of conquest, most of the population was found along the coast and within the more fertile valleys.

Although it may not be considered an exhaustive inventory, the study for the compilation of environmental and cultural data reviewed 11 known sites in the ROCC and identified 72 additional ones (See Figure 3-9). With this contribution, the current distribution of known sites in the ROCC is more biased towards riparian locations. Specifically, in the Rio Indio water basin, there exist several significant sites described below:

- **Uracillo / Pn-50.** It is a village reported by Stirling in 1951. This is one of the largest sites in the ROCC area and it has national and regional significance. It was occupied in the Middle Ceramic Period and achieved the height of development by AD 750 – 900. Stirling reported artificially modified terraces, which may contain graves, there are graves near the church, and there have been discoveries of gold artifacts by local residents. The site offers the opportunity to study an important regional center for the period, its position as an interior (frontier) lowland settlement, and its place in regional exchange networks.

- **Prehistoric Quarry / Cp-52**. This is another significant site in the basin where crypto-crystalline lithic material was obtained. A survey of this area and the surrounding region could yield valuable information since many Paleo-Indian and Pre-ceramic period artifacts are made from this raw material and additional quarry sites (e.g. Cp-62) of significant importance may be discovered. This site also has national and regional significance with regard to early technologies and raw material usage in Central American and the broader Caribbean area.

- **Hamlet / Cp-41**. This is a site with moderate potential in the Rio Indio basin including several rock-shelters and a hamlet. The hamlet (Cp-41) dates from ca. AD 550 – 750 and contains documented burials. Additional excavations at this site could yield information on

burial practices and data on the increasing social complexity characteristic of this period. The immediately surrounding area may also contain valuable data on raw material sources.

- **Other Sites**. Other sites, mainly rock shelters include some with burials (Cp-44), some with petroglyphs (Cp-37 and Cp-43), and others with the potential to contain intact sealed deposits (e.g., C-35 and Cp-58). Future research potential includes recording of petroglyphs and the intensive excavation of Cp--58.

3.6 Tourist, Recreational and Scenic Values

As indicated above, the best use for the landscapes of the Rio Indio watershed include the production of good quality water and the use of the scenic, biodiversity and historical values within a program of sustainable development based in part in tourist activities. It is important to point out that there is high compatibility between these uses of forest ecosystems with fragile characteristics and the production of water with good quality which interests the ACP for the supply of water for the canal operations and potable water to urban centers.

3.6.1 Ecological Landscapes

In the Rio Indio watershed only two of the five ecological landscapes of the ROCC are represented. These bioclimatic zones are: tropical pre-montane wet forests and tropical wet forest landscapes.

- **Ecological Landscape of the tropical pre-montane wet forest type.** It occupies an elevation ranging between 600 to 1250 masl covering approximately 9% of the Rio Indio watershed. It occupies the southern and highest end of the sub-watershed. In this landscape, the riparian ecosystem has been destroyed in up to 95% of its total surface area and has been substituted by human settlements, horticulture and cattle raising activities.

- **Ecological Landscape of the Tropical Wet forest type.** This landscape is the most extensive and occupies the remaining 91.0% of the Watershed area. The remaining primary forests occupy only 1.43% of the original area. As in the previous category, the riparian forest ecosystem has been mostly destroyed.

The typical conditions of these landscapes make it possible to classify the Rio Indio watershed as a large water producer. However, most of the primary forests have been destroyed, including the fluvial corridors, which diminishes the current value of the area for potential tourist

development, unless a program for the recovery and upgrade of these values is implemented. To that end, the status of the three types of forest habitat previously described should be taken into account, the conditions of which are summarized below:

- the **lowland tropical evergreen broadleaved wet forest,** is in an extremely endangered situation, and needs immediate intervention if its recovery and conservation is sought;
- the **submontane tropical evergreen broadleaved wet forest** situation is considered to be vulnerable. When considering all the ROCC, it is important to point out that a significant part of this habitat is in the National Park *General de Division Omar Torrijos Herrera*;
- the **montane tropical evergreen broadleaved wet forest.** At the level of all the ROCC, this type of habitat is quite stable and protected by the National Park *General de Division Omar Torrijos Herrera*; however, in the Rio Indio basin there are only some endangered fragments left due to anthropic threats.

3.6.1.1 Degree of Habitat Fragmentation

The degree of habitat fragmentation is of great significance for the viability of those species which have limitations to move among the isolated remnants, in most cases due to vulnerability to their natural predators. It is also important because if there is an increase of other type of conditions at the edge, the internal remaining forest habitat loses its capacity to maintain the conditions necessary for the survival of several species. Apart from the fragment size, other factors significant for the wild life species include form, connection and/or proximity to the river ecosystem. The fragmented habitat deteriorates even more with the recurrent use of fire, hunting, deforestation, invasion of forest fragments by crops and pastures and the associated application of herbicides and other agrochemical products, the presence of roads and lanes, and with the contamination from domestic waste.

As it may be observed in the following table, in the Rio Indio watershed, only very small fragments of mature forest were identified (Table 3-17). These 1,391 ha are divided in 4,955 fragments, and there are no categories larger than 80 ha. In the case of secondary forests, the situation is less dramatic; however the number of small forest fragments is of concern. Above all, the presence of three larger fragments of 400 ha, with a total of 2,688 ha is of special importance.

Table No. 3-17
Forest Fragmentation in the Rio Indio Watershed

Size of Fragment in hectares	# of Fragments	
	Mature Forest	Secondary Forest
< 80	4,955	5,851
81 - 160		6
161 - 400		4
> 400		3

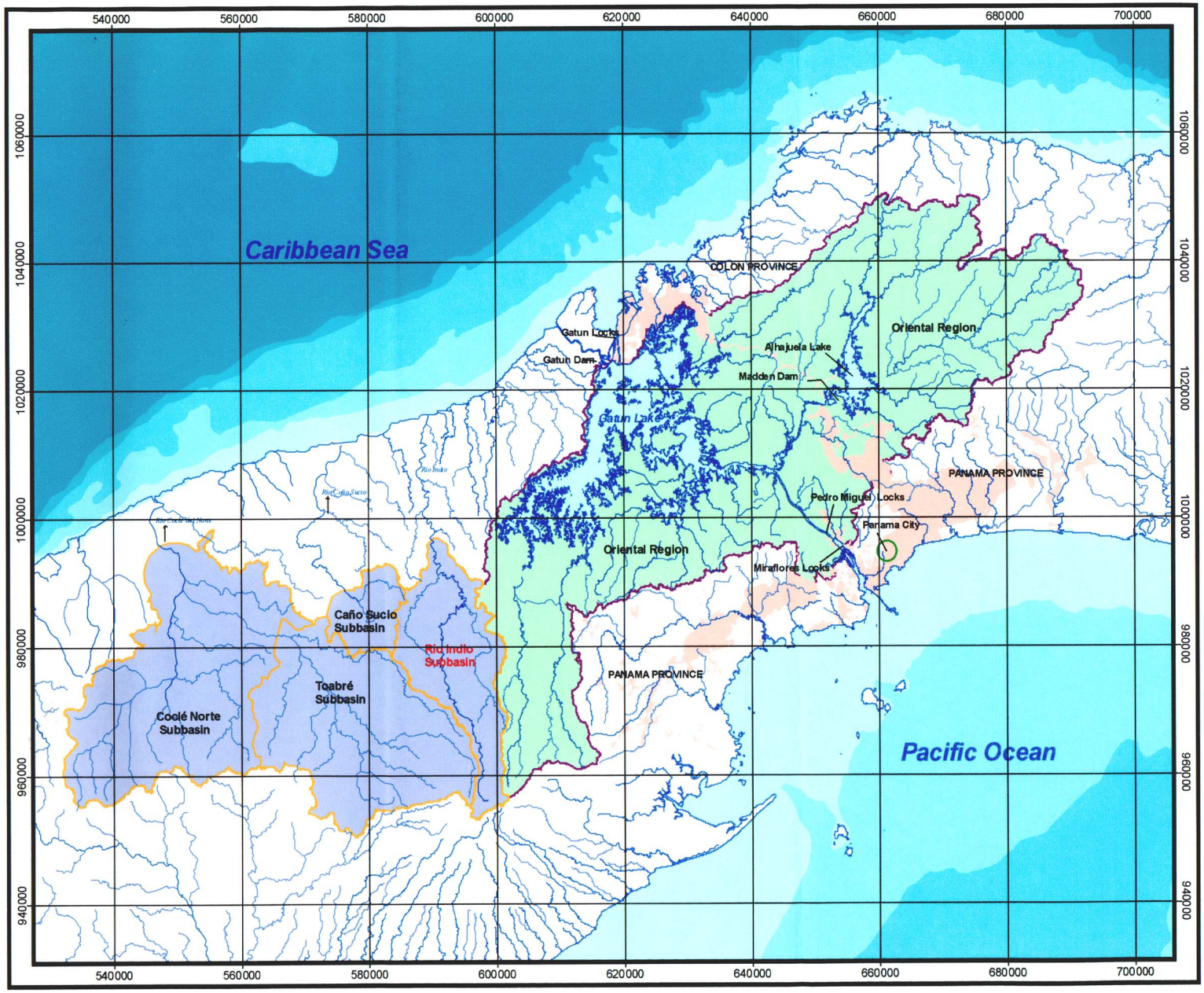
Source: URS, Study of Compilation of Socio-Economic Data, 2003.

3.6.1.2 Conservation and Connection Priorities

The greatest opportunity to influence the improvement of environmental quality and the conservation and recovery of wild life seems to be the connection between the National Park *General de Division Omar Torrijos Herrera* and the area of the Rio Indio Nacimiento[(53)]. In order to contribute to the restoration of the intervened areas and to foster biological connectivity, it is advisable to establish a recovery or reforestation program with native species which would extend from the National Park to the Rio Indio headwaters through biological corridors. The objective of this proposal is to contribute with alternatives to induce connectivity in this region of the country. The proposal of this biological corridor is accompanied by the conservation of the area of the Rio Indio Nacimiento at 1,000 masl.

This program should consider that secondary forests and some areas of underbrush and scrubland (six years of age or over), which may support the maintenance of biodiversity, the regulation of flow and the quality of water of the lotic ecosystems in all the territory of the sub-basin, if managed appropriately, protected, enriched, and if they serve as connection between the smaller fragments of primary forest. It is convenient to point out that apart from protecting, and in as much as possible creating a bumper area around each fragment, it is also essential to create and protect spatial connections between them so that there might be a functional continuity sustaining genetic diversity and biogeochemical cycles, such as that of water.

In this sense, the protection of the remaining trees close to the river ecosystems, and the rehabilitation of areas adjacent to them, constitute a clear priority for environmental upgrade. In this case, secondary forests must be protected and enriched, generating incentives to connect them to the different river environments, with emphasis on the ecologically most sensitive areas. The underbrush present the opportunity to start a reforestation process which must include the areas with slopes greater than 30°, through the use of indigenous and foreign species, depending on the degree of deterioration and degradation of the natural environments.



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

PANAMA CANAL BASIN

ACP PANAMA CANAL AUTORITHY (ACP)

LEGEND

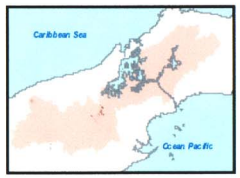
- Panama City
- Main Rivers
- Secondary Rivers
- Urban Areas
- Western Basin
- Oriental Basin

N W E S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

20 0 20
Kilometers

Regional Location



SCALE. 1:600,000

Figura N° 3-1

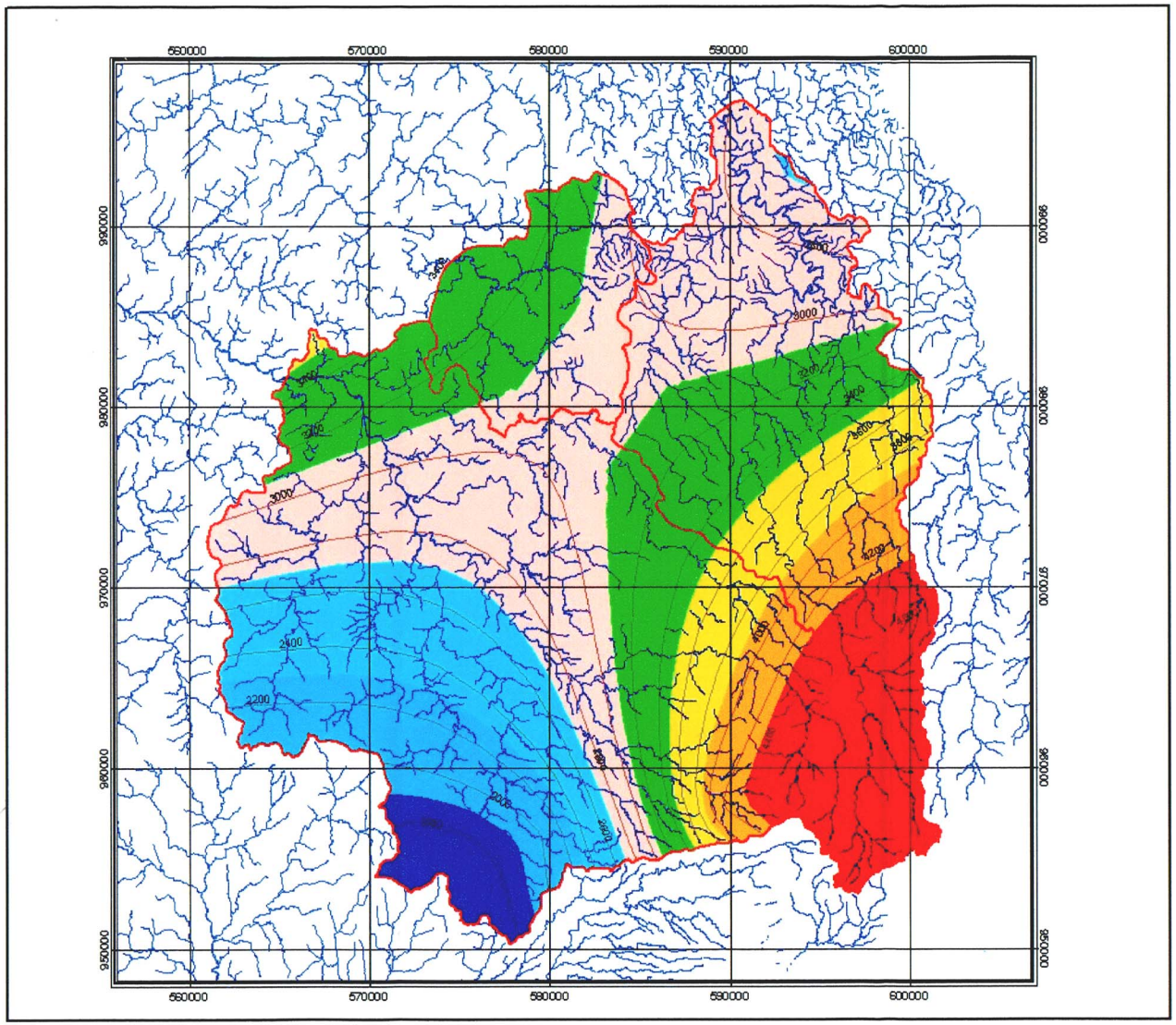


FIGURE 3-2
AVERAGE ANNUAL RAINFALL (mm)
IN THE OCCIDENTAL REGION

LEGEND

- Isolines
- Hidrographic System
- Subbasin Boundary

- 1500 - 1900 mm
- 1900 - 2300 mm
- 2300 - 2700 mm
- 2700 - 3100 mm
- 3100 - 3500 mm
- 3500 - 3900 mm
- 3900 - 4300 mm
- 4300 - 4700 mm

N
W E

Clark 1866 Spheroid
1927 North American Datum
UTM Zone 17

5 0 5 Km

SCALE 1:250,000

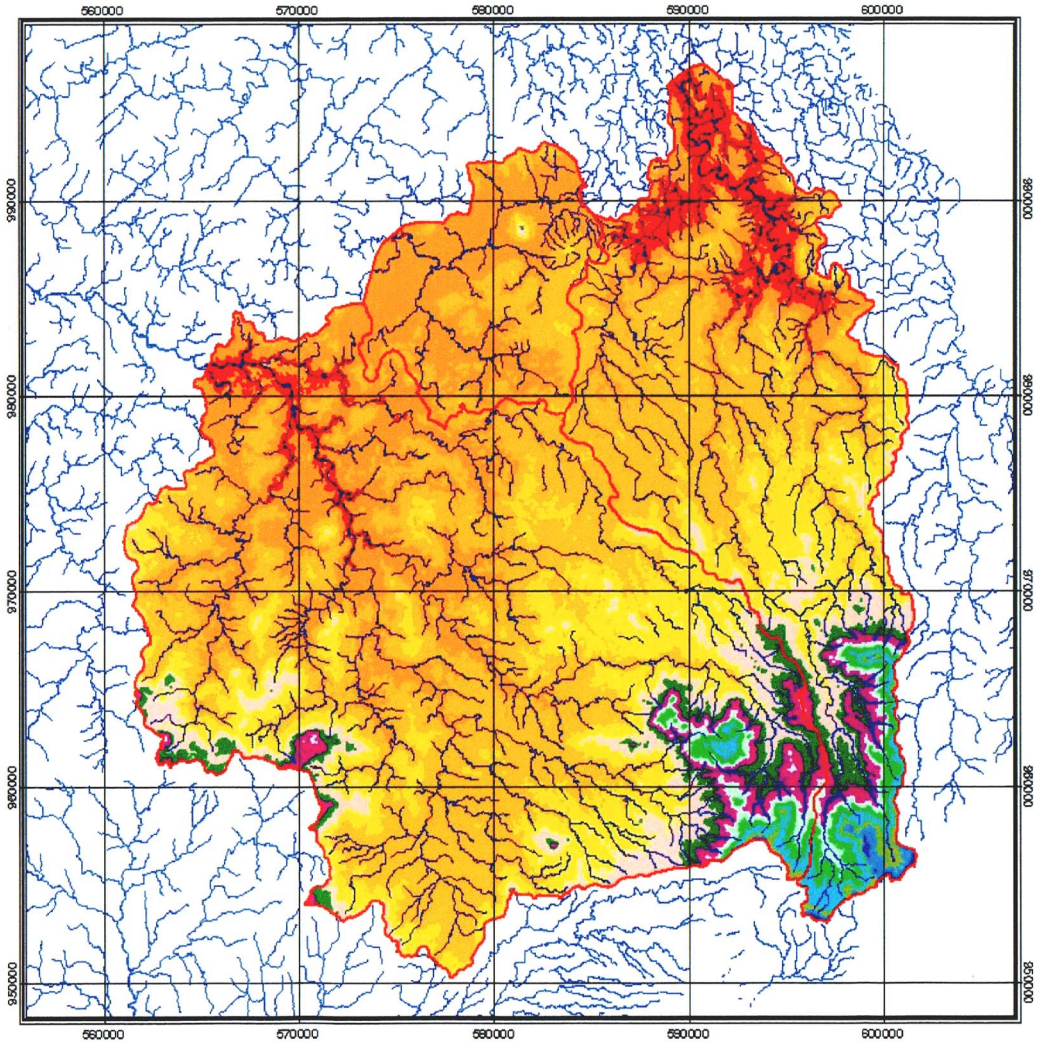


FIGURE 3-3
AVERAGE ANNUAL TEMPERATURE (°C)
IN THE OCCIDENTAL REGION

LEGEND

ISOLINES

SUBBASIN BOUNDARY

20.5 - 21.0 °C
21.0 - 21.5 °C
21.5 - 22.0 °C
22.0 - 22.5 °C
22.5 - 23.0 °C
23.0 - 23.5 °C
23.5 - 24.0 °C
24.0 - 24.5 °C
24.5 - 25.0 °C
25.0 -25.5 °C
25.5 - 26.0 °C
26.0 - 26.5 °C
26.5 - 27.0 °C

N
W E

Clark 1866 Spheroid
1927 North American Datum
UTM Zone 17

5 0 5 Km

ESCALA : 1:250,000

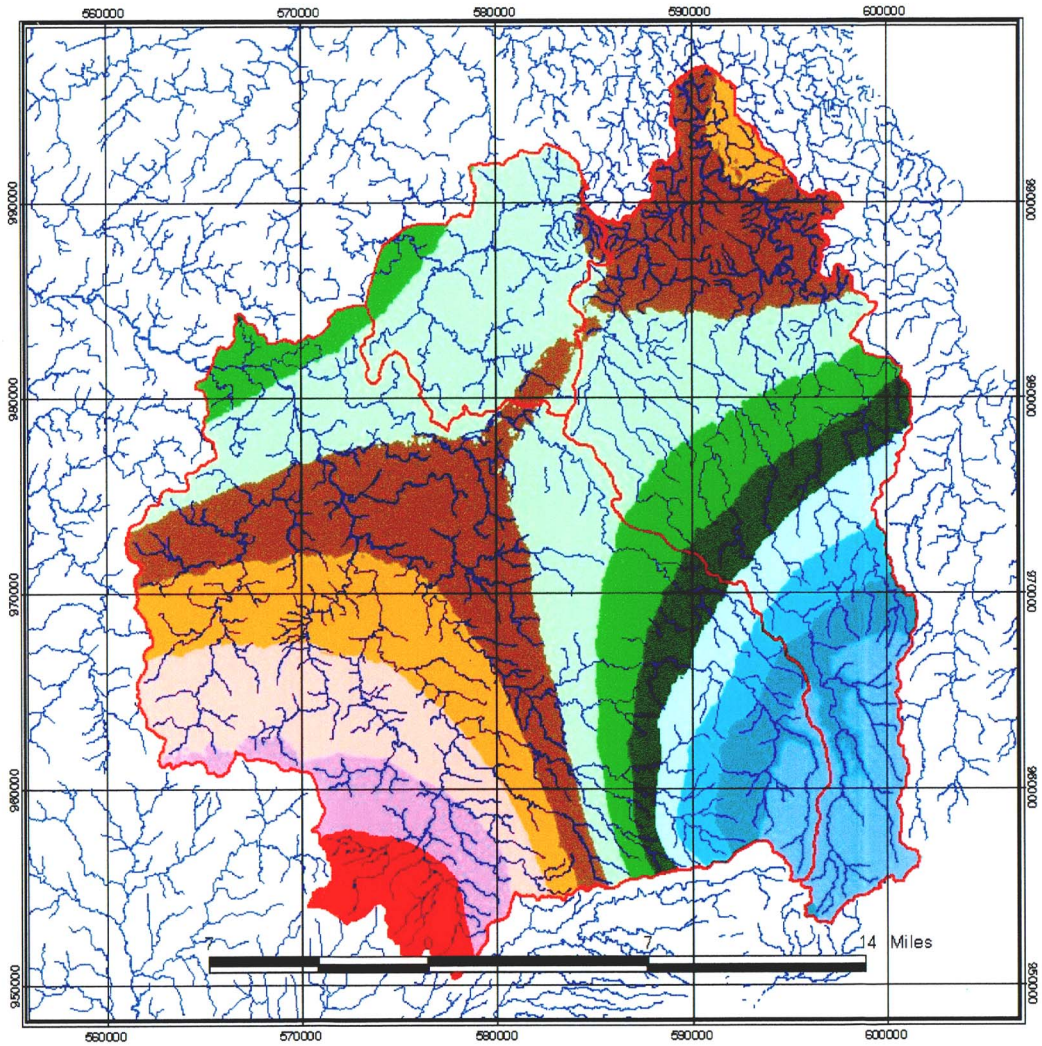


FIGURE 3.4
AVERAGE ANNUAL RUN OFF (mm)
IN THE OCCIDENTAL REGION

LEGEND

Hidrographic System

Subbasin Boundary

- 500 - 750
- 750 - 1000
- 1000 - 1250
- 1250 - 1500
- 1500 - 1750
- 1750 - 2000
- 2000 - 2250
- 2250 - 2500
- 2500 - 2750
- 2750 - 3000
- 3000 - 3250
- 3250 - 3500
- 3500 - 4000

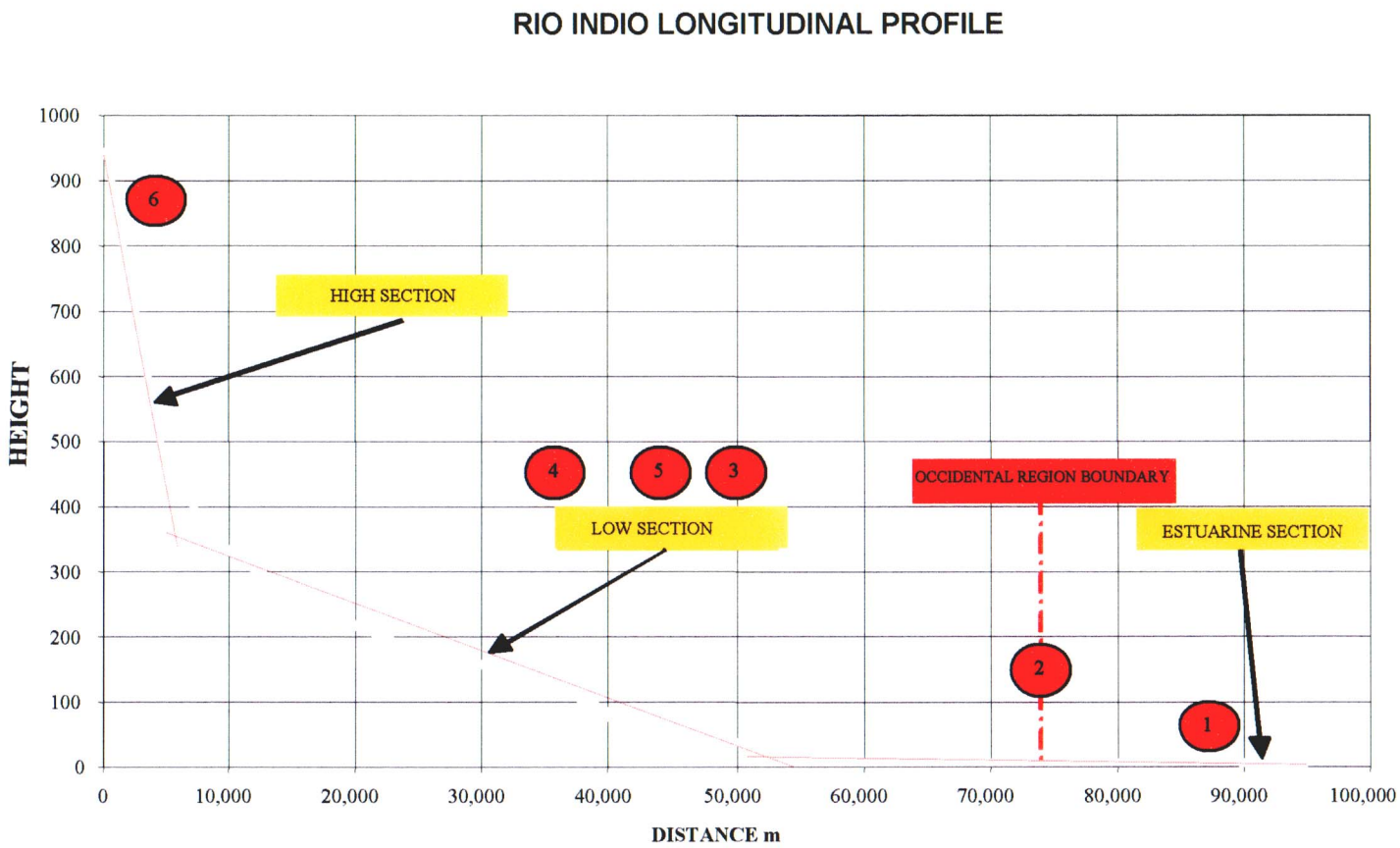
* Run Off Estimation in this image was determinated assuming all the study area covered by mature natural forest

N
W E

Clark 1866 Spheroid
1927 North American Datum
UTM Zone 17

5 0 5 Km

SCALE 1:250,000



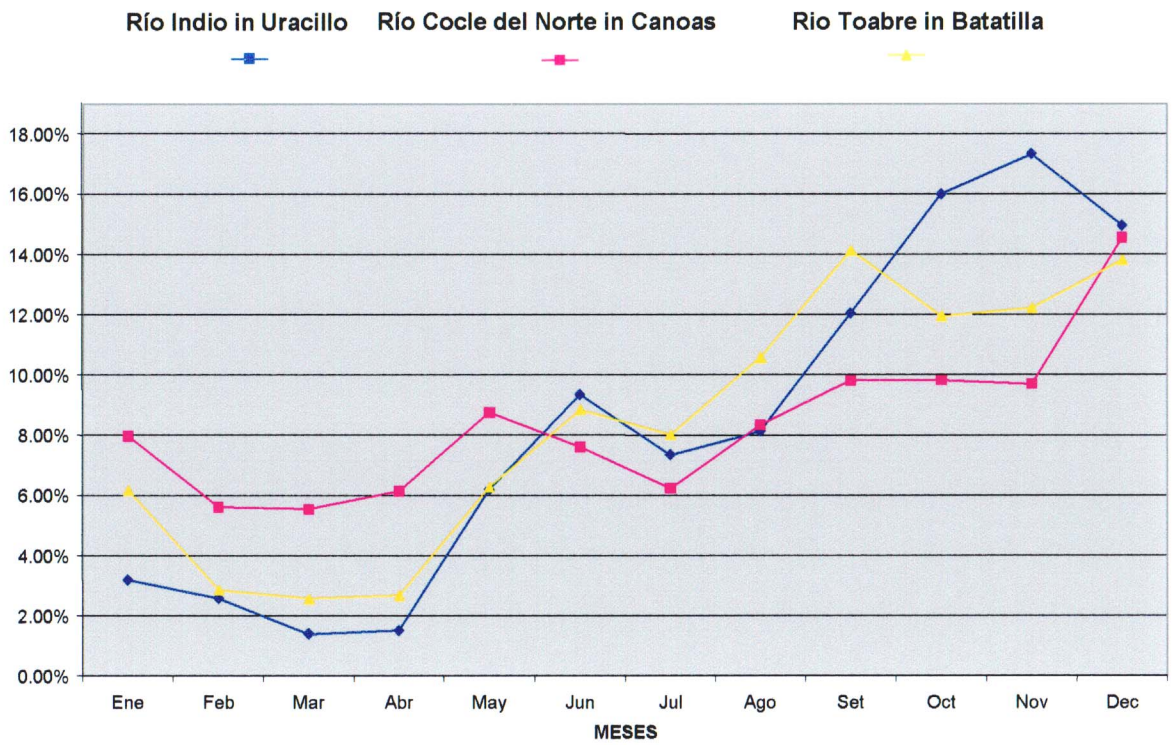
Environmental Evaluation of Water Resources Options for Indio, Caño Sucio and Toabre Rivers

URS

Figure 3-5

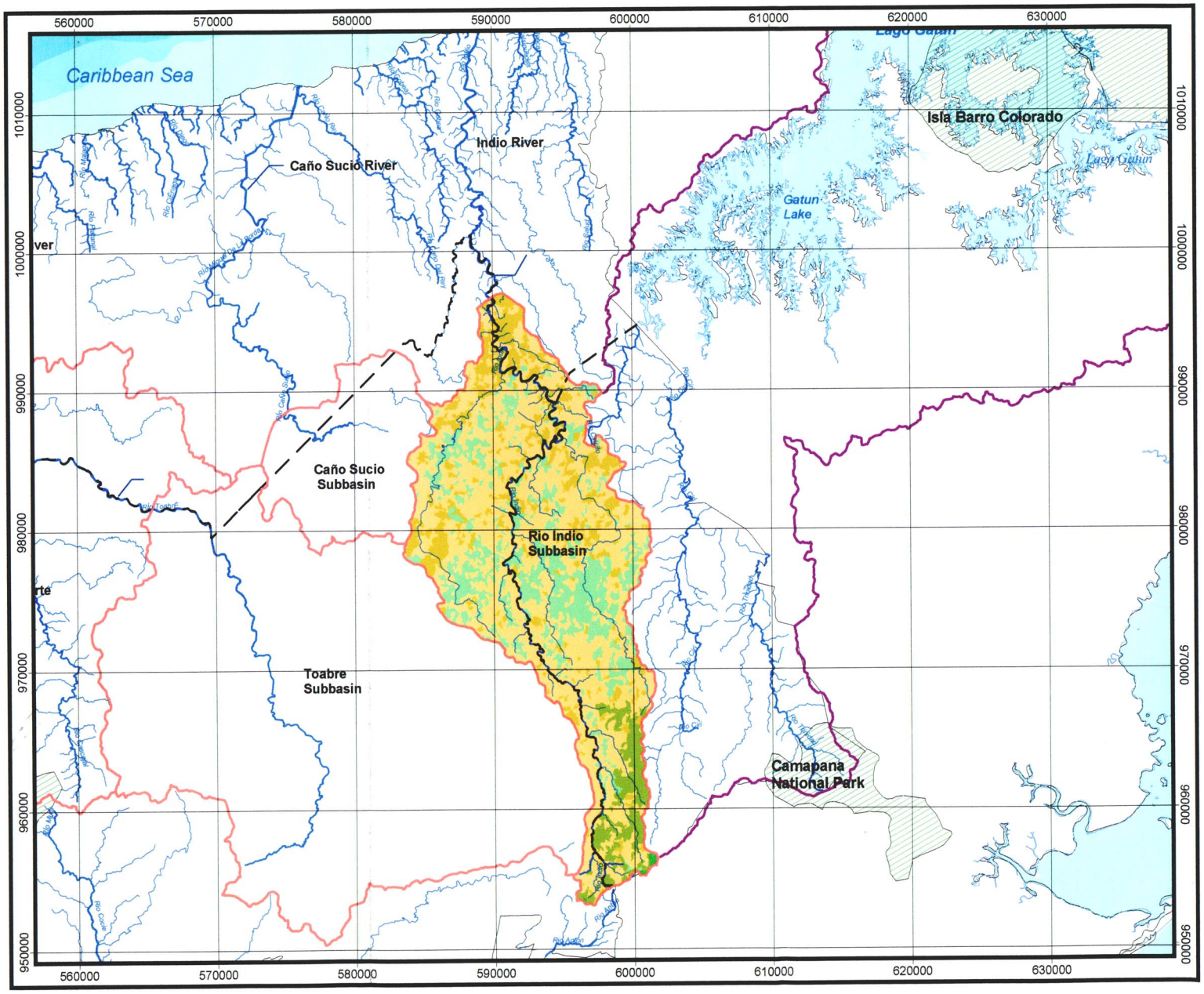
RIO INDIO LONGITUDINAL PROFILE

Figure 3-6: Seasonal Discharge in the ROCC



Average monthly discharge express in average annual percentaje

Environmental Evaluation of Water Resources Options for Indio, Caño Sucio and Toabre Rivers	URS	**Figure 3-6** **SEASONAL DISCHARGE IN THE ROCC**



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

VEGETATIVE COVERAGE RIO INDIO BASIN

ACP

PANAMA CANAL AUTORITHY (ACP)

LEGEND

- Towns
- Politic Division Boundary
- Main Rivers
- Secondary Rivers
- Oriental Region Boundary
- Occidental Region Boundary
- Protected Area
- Oriental Region

VEGETATIVE COVERAGE

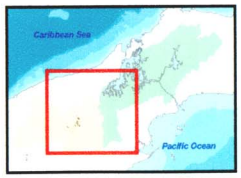
- Lowland tropical ombrophilous evergreen forest (< 500m)
- Montane tropical ombrophilous evergreen forest (> 1000 m)
- Submontane tropical ombrophilous evergreen forest (500 a 1000 m)
- Misty Forest
- Grassklabd or productive system with natural or spontaneous woody vegetation
- Stubble or productive system with natural or spontaneous woody vegetation

N W E S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

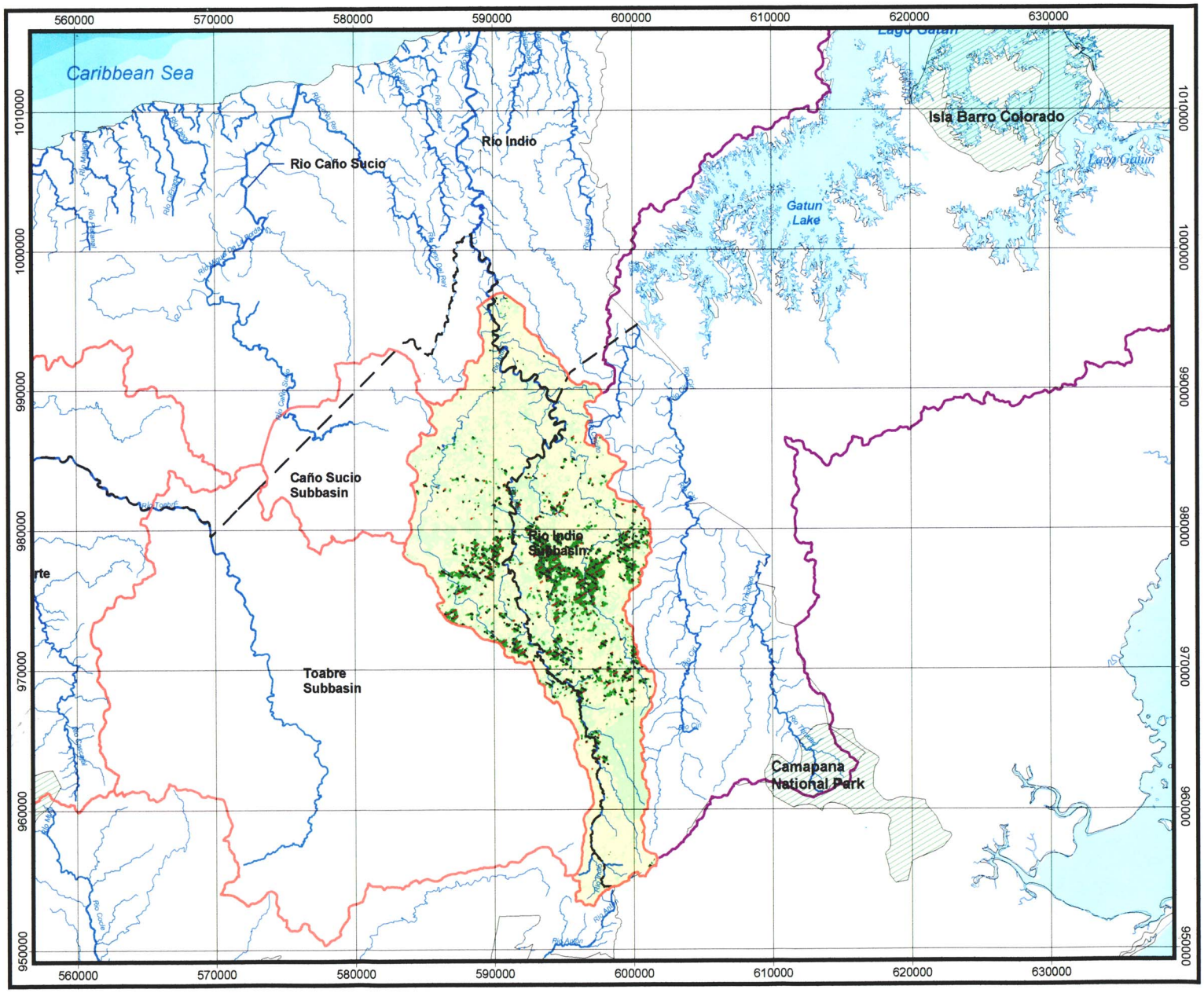
10 0 10Km

REGIONAL LOCATION



SCALE. 1:275,000

Figure N° 3-7



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

CHANGES IN LAND USE RIO INDIO BASIN

PANAMA CANAL AUTORITHY (ACP)

LEGEND

- Towns
- Politic Division Boundary
- Main Rivers
- Secondary Rivers
- Oriental Region Boundary
- Occidental Region Boundary
- Protected Area
- Oriental Region

Intervened Areas 1998-2000:

- Intervened Forest
- Other Uses

Forested Areas1983-1986:

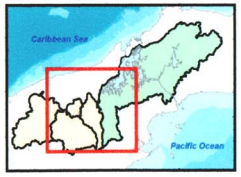
- Dense forest with little intervention, low hands
- Secondary/Intervened Forest
- Other Uses

N W E S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

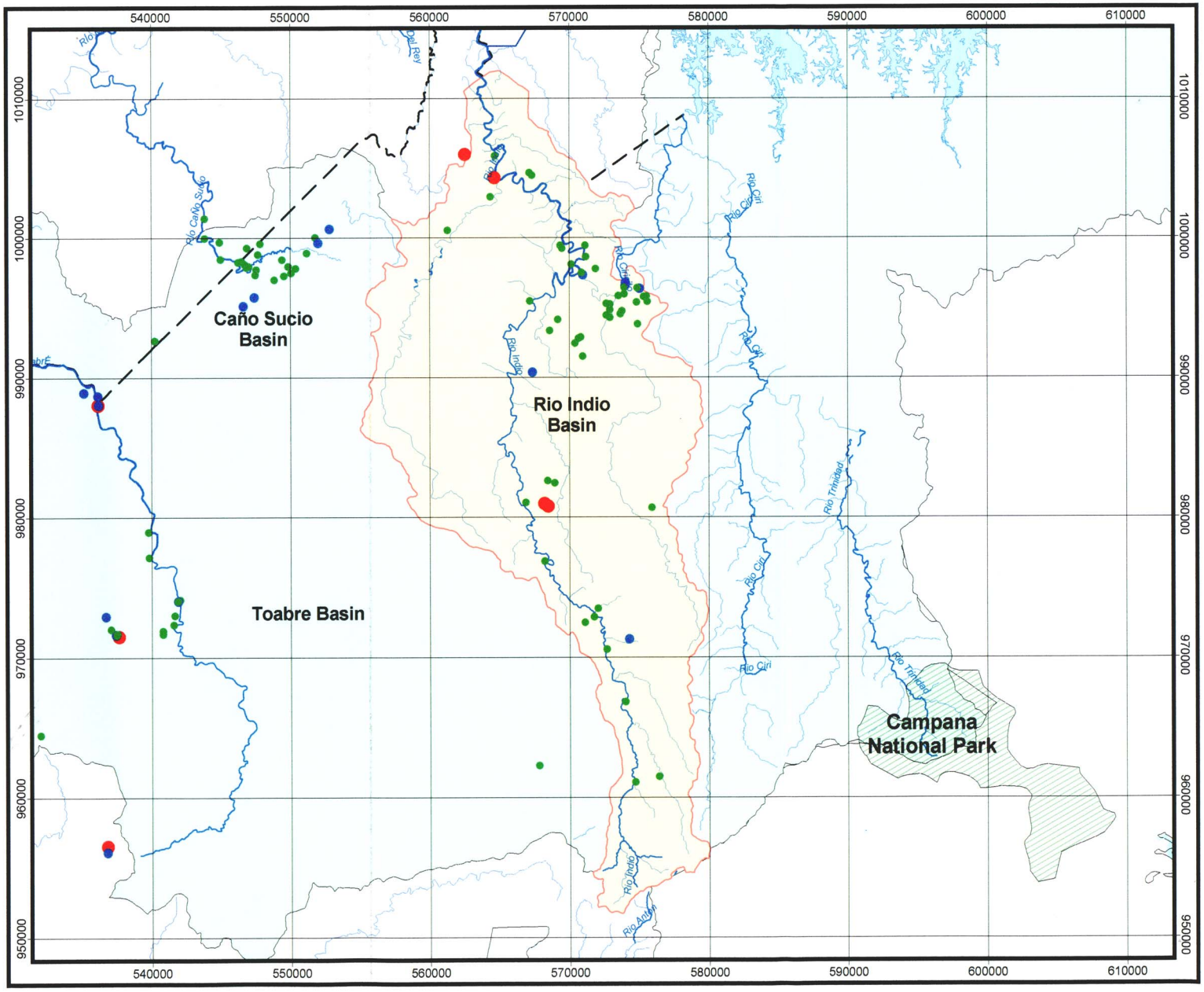
10 0 10Km

REGIONAL LOCATION



SCALE. 1:275,000

Figure N° 3-8



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

CULTURAL RESOURCES SITES

ACP

PANAMA CANAL AUTORITHY (ACP)

LEGEND

- Towns
- Province Boundary
- Main Rivers
- Secondary Rivers
- Protected Area
- Rio Indio Subbasin Boundary
- Panama Canal Basin

Cultural Sites by Range

- High
- Medium
- Low

N
W E
S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

10 0 10Km

REGIONAL LOCATION

SCALE. 1:200,000

Figure N° 3-9

4.0 IDENTIFICATION AND EVALUATION OF IMPACTS

This chapter presents the results of the identification and evaluation of the social-environmental impacts and potential risks for the water options under consideration in the Indio River Watershed. There are six options that have been described in chapter 2 of this report:

- Option 1: Indio 80-40
- Option 2: Indio 45-40
- Option 3: Upper Indio 50-40
- Option 4: Upper Indio 45-40
- Option 11: Teriá River Catchment
- Option 12: Teriá River + Headwaters of the Indio River

This chapter describes the social-environmental impacts and the potential risks for the different phases of the project, with major emphasis on the stages of construction and operation since the greatest number of impacts will be generated by them, as shown in Table 4-1. Also, a distinction is made between the environmental impacts that could potentially happen in the areas of direct and indirect influence. Finally, at the end of the chapter, a brief description of the social-environmental impacts and potential risks for each of the Options is presented.

It is important to indicate that Options 1 and 2 (Indio 80-40 and Indio 50-40) are Options with the most available information; therefore, the social-environmental impacts and potential risks can be identified and predicted with a greater degree of reliability. For other options, particularly for options 11 and 12, the impacts are assumed to be in many cases similar to the ones expected for the fist two because the conditions are more or less similar and specific information does not exist for these latter two options.

4.1 Identification and Classification of Potential Impacts

The identification and classification of the possible social-environmental impacts and risks takes into consideration the typical activities of this type of work, relating them to the social-environmental aspects that could be affected, through the use of matrices. The following paragraphs describe how the identification and the initial classification of the possible environmental impacts and risks were made. The other sections of this chapter analyze and quantify the impacts for each of the water options under consideration.

A Leopold Impact Identification Matrix, reformatted and adapted for this type of project, was used for the identification of the potential impacts for each social-environmental aspect. The result was the identification of the number of interactions or possible general effects on the natural goods and socioeconomic resources for the type of project under study.

The URS multidisciplinary team utilized the Leopold Matrix for the identification, evaluation, analysis and hierarchical structuring of the social-environmental impacts and potential risks to the physical, biological and socioeconomic aspects. For this purpose, physical elements such as the geology and seismology, soils, water resources, quality of the air and noise, were taken into consideration. Furthermore, biological elements such as terrestrial and aquatic flora and fauna were considered. The socioeconomic aspects included were: population, employment and revenue, commerce and market, community cohesion, local infrastructure, agricultural production, archaeological sites, tourism and scenery, land tenure and epidemiology.

In the identification matrix, 21 activities related to the water options were considered and 22 aspects of the physical, biological and socioeconomic environment. Of all the possible interactions (462 potential impacts), 171 were identified in a rough way for the type of project under study (Table 4-1). A summary of the potential positive and negative impacts identified by means of the matrix analysis is presented next.

Table 4-1
Number of Positive and Negative Interactions

Type of Impact	Stages					
	Planning	Construction	Operation	Abandonment	No action	Whole
Positive	1	19	4	4	11	39
Negative	8	97	11	1	15	132
	9	116	15	5	26	171

Nine impacts were identified in the planning stage, of which, 8 are negative and 1 positive. The last one refers to the employment of local people assisting with work of gathering information, as well as horseback and longboat transport services. The negative potential impacts identified in this stage refer to the socioeconomic aspects derived from the speculation of what might logically happen to affect people, community cohesion, agricultural production, land tenure and infrastructure.

As can be seen in Table 4-1, the construction phase, is where the greatest number of impacts occur. The positive potential impacts refer to the generation of employment and the increase of

commerce. The social-environmental impacts and potential risks will be described in sections of this chapter.

In the operation phase, the positive potential impacts also refer to the generation of employment and to the increase of tourism. In the abandonment phase, the negative potential impact is that the workers of the project would lose their jobs.

Finally, not carrying out the project (no action) also generates social-environmental impacts. The positive potential impacts refer to the implementation of regional development projects and the negative impacts are due to the direction of changes in land use.

Once the possible social-environmental impacts and potential risks were identified, they were classified based on the character of the impact, its type, manner of action, extension, intensity, duration, reversibility and the possibility of recovery, and the probability of occurrence. The classification of the social-environmental impacts and risks was carried out for all of the interactions mentioned in the previous paragraphs and the same identification matrix was used to classify the information. Both the identification and the classification matrixes are presented at the end of this chapter.

The following paragraphs describe the methodology used to classify, in a general way, the social-environmental impacts and risks for the identified interactions.

Character: characteristic that indicates whether an impact improves or degrades the environmental baseline conditions. It is qualified as:

> Positive (+) - impact that implies an improvement or recovery of the biophysical environment, or a socioeconomic benefit of the community involved.
>
> Negative (-) - impact that implies a deterioration of the condition presented in the environmental baseline.
>
> Neutral (+/-) - impact that does not modify the condition presented in the environmental baseline; causing neither benefit nor damage.

Type: characteristic that indicates whether the project is directly responsible for the impact or causes impact through other variables.

Direct (d) - when the affected environmental component receives the impact of the activity or acts of the project without the intermediate participation of other components.

The indirect (i) - when the affected environmental component receives the impact through another affected variable and not as a direct result of the project.

Extension: characteristic that indicates the spatial distribution of the impact. It is qualified as:

Localized (l) - when the origin and/or manifestation of the impact is produced in a defined or specific sector of the area of influence of the source.

Extensive (e) - when the effect caused by an activity is not located in a specific sector of the area of influence.

Regional (r) - When the impact appears in sectors of the area of influence that are not well defined.

Intensity: quality that reflects the degree of alteration of an environmental variable.

Low (l) - when the degree of alteration is small and it can be considered that the condition of the baseline is maintained.

Moderate (m) - when the degree of alteration implies evident changes with regard to the conditions presented in the baseline, but inside acceptable ranges. The recovery of the environment is expected.

High (h) - when the degree of alteration regarding the baseline is significant and in some cases unacceptable. The recovery may require a long time or be impossible.

Duration: quality that indicates the time that the impact or effect or alteration will be present. It is qualified as:

Temporary (t) - the temporary impact generally happens during the construction phase and the recovery of the resources happens during or immediately after the construction.

Short-term (s) - short-term impact lasts 3 years or less after construction.

Long-term (l) - an impact is considered long-term if the resource requires more than 3 years of recovery.

Permanent (p) - a permanent impact is a change in a resource where the resource recovery does not happen during the life of the project.

Reversibility: characteristic that indicates the possibility that the affected environmental component recovers the condition presented in the baseline in a natural way. It is qualified as:

Reversible (r) - after a certain time, the impact reverts naturally after the action that produced it is finished.

Irreversible (i) - when the impact does not reverts naturally after the action is finished; the recovery of the affected component requires a corrective action.

Mitigation Probability: indicates the mitigation probability of an impact.

Mitigable (mi) - impact can be minimized by corrective actions.

Immitigable (im) - Impact that cannot be mitigated by means of corrective actions.

Probability of Occurrence: characteristic that indicates the probability that an effect in the environment will occur. It is qualified as:

Improbable (i) - when low expectations exist that an impact will occur.

Probable (p) - when the expected occurrence of an impact is neither clearly probable nor improbable.

High Probability (h) - when high expectations exist that an impact will occur.

Sure (s) - impact with 100 % of probability of occurrence

4.2 Potential Impacts on the Physical Surroundings

The potential social-environmental impacts and risks to the physical environment have been classified to facilitate as those relating to either geology and seismology, soils, water resources, or air quality and noise.

4.2.1 Geology and Seismology

The evaluation of the potential social-environmental impacts and risks related to the geologic aspects, including seismic activity, is based on limited information which includes the geologic map of the Republic of Panama, historical records of seismic activity in the region, and previous studies realized by the ACP in the ROCC as part of the Master Plan for the Enlargement of the Canal. The studies realized to date do not include geologically detailed studies or other field studies, except in very limited areas in the proposed dam sites and along the proposed tunnel routes.

It is important to point out that the first four options provided by the ACP fell in the middle section of the Indio River Watershed where the altitudinal levels varies between 50 and 200 masl. On the other hand, options 11 and 12, conceptualized by the URS team, are located in the Teriá River catchment and the upper part of the Indio River watershed. The information available regarding the existing conditions of these areas is even more limited, since they were not included in the reconnaissance and feasibility studies carried to date by the ACP.

In general terms, the construction and later presence of the civil works associated with any of the six options could affect the geologic and geotechnical conditions of the area. More than impacts in the strict sense, these potential effects should be qualified as risks since there is no certainty of their occurrence. In general, these risks are related to seismicity, landslides and geologic stability.

The risks derived from the seismic activities for the development of Options are considered to be limited in consideration of the scant historical records that exist for the region. This does not imply that measures, actions and investments should not be taken during the_conceptualization, design, construction, operation and maintenance of the project. If the aforementioned is not taken into account, the impact of the seismic activity might be much higher under any of the water options. On the other hand, the social-environmental impacts and the potential risks of geological /geotechnical character, such as seismic, can be prevented, limited and controlled through the implementation of appropriate methods of design, construction, operation and maintenance.

One of the major geologic and geotechnical risks are **possible mass movements, especially landslides**, principally in cut areas, but also on natural slopes. The problem of landslides during the construction and the operation of the Panama Canal along the Culebra Cut are well known and well documented. Major slides have happened in volcanic as well as sedimentary geologic formations (for example, Las Cascadas, La Boca, Cucaracha among others). The principal factors that have played an important role in the instability of slopes along the Canal include the presence of clayish lutites in the diverse geologic formations and the existence of such geologic structures as bedding planes and an extensive system of faults.

Another critical factor in the instability of slopes, especially during the rainy season in this region of the country is the presence of residual soils. A clear example of this type of problems is the frequent slides along the Trans-Isthmian Highway. In accordance with the existing geologic information, all these conditions exist in the Indio River watershed. Although the cuts that are anticipated in this project are not of the same magnitude as the excavations that were required in the Canal, the risk of landslides in the Indio River options is a social-environmental impact and an important risk that will need measurements of prevention, reduction and mitigation.

Another element during the construction that implies geologic and geotechnical risks is the **stability during the construction of** water transference **tunnels** from the reservoir towards the watershed of Lake Gatún. Considering the limited information available to date, it is not possible to estimate exactly the degree in which the geologic conditions will impact their construction. It is believed, nevertheless, that they will cross a diversity of materials that change from relatively soft sedimentary rocks up to very hard volcanic rocks, with a variable degree of weathering and the presence of geologic structures (faults, planes of deposition, etc.).

The geologic, geotechnical, and seismic impacts due to the development of the resources of Indio River surface water can be divided into impacts during the construction of Option or options chosen and their impacts during the operation and maintenance. These are discussed in the subsequent paragraphs.

4.2.1.1 Potential Impacts during the construction phase

The infrastructure projects that are common to the six options and whose construction might affect the geologic and geotechnical conditions existing in the area include:

- Highways and access roads;
- Quarries and other sources of construction materials;

- Construction camps;
- Construction of river detours such as dikes, culverts, etc.;
- Construction of the dam, spillway and dikes;
- Construction of tunnels and water transfer channels; and
- Disposal of garbage and other solid wastes.

4.2.1.1.1 Possible direct impacts

The possible direct impacts include risks associated with landslides, geotechnical risks due to the construction of tunnels and channels and the disposition of the material excavated from the work sites.

4.2.1.1.1.1 Landslide Risks

During the construction phase, the greatest risk of landslides occurs in the cuts along the access highways and in areas of extraction of construction materials, especially taking into account the high annual precipitation and the high intensity of the rains in the study area. The feasibility study of Option 1 concluded that the fill materials and aggregates for concrete will have to come from quarries in formations of sandstone and andesite or basalt. It is anticipated that these quarries could result in very high steep cuts, which might produce major rockslides.

To date, not all of the sites and other details of design of the infrastructure of construction and access to project locations have been precisely defined. These factors, in combination with the limited field information that exists up to now, limit the possibility of realizing a detailed evaluation of landslide risk. Nevertheless, with the appropriate implementation of prevention measurements, reduction and mitigation during the design, construction and operation of these works, it is believed that this impact will be minimal.

4.2.1.1.1.2 Risks during the construction of tunnels

As for the risk of collapses and cave-ins during the construction of the water transfer tunnels, the only available information was for Option 1. The feasibility study prepared for the Indio River 80-40 Option has identified that among the conditions that must be anticipated during the excavation of the tunnel are the possibility of water infiltration and the need for different types of internal support, depending on the type and quality of the rock. The same study estimates that the possibility of finding dangerous gases or hydrothermal conditions during the excavation of the tunnel is minimal. As in the case of the risk of landslides, the resultant impacts of the

construction of the water transference tunnel can be minimized by the implementation of appropriate design and construction measures.

4.2.1.1.1.3 Disposal of the excavated material

An environmental impact resulting from tunnel construction is the disposal of the excavated material, which is estimated at a volume of 200,000 cubic meters for options 1 to 4 and approximately the half of this quantity for options 11 and 12. Although it is possible that part of this material could be used as fill material, the feasibility studies of Option 1 estimate that the majority will have to be discarded. The construction of new roads to the different projects, as well as the rehabilitation of some existing roads, will also generate waste material from the movement of earth. This waste material must be disposed in landfills previously identified and also must be consolidated to facilitate revegetation.

4.2.1.1.2 Possible indirect impacts

The types of socio-environmental impacts and potential risks mentioned previously might, in some cases, influence areas outside of the sites where the civil works are taking place, but in relatively limited and adjacent areas. Therefore, with the information available, social-environmental impacts and potential indirect risks related to the geologic and seismic characteristics of the region during the construction phase are not anticipated. The only exceptions are, perhaps, landslides, whose incidence can increase as the pressure increases on the vegetation which loses it effectiveness. This topic will be discussed further in relation with the potential impacts to the soil.

4.2.1.2 Potential Impacts during the Phase of Operation

The social-environmental impacts and potential risks of geologic and seismic nature are, during the phase of operation, principally associated with the structures that will be created in during construction phase and the activities necessary for their operation and maintenance. These principally include:

- Dams;
- Reservoirs;
- Systems of water transference (tunnels and channels);
- Highways and access roads, and
- Dredging of the reservoirs, in case it is necessary.

4.2.1.2.1 Possible direct impacts

During the operation of the proposed projects, social-environmental impacts and potential risks of a geologic or geotechnical character to the physical environment include the risk of landslides along the perimeter of the flooded areas and the possibility of instability of the foundations of dams and other large structures.

4.2.1.2.1.1 Risk of landslides

In addition to the geological conditions, one of the factors that make the risk of landslides in the hillsides of the reservoirs a critical problem is the great fluctuation in the level of the proposed reservoir in some of Options. One of these cases is Option 1, Indio 80-40, where the level of the reservoir would vary from 80 masl (maximum level of normal operation) down to a minimal level of 40 masl. Similar fluctuations are also proposed for Options 11 and 12.

Although the change of the level of the reservoirs would occur under highly controlled conditions (and the possibility of a rapid drop in level is minimal), it is believed that the risk of mass movements and principally, landslides in the area surrounding the reservoirs would increase in inverse proportion at the level of the water in the reservoir at any given moment. Therefore, all other factors being equal (for example, the geologic conditions), those alternatives with a major change in the level of the reservoir will have, in general terms, a greater risk of landslides throughout the life of the reservoir.

The above mentioned risk can be prevented, reduced and mitigated during the design phase of the reservoir, which must include the necessary geologic and geotechnical field studies and the proper execution of the construction projects. A mass movements monitoring system , principally on slopes in critical areas during the operation of the reservoirs, would also help to control the risk of slopes instability by allowing for the early identification of potential problems and implementation of corrective measurements.

4.2.1.2.1.2 Water filtrations

Other possible impacts of a geotechnical or hydrogeological character include the filtration of water, below or surrounding the dam, its impact on the dam's stability, and the possibility that exfiltration will occur at the bottom of the reservoir. In this case, the geologic information available does not seem to indicate the presence of limestone rock with karstic characteristics in the area of interest. While it is believed that the risk of exfiltration is minimal, this will have to

be evaluated further during the studies and final design phases, which must consider an injection curtain in the base of the foundation.

Water filtration across, around or below the dam can be minimized by means of an appropriate design. For example, the preliminary design of Option 1 (Indio 80-40) presented in the feasibility study incorporates a concrete covering on the upstream side of the proposed rock dam, which would eliminate the possibility of filtration across the dam. During the operation of the reservoir, the appropriate instrumentation of the dam would allow the evaluation of the risk of excessive water filtration and the possible environmental impacts of its stability.

4.2.1.2.2 Possible indirect impacts

The impact of an earthquake is considered to be an indirect effect because it is not caused by the development of the water option and because its effect would be felt downstream from the dam and from the reservoir. Considering the presence of a dam and its associated reservoir, the effect of an earthquake in the area would be much greater if one or more of the considered water options are actually implemented. The potential effect in the event of failure of the dam is directly related to the energy stored in the reservoir, which is in turn influenced by the quantity of water and the elevation of the water above sea level.

The historical earthquakes records in the region indicate that they concentrate on the west and the southeast of the country along the limits between the tectonic plates. Therefore, it is believed that the risk of a major earthquake that could affect the project is relatively small. Likewise, the formation of tsunamis produced by marine earthquakes is considered to be unlikely in the region. The feasibility study includes seismic parameters for the design of the Indio River project based on statistical analyses.

4.2.1.3 Comparison of Options

After reviewing the information about the existing conditions and the description of the water options, it is considered that none of the social-environmental impacts and potential risks of geologic, geotechnical or seismic character represents a factor that could be considered as a "fatal flaw", which would cause an alternative to be considered unfeasible. In general, it is believed that the social-environmental impacts, as well as the potential risks of geologic/geotechnical character (including seismic), could be mitigated or prevented through the implementation of appropriate methods of design and construction.

The level of impact will depend on Option and, in general, it will be greater in proportion to the magnitude of the project, that is to say, size of the reservoir, height of the dam, etc. In the following section, the pertinent factors are considered in order to establish, in a comparative manner, the risks that could affect each of Options to a greater or lesser degree.

Conceptually speaking, the social-environmental impacts and potential risks of geologic and geotechnical character are of similar natures for the six analyzed options. It is our opinion, nevertheless, that the risk of occurrence of these phenomena is minor in the mainly volcanic formations that are found in the areas to be flooded in the reservoirs of the Teriá River and Indio River headwater, assuming that the proposed facilities are appropriately designed and constructed.

On the other hand, also it is anticipated that the social-environmental impacts and risks during the construction of the projects previously described might be major in case of these options (11 and 12) given the abrupt terrain and the difficulty of access to the more remote zones. Furthermore, even if the risk of seismic activity in this region of the country is relatively low, the design of the dam and other facilities of the project will have to incorporate the seismic effects for an event for the period of recurrence established in the design criteria.

In the case of the construction of the transfer tunnel, a minor risk also exists for its size. In the case of Options 11 and 12, it is estimated that the required tunnel could be 50% shorter than under the other options. These option would thus also reduce the need of disposing of the material excavated during the construction.

The potential impact of a catastrophic earthquake could be relatively great for reservoirs on the Teriá River and headwaters of the Indio River (Options 11 and 12), in the event of failure of one of the dams. Considering the location of these reservoirs in the high zones of these catchments, the sudden discharge of the waters dammed resulting from a rupture of the dam might affect a much larger area, causing greater damage to property and loss of life. This would be exacerbated by the fact of these alternatives include two reservoirs instead of one as in the rest of Options. This risk can be diminishing with the use of a injection curtain in the base of the foundation. Nevertheless, the risk is partially compensated by the smaller volume of stored water when the above-mentioned reservoirs are compared with Option 1. Options 2, 3 and 4 have an intrinsic minor risk because they are located at the same general elevation as Option 1 and include minor volumes of water, including the reservoirs on the Teriá River.

In summary, Table 4-2 compares the values assigned for the geologic and geotechnical risks of each of the water options considered in the Indio River Watershed.

Table 4-2
Summary of the geologic, geotechnical and seismic risks for the construction and operation phases and for the area of direct and indirect influence

Options	Landslides	Tunnel Infiltration	Waste Disposal	Dam Infiltration	Earthquakes	Total Risk Score
1	3	1	3	2	1	10
2	1	1	1	1	1	5
3	1	1	1	1	1	5
4	1	1	1	1	1	5
11	2	1	2	3	1	9
12	2	1	2	3	1	9

1 = minor; 2 = medium; 3 = major.

As it can be appreciated in Table 4-2, Option 1 is the one that presents the greatest geologic, geotechnical and seismic risk since it is the one that includes a larger-sized reservoir and, in general, larger structures. Options 11 and 12 are of slight lower overall risk, while the options of least risk are 2, 3 and 4. The risk level assigned to each option is generally proportional to the magnitude of the project, that is to say, the size of reservoir, the volume of earth to be moved, and the height of dam. The potential risks of geological/geotechnical as well as seismic character can be mitigated or prevented through the implementation of appropriate methods of design and construction.

4.2.2 Soils

The water options in the Indio River watershed have the potential of affecting the soils because both the reservoirs and the permanent and temporary infrastructure will use land areas that are covered by soils of different classes. These impacts would take place principally during the construction phase of the selected options.

4.2.2.1 Potential Impacts during the Construction Phase

Table 4-3 includes a summary of the classes of soils that would be affected for each of the options considered in the Indio River watershed. These values are the result of overlaying the graphic description of six water options that have been planned for the Indio River watershed with the information about the agricultural classes. These overlays are depicted in Figures 4-1 to 4-6.

4.2.2.1.1 Possible direct impacts

The direct impacts are caused by the removal and/or the flooding of soils in the construction sites, borrowing pits, and areas to be flooded by the reservoirs. The values of the potential impacts include the areas of the possible reservoirs plus access roads to the different workplaces and earth borrow sites associated with each of Options. Information about earth borrow areas and the extraction sites of special materials has only been completed for Option 1; therefore, comparisons cannot be done between the options. In order to estimate the whole impact of every option it is necessary to assume that all of them would have similar sized area of earth borrow sites, which totals 840.4 hectares.

In this type of impact, the reservoir itself is the component that contributes most to the social-environmental impacts and risks. For this reason, Option 1 is the one that affects the most area, followed by Options 2, 11 and 12, with approximately the half of the impact. In all the cases, the majority of the affected soils belong to agricultural categories VI and VII that are characterized as soils of little agricultural value, not arable and suitable only for forests, grasslands and reservation lands.

Table 4-3
Potential Impacts (Hectares) on Soils that will be Directly Affected by the Water Options being Considered for the Indio River Watershed

COMPONENT		Categories					TOTAL
		III	IV	VI	VII	VIII	
Indio River	Roads	4,40	17,30	31,20	56,20	0,00	**109,10**
	Reservoir 80-40	0,00	0,00	2.516,30	2.022,20	0,00	**4.538,50**
	Reservoir 45-40	0,00	0,00	1.515,50	578,40	0,00	**2.093,90**
Upper Indio	Reservoir 50-40	0,00	0,00	689,20	162,60	0,00	**851,80**
	Reservoir 45-40	0,00	0,00	648,30	135,90	0,00	**784,20**
Teriá	Roads	0,00	0,00	7,40	1,80	0,00	**9,20**
	Reservoir	0,00	0,10	405,18	354,72	0,00	**760,00**
Upper Teriá	Roads	0,00	0,00	16,40	27,80	0,00	**44,20**
	Reservoir	0,00	0,00	490,30	334,20	0,00	**824,50**
Indio Headwaters	Roads	0,00	0,00	36,39	28,61	0,00	**65,00**
	Reservoir	0,00	0,00	105,50	4,50	0,00	**110,00**
Earth Borrow Sites		0,00	203,00	327,30	165,30	0,00	**695,60**
Quarry		0,00	0,00	0,00	58,80	0,00	**58,80**
Fluvial Deposits		0,00	0,00	85,90	0,00	0,00	**85,90**
	Total Excavations	**0,00**	**203,00**	**413,20**	**224,10**	**0,00**	**840,30**

CATEGORY / DESCRIPTION		OPTIONS					
		1	2	3	4	11	12
III	Arable, severe limitations in the variety of vegetation, requires special conservation or both	4,4	4,4	4,4	4,4	0,0	0,0
IV	Arable, severe limitations in the variety of vegetation, requiers very carefull management or both	220,3	220,3	220,3	220,3	203,1	203,1
VI	Not arable, with servere limitations, apt for forests, pastures, reserve lands	2.960,7	1.959,9	1.133,6	1.092,7	1.332,5	1.474,4
VII	Not arable, with severe limitations apt for forests, pastures, reserve lands	2.302,5	858,7	442,9	416,2	942,6	975,7
VIII	Not arable, with limitations that impede its use for the commercial production of plants	0,0	0,0	0,0	0,0	0,0	0,0
	TOTAL	**5.487,9**	**3.043,3**	**1.801,2**	**1.733,6**	**2.478,2**	**2.653,2**

In addition to the social-environmental impacts and direct risks by the removal or flooding of soils, the soils of the area can also be affected by processes of superficial erosion during the construction phase, especially given the high level and the intensity of precipitation in the area. The social-environmental impact of soil loss can be significant if the appropriate measurements of prevention, reduction and mitigation are not implemented during the construction of the structures. While it is difficult to predict the quantity of soil that can be affected in this way, efforts must be directed towards preventing, reducing and minimizing these impacts.

4.2.2.1.2 Possible indirect impacts

During the construction phase, there will be effects on the soils of the watershed and adjacent areas as a result of the induced development that will surely take place. The risk is that the soils of the area, relatively limited from an agricultural perspective, will be developed for inappropriate agricultural uses that could result in their erosion and deterioration. These could be prevented by means of a land use zoning plan and the adoption of suitable soil protection measures in agricultural activities. Of especially great concern is the use of areas with excessive slopes for the establishment of short-term agricultural activities, which are characterized by crops with limited root systems.

Once the cohesive effect provided by the roots of a forest has been eliminated, mass movement processes tend to be accelerated in areas with steep slopes, especially under the intense rains that characterize the region. These processes were documented during a site visit in December 2003. An unnaturally increased occurrence of landslides can have negative effects on biodiversity, and thus, diminish even more habitat quality, water quality since the quantity of solids in suspension, increase and the risk of increased sedimentation downstream.

4.2.2.1 Potential Impacts during the Operation Phase

On the contrary to what happens in the construction phase, the impacts during the operation phase are mainly indirect in nature, given that the loss or flooding of soils diminishes significantly once the civil works have been completed and the reservoir fills up to its normal operational level.

4.2.2.2.1 Possible direct impacts

During the operation phase, the direct impacts to the soil will be minimal because the reservoir and the structures will already have been built. New earthmoving activities, such as the

excavation of additional borrow pits to extract material for road rehabilitation, would affect the soil locally.

4.2.2.2.2 Possible indirect impacts

The induced development that is anticipated to take place during the operation stage in the area, will affect the soils that have agricultural limitations. The impacts will be from the erosion and the deterioration of the soils that are not suitable for agricultural. These soil impacts can be prevented by means of the implementation of the land use zoning plan for the watershed of the Indio River and the adoption of protective measures for the soils used in agricultural activities.

4.2.2.3 Comparison of Options

To compare the impact on the soil for each water option, the areas to be flooded by the reservoir, developed for quarries and earth borrow sites, and utilized for the construction of new roads are taken as a parameter (area of direct influence). Option 1 will affect most area directly, followed for Options 2, 11 and 12 with about half of that value, and Options 3 and 4 with about a quarter of the Option 1 value (Table 4-4).

Table 4-4
Summary of the soil impacts for the construction and operation stages and for the areas of direct and indirect influence

Options	Soils Flooded by the Dam(s)	Soils affected by Quarries, Earth Borrow Sites, and Roads	Soils affected by Induced Development	Total Score
1	3	2	3	8
2	2	2	3	7
3	1	1	2	4
4	1	1	2	4
11	2	2	3	7
12	2	2	3	7

1 = minor; 2 = medium; 3 = major.

The impact on the soil for the water options in the area of indirect influence in the construction and operation stages (induced development) is considered to present similar risks under all Options and, using project funds, it will be necessary to avoid them through a land use zoning plan and the promotion of conservation measures and the protection of soils used in agricultural activities.

4.2.3 Hydrological Resources

The studies that have been developed up to now in the Indio River watershed have been very useful for the identification and evaluation of the social-environmental impacts and the potential risks to its water resources. The social-environmental impacts and potential risks to the water resources in the Indio River watershed have been divided into four functional categories:

(a) Reduction of water levels and flow downstream from the dam;
(b) Sedimentation in the reservoir and its potential impact on the operation of the dam and downstream waters;
(c) Risk of eutrophication in the reservoir; and
(d) Water quality in the fluvial channel downstream from the reservoir, construction sites, and borrow pits.

The aforementioned impacts will appear mainly during the final phase of the construction (filling) and during the operation phase of the water options. The category that also appears significantly throughout the construction phase of the projects is the risk of deterioration of the quality of the water downstream from the dam sites and from construction in general. In the subsequent sections, we discuss how each of these potential impacts might manifest themselves during the construction and operation phases.

4.2.3.1 Potential Impacts during the Construction Phase

During the construction phase, the principal impacts are related to the risk of deterioration of water quality both by the direct action of the construction and by the indirect effects of the development induced in the watershed. The deterioration of water quality from an increase of suspended sediment, as well as both biodegradable and hazardous wastes, will have effects on the quality of the aquatic habitat downstream.

The other effects related to sedimentation in the reservoir – the risk of eutrophication and the reduction of flow downstream from the dam sites – would significantly manifest themselves after the structures have been built and the filling of the reservoir or reservoirs has begun. Therefore, these potential impacts appear in the section corresponding to the operation phase.

The effects on water levels and flows downstream from the dam sites will be minimal during the construction phase. Although during this time the river will be diverted from its river bed in a small section, its flow will not diminish significantly since there will be no transferences to other

watersheds. In relation to sedimentation in the reservoir, it is hoped that this should happen in small quantities since the cofferdam and the tunnel will have the effect of holding back the river, especially when its flow is high which is when more sediment is being transported by the system. Nevertheless, this is considered to be a localized effect of small magnitude, since, as was indicated in Chapter 3, the quantity of sediment that is mobilized by the hydrological system of the Indio River watershed is relatively low.

4.2.3.1.1 Possible direct impacts

As was mentioned previously, the principal direct impact during the construction phase is related to the risk of the deterioration of water quality. The quality of the water of the principal river and its tributaries can be deteriorated during the construction of the dam and related projects. By causing major deforestation and changes in the equilibrium of the slopes, the processes of erosion, sedimentation and of mass movements are accelerated, changing the patterns of external drainage and runoff and accelerating the coefficients of sediment delivery. This will contribute significantly to a deterioration in water quality, the contribution of sediments being the principal and more obvious aspect of the aforementioned deterioration, affecting biodiversity and hydrological aspects.

Since the deterioration in water quality is principally due to the contribution of sediments coming from the movement of earth, including excavations, it is appropriate to identify their principal sources. Experience in hydrological construction projects has demonstrated that during this stage the principal sources of water quality deterioration are, in order of priority, the following:

i) The construction of the temporary and permanent roads constitutes a significant contribution of sediments to bodies of water if appropriate preventive and corrective measures are not taken;

ii) Deforestation and loss of the protective effects of vegetation on soils, induced by the infrastructure built, principally roads and quarries, accelerates the processes of erosion, sedimentation and of mass movements, unbalances the slopes and the external drainage, concentrating the runoff and increasing the erosive capacity of the water and the coefficients of sediment delivery which deteriorate water quality and increases sedimentation downstream;

iii) Extraction such as rock quarries and riverbed sand pits can be also a source of sediments towards the bodies of water if opportune preventive measures are not taken. The contribution of sediments can be significant if stony materials are

extracted from the bank of the rivers, and as a result, the form of extraction must be an object of special study, avoiding breaking the steal of the riverbed;

iv) Earth movement at the dam site, tunnel, temporary derivations and auxiliary dikes (saddle dams) can contribute greatly to the quantity of sediments if preventive and corrective measures are not implanted, especially if done close to the principal bed of the river; and

v) The extraction of water from the rivers can suspend the sediments and degrade water quality downstream;

vi) Wastewater from sanitary facilities can also be a source of water quality deterioration in affected water bodies.

Other significant impacts on water quality are the residual discharges of human settlements, camps and work zones, as well as spills of residual hydrocarbons in the workshops and sites for parking machinery. These wastes must be dealt with by means of septic pits or other approved methods and there must be a strict control on the discharge of hydrocarbons to the soil and principally to recipient bodies of water. A single drop of oil spilled in the water, needs about 450,000 drops of water in order biodegrade.

4.2.3.1.2 Possible indirect impacts

The possible indirect impacts during the construction phase are associated with the development induced as a consequence of the work that would be realized for the development of the projects. These include induced development in the watershed as well as in the surrounding areas, especially the work sites and along the access routes. The impacts are similar in nature since a greater degree of economic and commercial activity resulting from an increased human presence, especially if they develop in an uncontrolled and spontaneous way, will lead to similar problems in the quality of the water to those that were described in the previous section.

4.2.3.2 Potential Impacts during the Operation Phase

The physical presence of the dam and reservoir has its most significant effect during the operation phase. This is especially true for the impacts associated with the alteration of the flows of both water and the solids normally transported along the river. The direct effects of this will occur in the river downstream from the dam and in the reservoir itself. Finally, it is also important to point out that the evolution of the conditions in the watershed upstream from the reservoir can have also a significant effect on this. The principal direct and indirect effects on

water resources as consequence of the possible development of one or more of the water options considered in the Indio River watershed are described in the following sections.

4.2.3.2.1 Possible direct impacts

The direct impacts during the operation phase of the options to be implemented in the Indio River watershed are defined by the presence of the reservoir structures and the interruption that these will establish in the free flow of the liquid and solids of the hydrographic system. In order to systematize the treatment of these impacts, the analyses relative to six important aspects were included. These aspects are:

- The effect on water levels and flow downstream from the dams;
- The erosion in the watershed and sedimentation in the reservoir;
- The possible effect on the riverbed downstream from the dams;
- The stability of the channel downstream from the dams;
- The risk of eutrophication of the reservoirs; and
- The possible effect on water quality downstream of the dams.

4.2.3.2.1.1 Level of the Water and Flow Downstream from the Dams

The information obtained during the feasibility study Option 1: Indio River 80-40 and the reconnaissance study realized for the whole Panama Canal Watershed and surrounding areas, constitutes the basis for estimating the possible effects of the development of the water options on the level of the water and the flow downstream from the dams.

The hydrological characteristics of the system before the project were established by means of statistical calculations based on the frequency distribution flows on the Indio River, and extrapolating from these using the technique of unit hydrographs. For the post-project conditions, hydrological simulations with a computational model (HEC-5) were performed. Table 4-5 shows a comparison between the conditions pre and post-project.

With the construction of the project there will be a significant decrease of the flow of the Indio River, downstream from the dam and therefore, a reduction in the risks of flooding. The dam sites of each Option are located at the following distances from the opening to the sea: the dam of alternatives 1 and 2 is located 31.2 kilometers from the sea; that of Options 3 and 4, 38.7 kilometers; and that of Options 11 and 12, 52.7 kilometers.

Table 4-5
Maximum river flow in the Indio River Downstream from the Reservoir

Period of Record (years)	Maximum Flow Pre-Project (m^3/s)	Maximum Flow Post Project (m^3/s)
2	562	57
5	657	71
10	713	79
25	780	89
50	820	100
100	859	108

The reduction of the water levels and flows of the Indio River, downstream from the dam site, will possibly provoke the following negative impacts, which will be discussed more extensively in other sections of the current chapter: less contribution of sediments, effects on aquatic organisms and greater difficulty in river transportation during periods of lesser precipitation.

4.2.3.2.1.2 Erosion of the watershed and sedimentation of the reservoir

Another potential impact to the physical environment as a result of the development of these projects is the accumulation of sediments in the reservoir. The excessive accumulation of sediments would require periodic dredging and the consequent suitable disposal of the dredged material. The analysis of the available information for the Indio River (option 1) suggests that the capacity of storage in the reservoir will not be affected by more than one and two percent after the operation of the reservoir for a period of 50 years and 100 years, respectively.

To analyze this potential impact of the accumulation of sediments in the reservoir, an analysis of the available information was carried out, a calculation of sediments load of in the Indio River watershed, and an estimate of the potential loss of storage capacity in the reservoir during a period of operation of 100 years.

The Department of Hydrometeorology of the Electrical Transmission Company, S.A. (ETESA) has gathered information on suspended sediments in areas of the ROCC. The methods of sampling and analysis are those recommended by the Division of Hydrological Resources of the United States Geological Survey (USGS). Specifically, ETESA gathered 46 samples in the Coclé del Norte River in Canoas and 56 samples in the Toabré River in Batatilla. Additionally, the ACP carried out samplings at three stations bordering Lake Madden and at another three stations bordering Lake Gatún. The ACP also carried out a sediment sampling campaign in Lake Madden

in 1983, which was updated in 1990. These results indicate a sediment production of 1.4 mm per year, approximately. The sediment loading curves versus flow, elaborated by ETESA assume a maximum concentration of 10,000 mg/l, which is greater than the concentrations measured in the samples. This was done to have a conservative estimate of sediment loads. Based on this assumption, annual sediment loads of 1.3 mm for the Coclé del Norte River and of 1.2 mm for the Toabré River were estimated.

Taking these estimates of sediment load as a base, a value of 1.4 mm / year has been adopted for the watershed of the Indio River(65). This load is indicative of current soil uses, which might change significantly if deforestation occurs or if there are increases in agricultural activity in the watershed. Using the drainage area of the watershed (381.1 km^2) and the value for the sediment load of 1.4 mm / year, results in a flow of sediments towards the reservoir of 533,540 m^3/año. The ACP has used in its calculations a specific gravity of the sediments of 1.04 ton/m^3. Thus, the annual load of sediments towards the reservoir of the Indio River would be approximately 554,880 tons.

The analysis of the potential loss of water storage capacity in reservoir was realized using the methodology proposed by United States Bureau of Reclamation. For the operational range of reservoir levels between 40 and 80 meters, the useful volume of the reservoir is of approximately 1,294 millions of cubic meters(65). The analysis realized here indicates that the capacity of storage in the reservoir will turn out not to be affected by more than one and two per cent after a period of operation of the reservoir of 50 years and 100 years, respectively.

The distribution of sediments in the reservoir was calculated using the method of increase of areas. This analysis indicates that the sedimentation in the reservoir does not represent a potential problem in this project. The loss of capacity of storage in the reservoir is presented in Table 4-6, supposing that the reservoir is completely full during most of the annual cycle. If on the other hand, it were supposed that the reservoir is at a low level tat the beginning of the rainy season (that is when the load of sediments increases), the loss of capacity of useful storage would be less.

It is important to point out that these flows were calculated using as base a rate of sediment generation in the reservoir of 1.4 mm per year. This flow supposes certain land use conditions which can change in the future due to such activities as deforestation or an increase in the agricultural activity in the zone. For this reason, monitoring of this generation of sediments in the watershed of the Indio River is advisable.

Therefore, the available information for Indio River (Option 1) and presented in the feasibility study, suggests that the rate of accumulation of sediments in the reservoir for any option in the Indio River would be minimal and the need of dredging is not anticipated.

Table 4-6
Potential Loss of Indio River Reservoir Storage Capacity

Period of Operation (years)	Storage	
	(MCM)	Percent Loss
5	1.2	0.1
10	2.4	0.2
20	4.9	0.4
25	6.1	0.5
50	10.8	0.9
100	23.2	1.9

This analysis concludes that sedimentation in the reservoir would not represent a significant problem in this project and, consequently, that the need for dredging is not anticipated. Nevertheless, it is necessary to emphasize the need to make sure that similar conditions continue in the future. It is very important to prevent landslides through periodic and routine roads maintenance, since these can be an important source of sediments into the reservoir.

4.2.3.2.1.3 Potential Effects on the riverbed, downstream from the dam

The capacity to transport sediments in a fluvial channel depends directly on the flow of water. In general, it can be supposed that there exists an equilibrium in which the sediment load remains more or less constant. Nevertheless, when a dam is constructed three potential effects can happen in this sense: 1) changes downstream due to the reduction of the flow in the fluvial channel, 2) a corresponding reduction in the load of transported sediments, and 3) a reduction in the capacity of the river to transport sediments.

The downstream effects, due to the reduction of flow, occur principally in the degradation in the mouths of the tributaries. After the runoff event occurs in the watershed, the water level in the principal river channel turns out to be diminished due to the presence of the dam. This causes a greater hydraulic gradient from the tributaries, and therefore the erosion potential increases at the discharge point to the principal river, which is the mouth of the tributary.

A reduction of the sediment load takes place as consequence of the capture of sediments in the reservoir. This results in an increase in the erosion of the river channel downstream from the dam, since this temporarily unbalances the erosion / deposition balance (the component of

deposition is eliminated due to the retention of these sediments in the reservoir). This degradation of the riverbed continues until a new equilibrium is reached due to cementation of the bed and/or a stabilization of the riverbank, which prevents the erosion of the riverbed. If the reservoir has an exit for the sediments to a sufficiently low elevation that connects it with the river downstream, then this temporary degradation is prevented.

The third effect that occurs is due to the reduction of the flow in the river downstream from the dam. This diminishes the capacity of the river to transport sediments, particularly those loads coming from the tributaries to the Indio River. This could cause an accumulation of sediments in the mouths of the tributaries, and a general reduction in the capacity of the watershed to transport sediments.

The methodologies that can be used to calculate the degradation of riverbeds downstream from reservoirs vary considerably in accordance with the size of the sediments, the magnitude of the discharge from the dam, and the required precision in the calculations. There are sophisticated computer models to calculate the potential degradation, based on hydraulic models for river channels combined with models of sediment transport. Models like these consider the distribution of the hydraulic properties, characterization of the sediments, and the temporal discharge patterns from the reservoir. Because this type of information is still not available for the Indio River, we have chosen a less sophisticated methodology, but one that has a verified track record regarding precision and orders of magnitude.

In the manual *Design of Small Dams*, from United States Bureau of Reclamation, two methods are recommended in accordance with the type of sedimentary material in the riverbed. If the riverbed is composed of material of sufficiently large size, which typically is not transported in suspension by the diminished flow of the river, a coating layer of sediments is established through time through the deposition of the finer materials transported by the river. This layer may establish equilibrium and prevent the degradation of the riverbed. The flow of the river continues transporting the finest material downstream. The development of this coating layer depends on the flow that circulates along the river once the reservoir begins operation. In fact, if the flow of discharge from the dam varies, then new layers formed successively; containing the finer material as the flow in the river increases.

The second method must be used if the riverbed is composed of thin materials (typically sand and gravels). The method consists of calculating the degradation of the riverbed supposing a continuous suspension of fine material in the water as a function of the discharge flow.

The hydraulic characteristics of the river channel downstream from the dam proposed for the Indio River are based on six (6) transverse sections and the use of a computational model (HEC-2) this work has been documented in the reference[65]. In this sampling work, the characteristics of the material present in the riverbed was determined, particularly the size distribution of sediment grains. These characteristics are summarized in Table 4-7.

Table 4-7
Characteristics of Bed Material in the Indio River

Class (Size)	Diameter of grain (mm)
D35	1.6
D50	6.0
D65	14.0
D90	50.0
Median	**16.5**

Because the bed material of the Indio River is composed of large materials, for this report we have chosen to use the first method described above. As such, we use four methods: Meyer-Peter Muller, Bottom Speed, Shields, and the Yang method (incipient movement) to calculate particle sizes that would not be transported by the resultant flow in the Indio River under conditions of the operation of the dam. It is useful to carry out these appraisals with more than one method since the assumptions implied involve diverse results in most cases. In case of the Indio River, for example, the particle sizes calculated using the Bottom Speed and Yang methods, produced results too large to be considered feasible. Table 4-8 shows the results obtained using the Meyer-Peter Muller and Shields methods for predicted conditions with and without the project.

Table 4-8
Size of Cover Layer (diameter of grain, in mm)
Indio River Downstream from the Reservoir

	Period of Time (years)					
	2	**5**	**10**	**25**	**50**	**100**
Without the Project						
Meyer-Peter Muller	29	30	31	32	33	33
Shields	41	44	45	46	47	48
With the Project						
Meyer-Peter Muller	9	10	11	12	13	13
Shields	13	14	16	17	18	19

It is possible to do a comparison of the size of the cover layer with and without the project, using an average grain size (median) of 16.5 mm. Under the conditions without the project, the size of grain of the cover layer is always greater than the median, and as a result, the riverbed tends to degrade, since the material on the bottom is easily dragged by the flow of the river. On the other

hand, with the project, the decrease of the flow downstream from the dam results in smaller grain sizes for the cover layer, indicating that the degradation of the riverbed would be reduced. This also might be indicative of a process of accumulation of sediments in the tributaries to the Indio River since, on having diminished the flow downstream, also it diminishes the ability of the river to carry sediments, as was discussed previously.

4.2.3.2.1.4 Stability of the Channel

The stability of the channel was evaluated taking as a base the potential for degradation of the riverbed, and the availability of material to establish a cover layer from the sediment load in the Indio River. Because the sediment load in the river diminishes as consequence of the capture of sediments in the reservoir, in general this results in a degradation of the riverbed downstream.

Nevertheless, the results presented in the previous section indicate that under the operative conditions of the Indio River project, the degradation of the riverbed is insignificant. Because of this, work to stabilize the river channel will not be needed. In fact, it is probable that the accumulation of sediments will take place in the mouths of the rivers flowing to the Indio River, contributing to the stability of these riverbeds.

It is important to emphasize that this deposition of materials in the riverbed combined with the reduction of flows and, as a result, of river levels, might affect navigation on the river, as it was indicated previously.

4.2.3.2.1.5 Risk of Eutrophication of the Reservoirs

The eutrophication is a process in which the water quality of the reservoir deteriorates due the exaggerated growth of algae and macrophytes, resulting from an increase in nutrient concentration, especially from nitrogen and phosphorus. The evaluation carried out previously considers the impacts that might happen to the water quality during the construction phase of the projects and during the operation phase of the considered water options, associated with the risk of erosion and sedimentation in the areas where the most significant movements of earth would be carried out, and the risks of spills of fuels, oils and other dangerous materials commonly use in the camps and work areas. Nevertheless, experience indicates that significant impacts can also occur in the water quality of the reservoirs due to the natural process of eutrophication during the operation phase; thus, an analysis of the risks that might present themselves as a result from rapid eutrophication is carried out in this section.

The estimation of the risks of eutrophication for the different water options evaluated was based on existing information. For reference, it is pointed out that the quality of the water of Lake Gatún and the reservoirs Alhajuela and Bayano[52, 37], the first with approximately 100 years of existence, is good, with the exception of some specific locations due to periodic discharges.

Furthermore, the results of the simulations of water quality in the operation phase of the Indio river reservoir (Option 1) prepared by the US Army Corps of Engineers (2003) have been useful for this analysis. The results of the model CE-QUAL-W2, which used as input information the results of the model HEC-5, describe the possible water quality of the reservoir, according to parameters such as: dissolved oxygen, total solids, coliforms, phosphorus, ammonium, nitrates, nitrites, chemical and biochemical demand of oxygen and temperature. Although it is admitted that the available information was not suitable for the calibration of the model, the authors think that the results obtained for this application are useful for deriving conclusions about the quality of the water in the reservoir of Indio River and its possible effects on the quality of the water downstream from the dam. To be conservative, the authors used extreme hydro-meteorological events to simulate the worst-case scenarios for the water quality that might occur in the reservoir.

The principal conclusions of the water quality model for the Indio river reservoir (option 1) are (US Army Corps of Engineers. 2003):

i) Quality of water discharged downstream of the dam site: The concentrations of dissolved oxygen will be lower in the layers near the bottom and, more than at any other time, when the reservoir is filling, which could negatively affect the water quality and the aquatic ecosystems downstream from the dam; This situation could be improved by changing the depth of the water discharged; and

ii) Quality of the water that would be discharged into Lake Gatún: The concentrations of dissolved oxygen will not affect the lake; thus it is not considered necessary to change the depth of the water at the tunnel intakes.

To complement the conclusions obtained by this model, a series of analysis were carried out using the morphologic and metabolic parameters known to determine water quality conditions and the quality of the aquatic ecosystem in the tropical reservoirs. These aspects are described below, and in as much as it is possible, are discussed using the values obtained with the model and values obtained in the literature on the Panamanian reservoirs mentioned previously.

Nutrient loads

The intensity of the process of eutrophication depends on the mixing capacity of the water in the reservoir, at its average depth, the morphologic characteristics, the time of water retention and, especially, the nutrient load, of both point and non-point sources located upstream of the reservoir. Phosphorus is normally the limiting nutrient in the process of eutrophication in the majority of freshwater water bodies, due to the relation between supply and demand is lower than that for other nutrients, and for this reason it is used as the principal nutrient in the analysis to determine the risk of eutrophication

The possible nutrient load (phosphorus) from non-point sources to the reservoirs can be predicted from current land use and the coefficients of exportation for phosphorus, under every land use category. The coefficients of exportation used were defined for tropical countries by Salas and Martino[17]. The total phosphorus load is obtained by multiplying the areas for each land use by the coefficients of exportation. If the total phosphorus load is subdivided over the area of the reservoir, the surface unit contribution of this nutrient is obtained for the water body. Annex 4-B presents the calculations carried out to estimate the nutrient load in the reservoirs for each of the options.

The annual phosphorus load in grams per square meter in each of reservoirs varies from 0.05 to 0.57. The reservoir in the headwaters of the Indio River receives the highest load (0.57); next follow the reservoirs in Upper Indio (options 3 and 4) with loads of 0.33 and 0.36, respectively, and Indio 45-40 (option 2) with 0.20. The reservoir in Upper Teriá receives the lightest load (0.05).

Table 4-9
Phosphorus loads from non-point sources into the possible reservoirs in the ROCC under study

Options and Reservoirs	Reservoir Area (km^2)	Watershed Load(tons/year)	Reservoir Load (g/m^2/year)
1. Indio 80-40	45.6	4.15	0.09
2. Indio 45-40	20.94	4.15	0.20
3. Upper Indio 50-40	8.52	2.81	0.33
4. Upper Indio 45-40	7.84	2.81	0.36
5. Teriá	7.56	1.02	0.13
6. Upper Teriá	8.17	0.38	0.05
7. Indio Headwaters	1.10	0.63	0.57

Nutrient point sources include discharges of municipal agro-industrial wastewaters. Therefore, the possible point sources were estimated from the socioeconomic information that provide the

population and the quantity of existing domestic animals in the drainage areas associated with each reservoir (Annex 4-B).

Given that none of the population centers or industries in the Indio River watershed has sewage systems, there are no municipal or agro-industrial discharges directly to any body of water. Families rely on latrines and individual septic tanks and the wastes are buried in the soil. The number of penned cattle, pig and poultry is very small; as a result they also do not discharge directly to any body of water. The majority of the cattle, pigs and chickens are not slaughtered in the watershed. Furthermore, refuse (manure and hen droppings) is incorporated into the soil, or are stored in areas susceptible to runoff. In short, very little of the point nutrient discharges end up in water bodies. The principal sources of nutrients are likely to come from the washing of clothes (detergents) and the bathing (soap) of people who live near to the rivers, as well as from cattle that drink directly from the river.

Table 4-10 shows that the water option that has the greatest potential phosphorus load from point sources (0.457 grams/m^2/year) is the Upper Indio (options 3 and 4), followed by Indio - Options 1 and 2 (0.391), Upper Teriá (0.334), Teriá (0.330) and Indio Headwaters (0.255). Nevertheless, it is not possible to quantify the percentage of the entire phosphorus load coming from point sources that end up in the respective reservoirs. Basterrechea (1984) estimated that point sources represent about 20 % of non-point sources. Therefore, the sources indicated in Table 4-9, are multiplied by 1.2 (20 %), to estimate the entire load in each case.

Table 4-10

Phosphorus loads for point sources to the possible reservoirs under study

Reservoirs	Watershed Area (km^2)	Watershed Load (tons/year)	Reservoir Load (g/m^2/year)
Indio 80-40	386.69	151	0.391
Indio 45-40	386.69	151	0.391
Upper Indio 50-40	262.4	120	0.457
Upper Indio 45-40	262.4	120	0.457
Teriá	94.02	31.03	0.330
Upper Teriá	35.63	11.91	0.334
Indio Headwaters	60.86	15.49	0.255

Estimation of the probable trophic level

Once the probable annual phosphorus load (Lp) that would discharge into each reservoirs was calculated, the model developed by Salas and Martino (1991) was used to determine the concentration of phosphorus in the reservoir..

Annex 4-B presents the spreadsheet of the calculations used to estimate the average phosphorus concentration in the reservoirs. Table 4-11 summarizes the parameter values that determine the trophic level of the possible reservoir options under study.

Options 1 to 4 are reservoirs that would transfer water directly to Gatún. In option 12, catchment water would be transferred from one catchment to another. The phosphorus load that would be transferred from one reservoir to an other is estimated for this option, assuming the concentration estimated by the model and multiplied by the volume of water transferred, assuming that this is 90% of the annual average discharge, since a minimum of 10% would be discharged downstream of the dam as ecological flow. Option 11, water is transferred from reservoir to another but in the same catchment, for which it is not necessary to carry the mentioned calculation.

Table 4-11
Summary of the trophic level of the water options in the ROCC

Options	Lp g/m²/year[/1]	Z (m)	Lp/Z	Tw year	Phosphorous[/3] (mg/m³)	Transference[/2] (Mm³/year)	New load (t/year)
1. Indio 80-40	0.11	34.58	0.0032	1.94	0.0017		
2. Indio 45-40	0.24	19.29	0.0123	0.50	0.0025		
3. Upper Indio 50-40	0.40	14.86	0.0266	0.20	0.0027		
4. Upper Indio 45-40	0.43	11.02	0.0390	0.13	0.0028		
Teriá	0.16	37.70	0.0043	1.22	0.0017		
Upper Teriá	0.06	29.99	0.0019	2.32	0.0012		
Indio Headwaters	0.69	18.18	0.0378	0.10	0.0022	203.2	0.40
11. Teriá Catchment	0.16	37.70	0.0042	1.22	0.0016		
12. Teriá and Indio Headwaters	(0.40 + 1.02) / 7.56 =0.19	37.70	0.0050	0.65	0.0012		

[/1] values of the Table 4-9 multiplied by 1.2 (20 %), to take into account the load from point sources.

[/2] the annual average discharge by 0.9 (90 %), since 10 % is discharged downstream from the dam site (ecological flow).

[/3] Estimated as $Cp = (Lp \cdot Tw^{0.75}) / (Z \cdot 3)$. Where: **Cp** = estimated Phosphorus Concentration; **Lp** = annual Phosphorus load per surface unit area; **Z** = average reservoir depth; and **Tw** = duration of water detention.

In summary, the phosphorus concentration for each of the options varies from 0.0012 to 0.0028 µg/l. As seen in Table 4-11, options 1, 11 and 12 present the lowest concentrations (between 0.0012 and 0.0017 µg/l). Options 2, 3 and 4 present concentrations between 0.0025 and 0.0028 µg/l. When the options include a downstream diversion, a greater nutrient load can be expected.

For comparison, the phosphorus concentrations estimated by the same model for the Bayano and Alhajuela reservoirs are 0.0018 and 0.0030 µg/l, respectively. These values are somewhat greater than the estimates for the conditions in the watershed of the Indio River. As indicated previously,

Lake Gatún and the Alhajuela and Bayano reservoirs still present good quality and comparatively little risk of eutrophication after several years of operation.

Graph 4-1 shows the relation of the water options to phosphorus probability levels for tropical systems generally. According to this classification, all water options qualify as oligotrophic (i.e., relatively low nutrient levels) and it may be concluded that none of the water options, under current conditions, would present risks of rapid eutrophication. Nevertheless, the cutting of vegetation in areas that would be flooded is recommended, to minimize this source of nutrients into the water body and to prevent problems similar to the ones observed in the Bayano.

Estimated Chlorophyll content

Chlorophyll "a" is a parameter that measures the density of the phytoplankton. Chlorophyll can be estimated from the concentration of phosphorus, especially when the system is limited by this nutrient as seems to be the case in the water options considered in the Indio River watershed. Calculations were carried out using the model proposed by the CEPIS (1991) and the concentrations of chlorophyll "a" were estimated from the model are presented in Table 4-12.

Levels of chlorophyll for tropical lakes have limits of 15 and 35 μg/l for mesotrophic (i.e., medium levels of nutrients) and eutrophic states, respectively. Chlorophyll concentrations estimated for the individual reservoirs vary from 0.09 to 0.27 μg/l. Therefore, the results obtained confirm the low risk of eutrophication that exists for all the considered options. Options 1, 11 and 12 present the lowest concentrations (between 0.10 and 0.15 μg/l). Options 2, 3 and 4 show concentrations between 0.24 and 0.27 μg/l. Concentrations of chlorophyll "a" estimated by the same model for Bayano and Alhajuela are 0.16 and 0.29 μg/l, respectively.

Light penetration

Finally, the depth of light penetration in the water column was considered. In the majority of lakes and reservoirs, the depth where light penetration is 1% of the intensity at the surface determines the water layer where there is oxygen production as a product of photosynthesis during daylight hours. This depth is known as the light compensation point, beyond which there is no photosynthesis. The relation that defines the light penetration in water is a negative exponential that depends on the coefficient of light extinction in the water column, which can be derived from the concentration of chlorophyll.

Graph 4-1: Positions of the Indio River Catchment Water Options and the Bayano, Alhajuela and Gatún Reservoirs in relation to the Nutrient Status of Tropical Freshwater Ecosystems

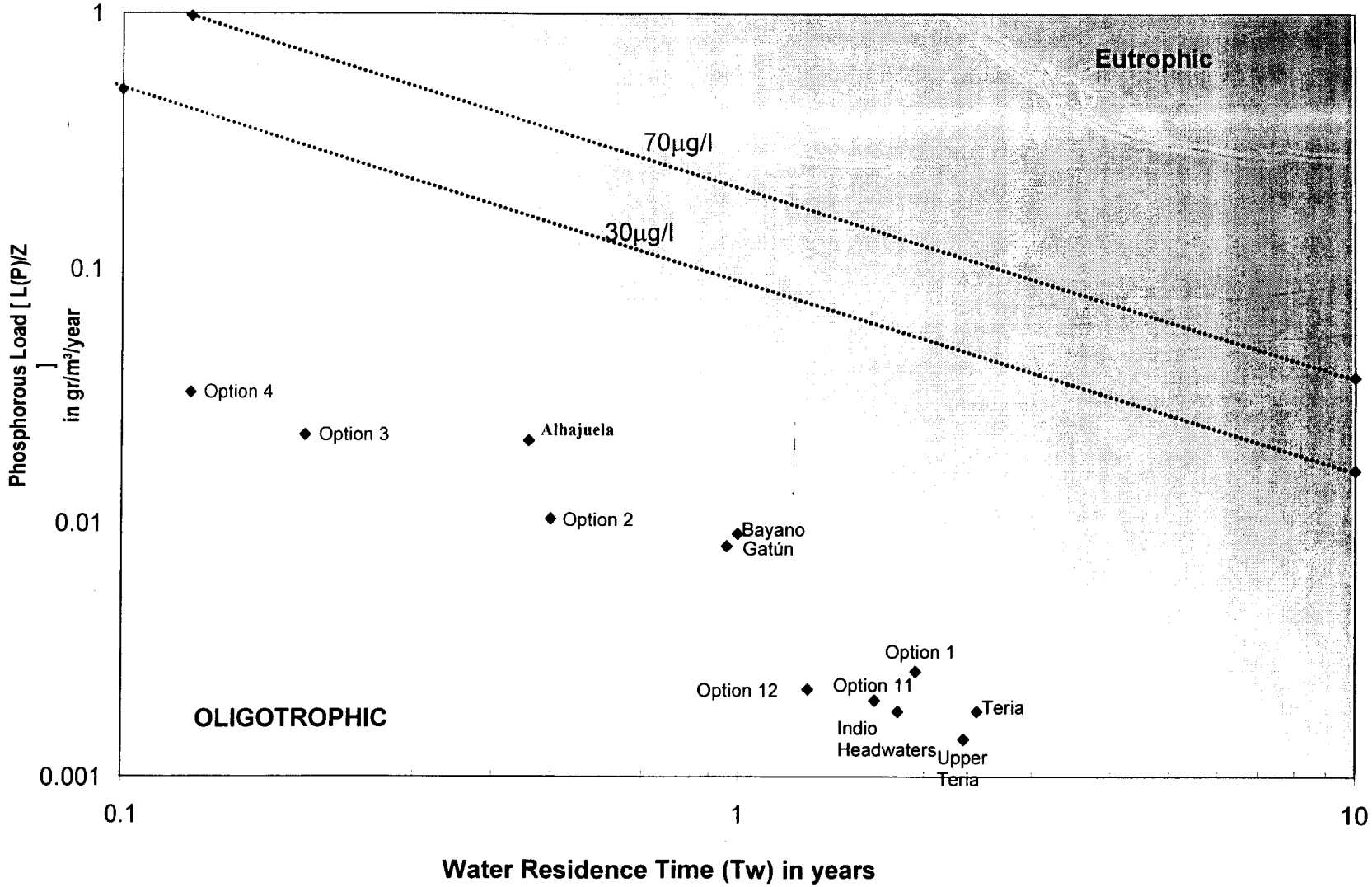


Table 4-12 below shows the depths where 1 % light intensity penetrates, as estimated from the model. The depths for all water options of the Indio River catchment show values for light compensation levels of over 15 meters. The depths estimated by the same model for Bayano and Alhajuela are 15.20 and 15.07 meters, respectively.

Thermal Stratification

The thermal stratification is a process that is observed in bodies of water by the formation of water layers of different densities, which are created principally by differences in temperatures. This separation into layers that are not completely mixed has important consequences in the metabolism of the reservoir and in its water quality, whose principal effect is a decrease in oxygen concentrations in the deeper part of the reservoir up to cases of complete anoxia.

Table 4-12
Summary of trophic levels for the water options in the ROCC

Options / Reservoirs	Phosphorus mg/m^3	Chlorophyll a[/1] mg/m^3	Light compensation Level (LCL in m)[/2]
1. Indio 80-40	0.0017	0.15	15.18
2. Indio 45-40	0.0025	0.24	15.10
3. Upper Indio 50-40	0.0027	0.26	15.07
4. Upper Indio 45-40	0.0028	0.27	15.06
Teriá	0.0017	0.14	15.22
Upper Teriá	0.0012	0.09	15.27
Indio Headwaters	0.0022	0.20	15.16
11. Teriá Catchment	0.0016	0.14	15.22
12. Teriá and Indio Headwaters	0.0012	0.10	15.27
Bayano Reservoir	0.0018	0.16	15.20
Alhajuela Reservoir	0.0030	0.29	15.07

[/1]. Chlorophyll "A" = 332 * $P^{1.21}$. Where P = phosphorus concentration (CEPIS, 1991).

[/2]. NCL = - ln (0.01) / k. Where: k = light extinction coefficient = 0.3 + 0.02 (chlorophyll "A" mg/m^3).

An aspect especially important to stratification is its stability, the period of time that the water body spends without completely mixing throughout the water column. In tropical lakes, periods of stratification and circulation do not present this regularity and depend principally on their morphologic characteristics, on extraordinary meteorological events, and on directed management actions.

To evaluate the possible dynamics of stratification and circulation, Muller and collaborators (1981) recommended the use of two indexes in reservoirs: the Froude densimetric number and the rate of water renewal. The values obtained for both indicators are shown in Table 4-13 and based on these it is possible to predict the development of a very stable thermal stratification in the case of the reservoirs that make up the different options that take advantage of the

hydrological resources of the Indio River watershed, due to their size and to their relatively long periods of water renewal. It is expected that the reservoir waters of Options 3 and 4 (Upper Indio) and the reservoir at the headwaters of the Indio River should circulate with a certain frequency, considering their comparatively low average depths.

Combining this information with the light penetration values, it expected that the position of the thermocline should be located at a depth of approximately 15 meters when the reservoir is stratified. Therefore, since the average depths of the reservoirs vary between 37.7 and 11 meters, it is expected that only part of the bottom of the reservoirs should be below the level of the thermocline. In other words, the thermal stratification will be clear only in the deepest levels of the reservoirs, below 15 meters. In case of Option 1 when the reservoir is at its normal operational maximum level (80 masl) the water volume below this depth would be 943 MMC or 60 % of the whole. Nevertheless, as the water level of the reservoir falls, this volume diminishes significantly and becomes only 102 MMC or 36 % of the entire volume at this level.

Levels and Distribution of Dissolved Oxygen

Oxygen is vital for most species, since the number of organisms that can survive by means of the decomposition of organic matter by anaerobic means is limited, especially among both the top plant and animal organisms. In fresh or continental waters, the distribution of oxygen is one of the principal limitations for the distribution of living species in the water body. For this reason, the concentration of oxygen dissolved in water is the most important parameter to be determined, because it indicates the "health" of the system.

The stratification of the water column marks significant differences in the content of oxygen in the depth gradient, because two large sections of the lake or reservoir are not mixed. In the lower part of the lake, the process of photosynthesis is not carried out and the dissolved oxygen is consumed by the process of respiration. When the demand for oxygen is high due to high levels of production in the epilimnion, as normally occurs in the eutrophic lakes and/or lakes where the period of stratification is very long, the water of the hypolimnion can become completely devoid of dissolved oxygen.

Table 4-13 Morphologic and Hydrologic Parameters of Reservoir Options and Catchment Areas Useful for estimation of the Dynamics of Stratification and Circulation in the Bodies of Water

									COMBINATIONS	
Options		**1**	**2**	**3**	**4**				**11[a]**	**12[a]**
		Indio River		**Upper Indio**		**Teriá River**		**Indio River**	**Teriá Catchment**	**Teriá River +**
Parameters	**Units**	**80-40**	**45-40**	**50-40**	**45-40**	**Teriá T-1**	**Upper Teriá T-2**	**Headwaters**	**T-1 + T-2**	**I. Headwaters**
Length	Km	27.6	22.8	14.5	14.5	7.6	7.7	3.5	7.6	7.6
Volume	Mm^3	1577	404	126.6	86.4	285	245	20	285	285
Reservoir Area	Km^2	45.6	20.94	8.52	7.84	7.56	8.17	1.1	7.56	7.56
Average Depth	M	34.58	19.29	14.86	11.02	37.7	29.99	18.18	37.7	37.7
Discharge	Mm^3/year	813.63	813.63	648.37	648.37	233.80	105.60	203.20b	233.8	376b
Residence Time	Years	1.94	0.50	0.20	0.13	1.22	2.32	0.10	1.22	0.76
Fraude Number[c]		**0.004**	**0.024**	**0.051**	**0.100**	**0.002**	**0.001**	**0.020**	**0.002**	**0.003**
Rate of Water Renewal[d]		**0.52**	**2.01**	**5.12**	**7.50**	**0.82**	**0.41**	**10**	**0.82**	**1.32**

[a] / For Options with more than one reservoir the calculations are based on the reservoir situated downstream.

[b] / it is assumed that 70 % of the flow of Indio Headwaters will be able to be transferred to the Teriá watershed.

[c] / The critical value of this indicator is 0.32 and values much greater than this are considered to be indicative that the reservoir will remain mixed most of the time, that is to say, that will not develop stratification. Values lightly less than 0.32 are indicative of stratification, but that this will be weak with several periods of circulation during the year.

[d] / The critical value of this indicator is 10. If the obtained value is greater than 20, it is believed that the reservoir will circulate, and if the value is less than 10 the reservoir will stay stratified. Values near 10 indicate that the reservoir supports a weak stratification.

The Depletion Rate can be estimated from chlorophyll concentrations by applying the relation used by the "Organización del Consejo de Europa" (OCDE)[1] and reported by Castagnino and Mendoza (1986). By applying this relation to the chlorophyll values mentioned above, the oxygen depletion values in the hypolimnion vary between 0.13 and 0.59 mg of oxygen per liter per month. In other words, during the year the consumption of oxygen is in the order of 1.56 to 7.08 mg/l. Assuming an initial river water oxygen concentration of 8.0 mg/l, a significant difference between Options is observed to exist since the period required for anoxic conditions to form varies between 1 and 7 years. In the case of the Indio River this is 3.9 years, for which it is believed that once the reservoir has stabilized there will not be a high risk of anoxia because at some water that arrives from the rivers is well oxygenated and will enter the hypolimnion and will help to reduce this deficit.

The results from the CE-QUAL-W2 model indicate that low oxygen concentrations would be expected at the bottom of the reservoir in Indio River (option 1), especially next to the dam site, where the discharge intake for the ecological flow will be, and to a lesser degree where the transfer tunnel towards Gatún will be. This situation is due partly to the greater depth that exists at the dam site with regards to the location of the tunnel intake. The low oxygen concentrations will be due to the demand of oxygen on behalf of the sediments, estimated at 1 gram O_2/m^2, at the water - sediment interface. Furthermore, the model estimates that during the period when the reservoir is filling, oxygen concentrations at the bottom will be less than those that will be reported when it is emptying. This is due to the circulation induced by the intake during the discharge process.

In order to predict what might be the behavior of the dissolved oxygen in the water column of the water options under study, what has happened in the Bayano reservoir is described next. The values of dissolved oxygen reported in the water column next to the Bayano dam site, between 1976 and 1996, indicate that the oxygenated layer did not exceed 10 meters, in a water column between 40 and 60 meters in depth[(52)]. During the dry season, the northern winds induce a turbulent diffusion of the oxygen in the water column of the reservoir, which affects depths up to 20 meters. When the intensity of the winds diminishes, the oxygenated zone retreats to depths of 10 meters or less.

The fact that all of the arboreal vegetation was not cut in the Bayano reservoir basin (only 30 % was cut) caused a deterioration of the quality of the water after the trees and the flooded vegetation decomposed[(52)]. The liberated nutrients of this decomposition process favored the development of floating aquatic plants that covered significant areas of the reservoir. This situation contributed to the anoxia at the bottom of the reservoir, to the presence of sulfuric acid

at different depths, and to the proliferation of aquatic plants. The presence of sulfuric acid has provoked corrosion in the iron and copper metallic parts of the mechanical and electrical installations. In Bayano, the sulfur that volatilizes from the turbine water precipitates on the facilities causing them to corrode. The water options considered in this study that contemplate the generation of hydroelectricity will have to take in account of this situation, as well as the expediency of cutting the arboreal vegetation. Candanedo and D'Croz (1983) indicated that the low oxygen situation at the bottom is considered to be transitory and depends on the quantity and nature of the submerged vegetation, the concentration of nutrients in the flooded soils, the flow and the quality of the tributaries and the rate of water renewal of the reservoir. In the last year reported for the Bayano reservoir (1996), the reservoir was still in transition after 20 years.

The maximum length of open water (fetch) is important to the production and size of waves and their effect on the oxygenation, since their continued and uninterrupted action of the wind on the surface of the water is indispensable for the formation of waves. The relatively large distances of open waters in the different water options, as well as the winds of average intensity and their direction, can be used to predict that big waves will be generated which will be important for the limnological behavior of the reservoirs.

In short, it is expected that in the water options considered in this study, there should appear an oxygenated layer in the first 10-15 meters of the water column and its depth will vary depending on the wind presence of certain intensity. The interpretation of this information suggests that there will be a water layer of approximately 15 meters or more of depth with conditions adapted for the growth of the fish and of other aquatic organisms that require aerobic conditions for their development and survival.

In summary, it is expected that there should be little risk of eutrophication and in general good water quality conditions for the Indio River watershed. A more or less stable thermal stratification is expected in the reservoirs with depths over 15 meters, which will be influenced by the presence of the winds, especially during the dry season. The water options that present a weakest stratification will have the greatest reoxygenation, which would allow them to have, in general, better conditions to decompose their load of pollutants.

Although critical water quality conditions are not expected once the reservoirs associated with the six options have become stable, it is advisable to have in place mechanisms to control their water quality. The location of the water intake structures must be flexible to be able to discharge water from several levels in order to induce or to restrict the circulation of the reservoir in order

to manage the quality of the reservoir water as well as the discharges downstream or towards the Lake Gatún watershed.

4.2.3.2.1.6 Quality of the water downstream of the dam

The low oxygen concentrations at the bottom of the reservoirs (anoxia) will cause the liberation of metals and other elements from the sediments. The fact that there is interest in the exploration and mining development in the watershed, demonstrates that metals are present and which might already constitute part of the sediments. Nevertheless, since there is no metal analysis of the sediments, it is not possible at this time to clarify this question.

Ammonium is a compound that is harmful to the fish and which can cause their death. Fish downstream from the dam can be adversely affected by the potentially high concentrations of ammonium in waters released from the dam. That is why water intakes at different depths, in order to guarantee that oxygen concentrations are not so low that they could provoke the stated problems, must be taken into consideration.

4.2.3.2.2 Possible indirect impacts

The possible indirect impacts are associated with the induced development that will happen in the Indio River watershed and its surroundings because of the development of the chosen option. If development does not operate within the framework of an integrated sustainable development management scheme that is in agreement with the biophysical limitations of the ecosystems, there can be consequences on the quality of the environment and additional socio-environmental risks for the safe operation of the chosen water option or options and for the well-being of the local communities can be introduced.

One of the most notorious indirect impacts could be the increase in the production rate of sediments in the watershed, estimated at 1.4 mm per year. Increasing deposition rates in the reservoir would mean the loss of capacity at a greater speed than currently. This is especially important if the spontaneous development and disorderly colonization that has happened until now continues without the benefits of a land use zoning plan for the Indio river watershed, directed at the protection and conservation of this water resources. For this reason, it is advisable to monitor the generation of sediments and the adoption of a zoning scheme and soil conservation practices that are appropriate for the biophysical characteristics of the watershed.

Another important indirect impact on the water quality of the Indio River could be the settlement of a greater number of people along both banks of the river downstream from the dam. The reduction of the downstream flow from the dam site might enable people of the area use the areas near to the Indio River for activities with greater permanence, due to the decrease of the fluctuations of flows and water levels throughout the year.

4.2.3.3 Comparison of options

The reduction of flood risks due to the effect of the attenuation of flows downstream from the dam sites will depend on the location of each one of the dam sites. The alternatives that have the dam sites at highest elevations (11 and 12) will involve the reduction of flood risks along a greater stretch of the river. Therefore, the reduction of the flood risks for Options 11 and 12 will include the longest stretch of river, Options 3 and 4, a lesser stretch of river, but greater than alternatives 1 and 2.

The effects caused by the reduction of the water levels and flow on the people who travel by motorboat and on aquatic organisms are considered to be opposite to that indicated in the previous paragraph. The water options located farther up-stream will have less affect because they regulate smaller volumes of water and, therefore, they will have less impact on transportation and/or aquatic organisms.

The deterioration in water quality of the principal river and its tributaries can result from the movement of earth if adequate and opportune measures to minimize runoff are not implemented. Therefore, the major water options will have a greater volume of earth movement and, as a result, greater potential consequences due to runoff. As such, Option 1 is the one that might result in the greatest runoff, followed in decreasing order by Options 12, 11, 2, 3 and 4.

Sedimentation is not predicted to be a potential problem under any of the options and consequently the need for dredging is not anticipated. The degradation of the riverbed downstream from the dam site is expected to be insignificant for all water options. For that reason, no work will be necessary to stabilize the river channel. In fact, it is probable that the accumulation of sediments will happen at the mouths of the rivers flowing to the Indio River, contributing to the stability of these riverbeds. Finally, as to the risk of eutrophication, although this is considered to be low for all options, the estimated concentrations of phosphorus and chlorophyll for the reservoirs of Options 1, 11 and 12 present the smallest values, followed by options 2, 3 and 4.

Table 4-14 summarizes the potential environmental impacts and risks to the water resources for each of the options. These impacts and risks are water level and flow downstream from the dam site, erosion and transport of sediments, risk of eutrophication of the reservoir, and water quality downstream from the dam site. The values assigned to each variable, in accordance with the criteria of URS specialists, show that options 1 and 2 are those which present the highest overall impact, while Options 11 and 12 present the lowest total values.

Table 4-14
Summary of the impacts to the water resources for the different water options, in the construction and operation phases, in the areas of direct and indirect influence

Options	Water level and flows, downstream	Transport and sedimentation	Risk of eutrophication	Water quality, downstream from dam	Total Score
1	3	2	1	1	7
2	3	1	2	1	7
3	2	1	2	1	6
4	2	1	2	1	6
11	1	2	1	1	5
12	1	2	1	1	5

1 = minor; 2 = medium; and 3 = major.

4.2.4 Air quality

The potential impact on air quality in the Indio River watershed and surrounding areas, as a result of the execution of one or more of the water options under study, can be grouped in two main categories: 1) the impacts that can be expected from the increase in the traffic and the movement of earth related to construction activities and 2) the impacts associated with the possible change in the incidence of forest fires.

<u>Impacts Associated with Traffic and Earth Movement</u>
The emissions coming from the tailpipes of the heavy vehicles can be highly polluting, especially in the case of diesel engines. The pollutants released are gases and particles that harm the health of the human beings in the following ways:

- Hydrocarbons (HC). These contain carcinogenic reagents such as the benzopyrene; its last derivative, peroxyacetyl nitrate (PAN) destroys plants and irritates the eyes.
- Carbon monoxide (CO). A gas resulting from incomplete combustion that can displace oxygen in the process of blood oxygenation and has a role in global warming.

- Suspended particles. These include dust raised by the movement of vehicles and the movement of earth. They irritate the eyes, nose and throat, affect photosynthesis when they stick to leaves, and diminishes agricultural and forest productivity.
- Sulfur Dioxide (SO_2). A gas resulting from the ignition of fossil fuels, principally oil and coal. It can affect the eyes and the mucous membranes. In combination with particles, it can form sulfuric acid in the lungs.
- Oxides of Nitrogen (NO_x). These gases form from the ignition of fossil fuels, principally diesel. They are highly poisonous, affecting the airways and increasing sensibility to pollen.
- Particles from the combustion of diesel. They have been catalogued as probable cancer causing agents and causes of respiratory illnesses.

Impacts on the Incidence of Forest Fires

It is known that the area under study belongs to one of the zones of the Republic with the greatest incidence of fires during the dry station, as registered in the Central American map of fire recurrence. The inundation of the reservoirs resulting from the implementation of some of the options under consideration would imply the elimination of forested land, which at present it is highly susceptible to the fires, be they caused by the nature or by the humans. As a consequence, the result would be an important local decrease in the emission of gases and/or compounds associated with combustion (CO, CO_2, and particles).

4.2.4.1 Potential Impacts during the Construction Phase

Both types of impacts discussed in the previous section can occur during the construction phase. The first one would be a consequence of the operation of the machinery and the second, an induced effect of the social and economic changes that can appear in the region.

4.2.4.1.1 Possible direct impacts

To determine the areas that could be affected by vehicle emissions, it was considered that the majority of the emissions would be located along the main roads and accesses to the project, as well as in the areas of quarries and work fronts. Based on the previous URS experience and on the principles of the dispersion gas and particles suspended in the air, it has been established that at a distance of 45 m on both sides of the roads permissible concentrations of atmospheric pollutants would be found, therefore it is assumed that the area of impact will not go beyond this 90-m "strip".

As soon as the area of impact was established, we proceeded to take into account those towns that would be negatively affected by the different alternatives. The following Table 4-15 shows the results of this exercise and indicates the number of towns that might be affected by the different types of work that form part of the alternatives.

Table 4-15
Number of Towns potentially affected by the Emissions of Combustion Gases and Particles by Alternative and Type of Work

Alternative	Type of Work					Total
	Roads	Dam	Quarries	Tunnel / Channel	Dikes	
1 - Indio 80-40	9	1	7	1	2	20
2 - Indio 45-40	10	1	7	1	0	19
3 - Upper Indio 50-40	6	1	5	1	0	13
4 - Upper Indio 45-40	6	1	5	1	0	13
11 – Teriá Catchment	5	1	0	3	0	9
12 - Upper – Indio Headwaters	7	2	0	3	0	12

Notes - Detailed tables listing the towns that would be affected by each alternative are presented at the end of the chapter.
Source: Elaborated by the authors with information from the Socioeconomic database for the ROCC and raster images of maps from the General Controller's office.

As can be seen in Table 4-15, Alternatives 1 and 2 would affect the air quality of a slightly greater number of towns than other alternatives considered in the Indio River watershed. When air quality is analyzed, it is important to consider who will be affected. Table 4-15 indicates the number of towns that would be affected; nevertheless it does not mention such sensitive affected targets such as churches, schools and health centers. Using the available information in the socioeconomic database of the study area, the number of sensitive locations that would be affected by each alternative was determined and presented in Table 4-16.Even if alternatives 11 and 12 affect the smallest number of towns, they affect the greatest number of sensitive locations.

Table 4-16
Number of Targets Sensitive to Air Quality Impacts by Alternative

Alternative	Type of Infrastructure			Total
	School	Church	Health Center	
1 - Indio 80-40	1	1	0	2
2 - Indio 45-40	1	1	0	2
3 - Upper Indio 50-40	0	0	0	0
4 - Upper Indio 45-40	0	0	0	0
11 – Teriá Catchment	2	3	1	6
12 - Upper – Indio Headwaters	3	4	1	8

Source: Elaborated by the authors with information from the Socioeconomic database for the ROCC

The mitigation measures associated with these impacts should include the spraying of water on the construction roads and work fronts for the control of dust and the periodic systematic maintenance of the work vehicles. These measures are described in detail in the next chapter (Environmental Management Plan).

4.2.4.1.2 Possible indirect impacts

Just as the options being considered are likely to have effects derived from vehicle traffic and the movement of earth, principally during the construction phase, there may also be effects due to changes in the incidence of forest fires in the area.

The induced development that will be generated after the construction of any of the water options will result in an increase of the number of vehicles in the region. Nevertheless, it is believed that the increase in traffic will not be significant compared with the traffic generated by the project during this construction phase.

4.2.4.2 Potential Impacts during the Operation Phase

4.2.4.2.1 Possible direct impacts

The increase in vehicle traffic during the operation phase due to the project is predicted to be minimal, given that this will involve only operation and maintenance personnel vehicles.

Nevertheless, the presence of the projects themselves, and especially of the bodies of water that would be part of any of the options that may be chosen, would limit the surface susceptible to forest fires. Therefore, it is expected that their incidence should diminish for this reason.

4.2.4.2.2 Possible indirect impacts

Although the water bodies would reduce the land areas susceptible to forest fires, better access to the area might intensify human activity, deteriorating even more the forests remnants. The alteration of the vegetation coverage (from forest to grassland or stubble) might contribute even more to the fires in the area. Therefore, while at first glance, the water options might appear to have a positive effect on the emission of combustion gases, there exists a high risk that the fires would be intensified as result of greater human presence and activity in the area.

Due to what has just been indicated, the mitigation activities for the water options will have to include measures for the reduction of potential fires, by means of reforestation programs and the control of settlements induced by options under consideration.

On the other hand, it is considered that the development induced by the project during the operation phase will also contribute with an increase in vehicle traffic. This traffic increase might be of greater importance during this stage because the traffic generated by the project will be minimal.

4.2.4.3 Comparison of options in relation to their potential impact on air quality

Table 4-17 summarizes the socio-environmental impacts and potential risks to air quality, relating to vehicle traffic, the movement of earth, and forest fires. The values assigned to each variable, in accordance with the criteria of URS specialists, show that Options 1, 2 and 12 are those which present the greatest potential for impacts, followed by Option 11, and then Options 3 and 4.

Table 4-17
Summary of the impacts on air quality for the different water options, in the phases of construction and operation and in the areas of direct and indirect influence

Options	Impact of vehicle traffic and of the movement of earth in:		Incidence of forest Fires	Total
	Towns	Sensitive locations		
1	3	1	2	6
2	3	1	2	6
3	2	0	2	4
4	2	0	2	4
11	1	2	2	5
12	2	2	2	6

1 = minor; 2 = medium; and 3 = major.

4.2.5 Potential Impact on Noise Levels

The construction activities associated with the water options would imply the use of heavy equipment for the transfer of materials and the movement of earth; as well as other equipment like compressors, generators, vibrators and shredders, among others, which would contribute to a temporary increase in noise levels.

The noise generated by the circulation of vehicles and trucks, is due principally to the interaction between wheels and the ground, and the condition of the engine. To express the noise produced

by the traffic, the levels of sound pressure are used at a fixed distance from the axis of the road. The unit used for the level of sound pressure are decibels A (dBA), which express the sensibility of the human ear to the noise.

The determination of the area of influence for noise was accomplished through the analysis of the following variables: estimated speed of operation and the daily volume of heavy truck traffic. Using the methodology of the U.S. Department of Housing and Development - Noise Assessment Guidelines for noise caused by vehicle traffic - it was assumed that the daily volume of trucks would not exceed 500 and that the speed would not exceed 60 km/h. The indicated guidelines assume that the vehicles travel at 55 miles / hour (88 km / hour) for which a correction factor is applied to the number of trucks per day. This factor is 0.53 and on applying it to 500 vehicles per day a value of 265 trucks per day is obtained. Nevertheless, the methodology used also recommends that a correction be made for road slope; the greater the slope the greater the noise effect will be. Assuming average slopes on the order of 3 %, the correction factor to use is 1.7, which results in 450 trucks per day. Using "Workchart 2 - Heavy Trucks" of the mentioned guidelines, it is possible to determine the daily volume of trucks traffic, as well as the desired average diurnal-nocturnal noise level. Using an average diurnal-nocturnal noise level of 60 dB as the desired value for the exterior of a target structure, the effective necessary distance (from the target of the noise to the center of the street) will have to be approximately 80 m. Therefore, to evaluate those targets that would be affected one way or another, a strip 160 m wide (80 m on either of the center of street) was utilized.

4.2.5.1 Potential Impacts during the construction phase

During the construction phase the potential impacts, both direct and indirect, are associated mainly with the environmental noise generated by vehicle traffic.

4.2.5.1.1 Possible direct impacts

Once the affected area was established, we proceeded to take into account those towns that would be negatively affected by each of the different alternatives. As can be seen in Table 4-18, the location of the towns, access roads and work areas would be the same as those described for the possible effects on the air quality; Alternatives 1 and 2 have greatest potential affects.

Table 4-18
Quantity of Towns Affected by Noise by Alternative and Type of Work

Alternative	Type of Work					Total
	Roads	Dam	Quarries	Tunnel / Channel	Dikes	
1 - Indio 80-40	12	1	12	1	2	28
2 - Indio 45-40	15	1	12	1	0	29
3 - Upper Indio 50-40	6	1	5	1	0	13
4 - Upper Indio 45-40	6	1	5	1	0	13
11 – Teriá Catchment	5	1	0	3	0	9
12 - Upper – Indio Headwaters	8	2	0	3	0	13

Note - Detailed tables listing the towns that would be affected by each alternative are presented at the end of the chapter.
Source: Elaborated by the authors with information from the Socioeconomic Study of the ROCC and raster images of maps from the General Controller's office.

When the theme of noise is analyzed, it is important to consider those who are the targets. Table 4-18 indicates the number of towns that would be affected, nevertheless the sensitive targets such as churches, schools, health centers, and, in particular, dwellings are not mentioned. Using the available information in the socioeconomic database of the study area, the number of sensitive targets that would be affected by each alternative was determined and is presented in Table 4-19.

Table 4-19
Number of Targets Sensitive to an Increase in Noise Levels by Alternative

Alternative	Type of Infrastructure			Total
	School	Church	Health Center	
1 - Indio 80-40	1	2	1	4
2 - Indio 45-40	1	2	1	4
3 - Upper Indio 50-40	0	1	1	2
4 - Upper Indio 45-40	0	1	1	2
11 – Teriá Catchment	2	3	1	6
12 - Upper – Indio Headwaters	3	4	1	8

Source: Created by the authors with information from the Socioeconomic Database of the ROCC

While Alternatives 1 and 2 affect the greatest number of towns, Alternatives 11 and 12 affect the greatest number of sensitive recipients.

The mitigation measures associated with these impacts must include the control of the schedule of vehicle traffic, vehicle speed, periodic systematic maintenance of work vehicles, and, in some very particular cases, the use of sound barriers.

4.2.5.1.2 Possible indirect impacts

The induced development that will be generated alongside the construction of any of the water options will result in an increase of the number of vehicles in the region. Nevertheless, it is

believed that the increase in traffic will not be significant compared with the traffic generated by the project during the construction phase.

4.2.5.2 Potential Impacts during the Operation Phase

In the operation phase, the sound levels emitted by the water options components are added at the noise levels associated with vehicle traffic. Nevertheless, since the use of large internal combustion engines is not anticipated, noise levels are expected to be relatively modest.

4.2.5.2.1 Possible direct impacts

The increase in noise from vehicle traffic during the operation phase due to the project is expected to be minimal, since there will be only operation and maintenance personnel vehicles. Nevertheless, waste disposal and hydroelectric generation equipment can require the establishment of dampening areas between them and the location of the sensitive targets described previously.

4.2.5.2.2 Possible indirect impacts

It is believed that the development induced by the project during the operation phase will also contribute to an increase in vehicle traffic and, in consequence, in sound levels. This vehicle increase could be more important during this stage because the traffic generated by the project will be minimal.

4.2.5.3 Comparison of options

Table 4-20 summarizes the potential environmental impacts and risks to towns and targets sensitive to noise. The values assigned to each variable, in accordance with the criteria of URS specialists, show that options 1, 2 and 12 are those that present the greatest potential impacts. The mitigation measures associated with these impacts will have to include the control of vehicle traffic schedules, vehicle speed, periodic systematic maintenance of work vehicles, and, in very particular cases, the use of sound barriers. These measures are described in detail in the next chapter (Environmental Management Plan).

Table 4-20
Summary of noise impacts for the different water options, during the construction and operation phases and in the areas of direct and indirect influence

Options	Impact of vehicle traffic on:		Total
	Towns	Sensitive targets	
1	3	2	5
2	3	2	5
3	2	1	3
4	2	1	3
11	1	2	3
12	2	3	5

1 = minor; 2 = medium; and 3 = major.

4.3 Potential Impacts on Biological Diversity

The socio-environmental impacts and potential risks on biological diversity are intimately related to the transformation of environment in construction sites and, in the case of areas that would be covered by water, permanent flooding. The construction of a dam and the resulting flooding of upstream areas will result in the loss of the terrestrial vegetation and the conversion of terrestrial habitat to aquatic habitat.

In addition, the presence of the dam itself will establish a barrier for the free movement of those organisms that need several habitats along the fluvial ecosystem in order to complete their life cycles. On the other hand, the presence of the reservoir itself provides a new habitat to be colonized by species capable of adapting to it. Finally, the reduction of the flow of water and sediment and the changes in the quality of the water, downstream from the reservoir sites can change the salinity gradient and the frequency of flooding that determine the distribution of species in estuaries and coastal zone ecosystems.

4.3.1 Terrestrial Vegetation Communities

The construction of auxiliary facilities, such as access highways, support areas for the construction, pumps and tubes, will affect both the terrestrial flora and fauna. These impacts can appear during the construction as well as the operation phase, although the relative importance of each one is different for each case.

4.3.1.1 Potential Impacts during the Construction Phase

The construction phase is when possible impacts to the terrestrial vegetation communities will be most evident as the result of the elimination of the vegetation that is currently present in those

places where facilities will be constructed and the areas that will be flooded. Furthermore, the elimination of additional areas of existing vegetation may result from the development induced in the project area of influence.

4.3.1.1.1 Possible direct impacts

Therefore, the direct impact on the terrestrial vegetation communities is a function of the areas necessary for the development of each of the considered options. To determine the areas that would be affected by each, we overlayed the description of each one of the six options over the vegetation coverage map (Tables 4-7-12). This exercise generated an estimate of the area affected by each option and its components and is summarized in Table 4-21.

Table 4-21
Number of Hectares Affected by Vegetation Type

Description	Forest	Pasture	Stubble	TOTAL
Indio River				
Roads	18,92	45,17	27,41	**91,50**
Reservoir 80-40	984,26	1731,3	1347,3	**4062,86**
Reservoir 45-40	377,93	812,3	573,3	**1763,53**
Upper Indio				
Reservoir 50-40	188,08	331,1	212,1	**731,28**
Reservoir 45-40	173,21	301	193,3	**667,51**
Teriá				
Roads	0,00	6,67	2,55	**9,22**
Reservoir	13,72	17,74	132,63	**164,09**
Upper Teriá				
Roads	7,88	20,3	7,59	**35,77**
Reservoir	66,39	3,95	346,96	**417,30**
Indio Headwaters				
Roads	11,34	23,72	14,99	**50,05**
Reservoir	0,34	0	22,9	**23,24**
Earth Borrow Sites	126,32	118,39	204,32	**449,03**
Sand Quarry	10,85	30,08	15,1	**56,03**
Fluvial Deposits	7,66	13,52	48,17	**69,35**
Total Roads	144,83	161,99	267,59	**574,41**
Options	**Forest**	**Pasture**	**Stubble**	**Hectares**
1. Indio 80-40	1148,01	1938,46	1642,30	**4728,77**
2. Indio 45-40	541,68	1019,46	868,30	**2429,44**
3. Upper Indio 50-40	351,83	538,26	507,10	**1397,19**
4. Upper Indio 45-40	336,96	508,16	488,30	**1333,42**
11. Teriá Catchment	224,94	183,68	747,18	**1155,80**
12. Teriá + Indio Headwate	236,62	207,40	785,07	**1229,09**

Source: Database of the 'Estudio de Recopilación de Datos Socioeconómicos, 2003.'
Note: This table only reflects the surface affected for three soil use types. Consequently, the total surface for these three uses does not equal the surface area of the reservoir.

The six options considered in the Indio River basin will affect an area that varies between 1,155 hectares (Option 11) and 4,728 hectares (Option 1) of vegetation due to the flooding of the reservoir, the access roads and the area for quarries and borrow pits for construction materials. It is important to point out that an effort was made to define the possible access roads for each options, nevertheless, the area for quarries and earth borrow sites were taken from the feasibility

study for the Indio River 80-40 (Option 1), which represents an approximate area of 574 hectares of vegetation that would be affected. It is assumed that a similarly sized area would be affected by any of other options and, therefore, this value was added to the totals obtained for each alternative.

In terms of impact importance from the point of view of the terrestrial communities, it is necessary to take in account the type of vegetation that is being affected for each alternative. The majority of the area in the Indio River watershed is covered by pastures and stubbles. From an ecological point of view, the principal effect of the different options is the additional loss of natural vegetation. The forested areas are more valuable for biological diversity than the areas of bushes and stubbles. The forested area that would be affected by each of the alternatives is less than the areas of the other coverage types considered in this analysis (pastures and stubbles). The natural coverage of mature forest has been severely diminished in the region, leaving only a mosaic of highly fragmented patches of forest.

In terms relative of the total area to be affected, the six alternatives present the same pattern (Table 4-22): the majority of the area to be affected (34.73 % to 64.65 %) is currently covered by stubble vegetation, followed by pastures (15.89 % to 41.96 %), and mature forest (19.25 % to 25.27 %). The relative weight of the percentage of forest to be affected by the different options is significantly less than the percentage of the entire area of the Indio River watershed (10,146.9 hectares).

Table 4-22
Percentage of the Entire Area Affected for Each Option

Option	Forest	Pasture	Stubble
1. Indio 80-40	24.28%	40.99%	34.73%
2. Indio 45-40	22.30%	41.96%	35.74%
3. Upper Indio 50-40	25.18%	38.52%	36.29%
4. Upper Indio 45-40	25.27%	38.11%	36.62%
11. Teriá Catchment	19.46%	15.89%	64.65%
12. Teriá + Indio Headwaters	19.25%	16.87%	63.87%

Between 224 and 1,148 hectares of forest will be affected, depending on the alternative that is implemented. The alternative that includes a greatest amount of affected forest is Option 1 (Indio River 80-40). For all options, the number of hectares of stubble to be affected is greater than the number of hectares of forest. The affected area covered by pasture is also greater than the surface covered by forest for four of the six options.

Resolution No. AG-0235-2003 establishes the tariff to be paid for ecological indemnification, for cutting permissions, and the elimination of forests, stubbles and pastures. These are payments that the developer, in this case the ACP, would have to make to ANAM. The tariffs are B/. 5,000 per hectare of felled forest, B/. 1,000 per hectare for the cutting of stubbles (secondary young forest), and B/. 500 per hectare for the elimination of grasslands. Table 4-23 shows the calculations and payments that must be made for the cutting and elimination of arboreal vegetation and shrubs. The compensation costs for the cutting of the different types of vegetation go from around B/. 6.8 million for option 1, followed by options 12, 11 and 2, between B/. 4.4 and 3.7 million and options 4 and 3 with B/. 2.5 million, approximately.

Table 4-23
Payments in Concept of ecological indemnification for each option

Description	Forest	Cost	Pasture	Cost	Stubble	Cost	TOTAL	Total Cost
Indio River		5,000		500		1,000		
Roads	18.9	94,600.0	45.2	22,585.0	27.4	27,410.0	**91.5**	**144,595.0**
Reservoir 80-40	984.3	4,921,300	1,731.3	865,650	1,347.3	1,347,300	**4,062.9**	**7,134,250.0**
Reservoir 45-40	377.9	1,889,650	812.3	406,150	573.3	573,300	**1,763.5**	**2,869,100.0**
Upper Indio	0.0		0.0		0.0			
Reservoir 50-40	188.1	940,400	331.1	165,550	212.1	212,100	**731.3**	**1,318,050.0**
Reservoir 45-40	173.2	866,050	301.0	150,500	193.3	193,300	**667.5**	**1,209,850.0**
Teriá	0.0		0.0		0.0			
Roads	0.0	0	6.7	3,335	2.6	2,550	**9.2**	**5,885.0**
Reservoir	13.7	68,600	17.7	8,870	132.6	132,630	**164.1**	**210,100.0**
Upper Teriá	0.0		0.0		0.0			
Roads	7.9	39,400	20.3	10,150	7.6	7,590	**35.8**	**57,140.0**
Reservoir	66.4	331,950	4.0	1,975	347.0	346,960	**417.3**	**680,885.0**
Indio Headwaters	0.0		0.0		0.0			
Roads	11.3	56,700	23.7	11,860	15.0	14,990	**50.1**	**83,550.0**
Reservoir	0.3	1,700	0.0	0	22.9	22,900	**23.2**	**24,600.0**
Borrowing Pits	126.3	631,600	118.4	59,195	204.3	204,320	**449.0**	**895,115.0**
Sand Quarry	10.8	54,235	30.1	15,040	15.1	15,100	**56.0**	**84,375.0**
Fluvial Deposits	7.7	38,300	13.5	6,760	48.2	48,170	**69.4**	**93,230.0**
Total Roads	144.8	724,135	162.0	80,995	267.6	267,590	**574.4**	**1,072,720.0**
							TOTALS	
Options	**Forst**	**Cost**	**Pasture**	**Cost**	**Stubble**	**Cost**	**Hectares**	**Balboas**
1. Indio 80-40	1,148.0	5,740,035	1,938.5	969,230	1,642.3	1,642,300	**4,728.8**	**8,351,565.0**
2. Indio 45-40	541.7	2,708,385	1,019.5	509,730	868.3	868,300	**2,429.4**	**4,086,415.0**
3. Upper Indio 50-40	351.8	1,759,135	538.3	269,130	507.1	507,100	**1,397.2**	**2,535,365.0**
4. Upper Indio 45-40	337.0	1,684,785	508.2	254,080	488.3	488,300	**1,333.4**	**2,427,165.0**

Description	Forest	Cost	Pasture	Cost	Stubble	Cost	TOTAL	Total Cost
11. Teriá Catchment	224.9	1,124,685	183.7	91,840	747.2	747,180	**1,155.8**	**1,963,705.0**
12. Teriá + Indio Headwaters	236.6	1,183,085	207.4	103,700	785.1	785,070	**1,229.1**	**2,071,855.0**

4.3.1.1.2 Possible indirect impacts

The induced development that will be generated by any of the water options could contribute to an increase in the rate of land use change and in consequence, the cutting of the different types of vegetation. The cutting of the arboreal vegetation would have major negative effects on the terrestrial communities.

4.3.1.2 Potential impacts during the Operation Phase

The potential impacts on the vegetation coverage and the terrestrial flora during the operation phase are somewhat different, since the removal of vegetation for causes directly attributable to the project no longer exists. Nevertheless, the indirect impacts resulting from induced development still persist.

4.3.1.2.1 Possible direct impacts

Direct impacts will not be generated during the operation phase, since maintenance tasks not require them. Nevertheless, there could be hunting and the collection of plants and live animals, as well as illegal or unauthorized settlements in the area of the project.

4.3.1.2.2 Possible indirect impacts

The induced development that might occur during the operation will be similar for all water options. The possible impacts associated with this development are associated with the elimination of additional areas of vegetation as greater population levels are established in the watershed and the areas adjacent to it.

It also is possible that the minor flow of water downstream of the dam sites during the operation phase could affect the conditions of some coastal ecosystems such as the mangroves and the wetlands. Nevertheless, according to the habitat map prepared using the compilation of environmental and cultural information, these types of ecosystems are very limited in the Indio River Watershed and the adjacent area of influence. So limited in fact, they could not be mapped at the scale of 1:50,000 in which the map was prepared.

4.3.2 Terrestrial Fauna Diversity

The development of one or more of the water options to support the enlargement of the Panama Canal might adversely affect the terrestrial fauna diversity in the Indio River Watershed. The majority of the impacts can be reduced and mitigated by means of ecological restoration to compensate for the caused effect, but some negative potential impacts (for example, on rare or in danger of extinction species) must be avoided at all costs during the project planning.

The majority of ecosystems are extremely adaptable to human intervention, if and when the basic conditions of the climate, availability of nutrients and species composition are not completely lost. Based on this consideration, the negative impacts of the development on ecosystems can be considered to be unrecoverable if the conditions that prevent the reestablishment of the aforementioned ecosystems persist. In this way, the construction and creation of reservoirs that flood terrestrial habitat constitute an irreversible commitment of these terrestrial resources. The local extinction of species is perhaps the most serious and irreversible impact and the one that is considered to be generally unacceptable. The proposed water options will flood terrestrial habitat that has a relatively low value and that is not vital for any species listed as rare, threatened or in danger of extinction.

In general, forest, and especially mature forest, is the most important type of habitat for native species. Species that inhabit highly humanized ecosystems such as pasture and stubble areas are relatively common and they are well represented and distributed because their habitat requirements are generalized. The animals that are ecologically important for their specialized role and influence in the functioning of the ecosystem and that contribute most to the general biodiversity concentrate in areas of little-disturbed forest. The rare and threatened species of the region also normally live in mature forest, although they can use disturbed areas to obtain part of their food. The relatively small areas of evergreen forest in the highest parts of the Indio River Watershed are among the least disturbed areas of the watershed and, therefore, they are currently the most diverse and important ecosystems of the project area.

Because of the high degree of human intervention, including agricultural soil uses in the lowest parts of the watersheds, much of indigenous fauna that once inhabited the original forest are already absent. From a global ecosystem perspective, the food chain has been highly modified and ecological properties such as biodiversity and the normal processes of circulation and transport have been greatly diminished. The compilation of recent information regarding these disturbed habitat areas inside the watershed, which consists of areas potentially affected by the flood, identifies the presence of mammals, principally small species such as weasel, sloth,

armadillo, paca, coatimundi, squirrels, and a variety of insectivorous and frugivorous bats. The only large mammals reported in the area are the white-tail deer (*Odocoileus virginianus*) and the red brocket (*Mazama americana*).

Species that require dense forest covering (for example, monkeys, various species of bats, and rodents) and the larger carnivorous animals such as the jaguar *(Panthera onca),* the cougar *(Puma concolor),* and the ocelot *(Leopardus pardalis)* are scarce or absent. The introduced and domestic species (for example, chickens, cows, and goats) are the species that inhabit this disturbed habitat near human dwellings. Agricultural use has simplified the structure of the habitat and reduced the diversity of plants species, limiting even more the diversity of animal species.

The relocation of human populations that will be displaced from areas that will be flooded by the reservoirs will cause some additional degree of deforestation. Furthermore, the availability of better access to the region also would favor human disturbance in areas currently covered by forest. The species and groups of animals that would be expected to be most affected by the execution of one or more of the water options include:

- Arboreal mammals and birds including monkeys *(Aotus lemurinus, Alouatta palliata),* several species of bats and macaws that need mature forest cover;
- Large predators such as the cougar and the jaguar;
- Highly specialized species of birds, mammals, reptiles, amphibians, and invertebrates that are adapted to the structural complexity and biological diversity of the mature evergreen broad-leaf forest; and
- Large herbivores such as deer and tapir.

The absence of these species, which play an important role in several functional groups of regional food chains, could create instability in ecosystem organizational processes (for example, adverse effects on nutrient cycles) in addition to direct effects on the species and stated groups.

4.3.2.1 Potential impacts during the Construction Phase

The construction of a dam and the consequent flooding of areas upstream results in the loss of terrestrial habitat and in the conversion of terrestrial habitat to aquatic and coastal habitat. The construction of auxiliary facilities, such as access roads, areas of support to construction, and tunnels, also directly affect the terrestrial habitat of animals. While the loss of the habitat would

negatively affect the majority of terrestrial fauna species, the creation of lakes will provide additional habitat for such waterfowls as the herons, egrets, ducks and geese. This effect, nevertheless, would be more evident during the operation phase of the water options.

4.3.2.1.1 Potential direct impacts

The direct environmental impacts on the terrestrial fauna are principally a result of habitat loss. Some additional impacts may come from noise during construction and operation. Some direct impacts on terrestrial fauna will be irreversible, but generally insignificant because of the poor quality of the habitat that supports a low level of diversity, incomplete food webs, and the general absence of important predators or rare, threatened or endangered species in the majority of the areas that would be potentially affected. On the other hand, the options might provide some ecological positive impacts (for example, habitat increased for waterfowl), that must be considered in the general evaluation of impacts.

Of special consideration among the impacts to the terrestrial fauna is the death of relatively slow moving species (some amphibians and reptiles) that cannot escape the area that will be cleared for the construction and flood. In addition to these slow moving species, this includes the immature young of other species of greater mobility (birds, mammals). To reduce this effect to the minimum possible, it is necessary to implement a fauna rescue and salvage program during the construction phase and the filling of the reservoir.

4.3.2.1.2 Potential indirect Impacts

There exists the risk of additional indirect impacts as result of unsustainable activities as hunting, which must be prevented at all costs. If these impacts are not controlled, they can become more significant than the direct impacts of the flood. The induced development that will be generated by the project, especially during this phase, is also a threat to the fauna. Among these indirect development impacts that can affect terrestrial fauna populations and the biodiversity in adjacent areas and during later periods can be mentioned fires, erosion, and sedimentation from the construction of roads as well as areas that are disturbed by them.

4.3.2.2 Potential impacts during the Operation Phase

The impacts for the terrestrial fauna and its diversity during the operation phase are expected to be, in general terms, of lesser magnitude than during the construction phase, especially those that can be directly attributed to the actions of the water operation.

4.3.2.2.1 Potential direct impacts

During the operation phase, project activity diminishes significantly and, as a result, the effects on the fauna will be minimal. The project work vehicles are expected to sporadically collide with animals on the roads, but this is anticipated to be an infrequent and minor impact.

4.3.2.2.2 Potential indirect impacts

The induced development that will be generated by the project even during the operation phase, although on a smaller scale than during the construction phase, would affect the fauna. On the other hand, the options might provide some positive ecological impacts, such as the creation of new habitat for birds and other aquatic vertebrates in the reservoirs. This habitat might be especially valuable for species of crocodile and caimans.

4.3.3 Aquatic vegetation communities

The construction of reservoir results in the conversion of terrestrial habitat into aquatic habitat. These new aquatic habitats present opportunities for the establishment of communities of aquatic plants, fish, and other organisms that are better adapted to the new conditions. On the other hand, the presence of the reservoir and the dam, as well as the water diverted out of the watershed, modifies the hydrologic regime of the downstream sections of the river and its relation with the wetlands that typically exist in the flood plains. In this section, the potential effects that the development of the possible water options would have on the vegetation and the aquatic fauna are described in this section.

There are two principal aspects of the possible impacts and risks associated with the aquatic vegetation. The first one is the survival and distribution of the species and the other is the risk that aquatic weeds may affect the operation of the water bodies that are created according to the chosen alternative. The uncontrolled proliferation of these communities of aquatic plants can create negative biological effects as well as operational effects for the reservoir.

The creation of tropical dams or reservoirs is often accompanied by an excessive and uncontrolled proliferation of aquatic weeds, as in case of the floating fern *(Salvinia* spp.) in the African lakes of Kariba, the water hyacinth (*Eichhornia* spp.) in Lake Lempa (El Salvador) and in Apanas (Nicaragua), and *Pistia stratiotes* in Lake Bayano.

In general, there is little information about the aquatic plants in Panamanian reservoirs, Candanedo (1978) and Von Chong (1986) being the most relevant publications on this topic. Table 4-24 shows the families and species of aquatic plants reported by the Consortium TLBG/UP/STRI for the Indio River and its tributaries. In the watershed of the Indio River, the current altitudinal distribution of aquatic species suggests that only two species are located inside the area of the future reservoir: the Areaceae *Spathiphyllum quindiuense* and the Cychlantacea *Dicranopygium crinitum.* Nevertheless, more than 20 other species are in the watershed and they might possibly become established in the reservoir.

Spathiphyllum quindiuense might proliferate significantly in the reservoir since it usually grows in the margins of the reservoirs (0 - 3m), including, on occasion, large extensions of water and preventing free navigation. *Dicranopygium crinitum* might establish in some areas, but it is anticipated that it will not prosper since this species grows principally in habitats near to currents, between the rocks exposed to currents, but not submerged. In the up-stream zones from the future reservoir, two other species *Sagittaria platyphylla* and *Heteranthera reniformis* exist, which can colonize the shores of the reservoirs in shallow depths.

Based on the experience and of Panamanian and other tropical reservoirs, it is anticipated that the species *Pistia stratiotes* (water lettuce), *Eichhornia crassipes* (water hyacinth), and *Hydrilla verticillata*, which have great infestation potential, constitute a latent and potential danger for the reservoirs that are part of any of the options.

In general, the littoral zone of the lakes and reservoirs constitute suitable habitat for the development of the aquatic plants. Therefore, as a manner of evaluating the range of habitat that can be available for the proliferation of these organisms, the length of the perimeter of each one of the water bodies that can form individually or in association with another selected water option was estimated.

Table 4-24
Species of Macrophytes and their Altitudinal Distribution in the Indio River

Family	Species	Altitudinal Distribution (m)	Indio
Alismataceae	*Sagittaria platyphylla*	20	X
Apiaceae	*Hydrocotyle bonariensis*	600	X
Araceae	*Montrichardia arborescens*	20; 30	X
Araceae	*Pistia stratiotes*	20	X
Araceae	*Spathiphyllum friedricsthalli*	20; 30	X
Araceae	*Spathiphyllum sp.*	20; 200	X
Araceae	*Spathiphyllum quindiuense*	600; 160; 105	X

Family	Species	Altitudinal Distribution (m)	Indio
Araceae	*Spathiphyllum phryniifolium*	160	
Brassicaceae	*Nasturtium officinale*	600	X
Cyclantaceae	*Dicranoyigium crinitium*	600; 200	X
Cyclantaceae	*Dicranopygium wedelli*	160	
Cyperaceae	*Eleocharis geniculata*	30; 450	
Hydrocharitaceae	*Hydromystria laevigata*	600	X
Hydrocharitaceae	*Hydrilla verticillata*	30	
Nymphaeaceae	*Nymphaea blanda*	20; 160	X
Onagraceae	*Ludwigia helminthorrhiza*	20	X
Podostemaceae	*Marathrum alleni*	600	X
Podostemaceae	*Maranthum haenkeanum*	450	
Podostemaceae	*Marathrum oxycarpum*	200; 500	
Podostemaceae	*Tristicha trifaria*	160	
Pontederiaceae	*Eichhornia crassipes*	20; 30	X
Pontederiaceae	*Heteranthera reniformis*	600; 200	X
Pontederiaceae	*Pontederia rotundifolia*	20; 30	X
	Total:		16

This information is summarized in Table 4-25. The relevancy of this parameter is due to the fact that the greater the perimeter the greater the possibility that aquatic plants find places suitable for their development. In order to compare options the perimeter was subdivided by the area of each reservoir. Another way of evaluating the susceptibility of the shore in every reservoir to the development of aquatic plants is the comparison of the perimeter with that of a circle of equal area. This criterion, called "Littoral Development" provides a relative index that permits the comparison between several alternatives. In general, the greater the littoral development, the greater is the potential for the colonization of bodies of water by aquatic plants.

In Bayano, macrophytes invaded the reservoir three weeks after having been filled[52]. From the filling of the reservoir up to beginning of the 1980s, the area that aquatic plants covered was around 7,000 hectares, *Pistia* being the dominant species (5,000 ha). In 1999, when a study was carried out by Berger, the area was between 3,000 and 3,500 ha, being *Pistia* and *Polygonum* which covered the largest surface area (about 1,000 ha for each).

Table 4-25
Morphometric Characteristics of the Reservoirs

Options	Indio (80-40)	Indio (45-40)	Upper Indio (50-40)	Upper Indio (45-40)	Teriá	Upper Teriá	Indio Headwaters
Perimeter (km)	*182.9*	*96.6*	*36.8*	*38.1*	*39*	*58*	*10*
Perimeter/area Reservoir (km/km^2)	*4.0*	*4.6*	*4.3*	*4.9*	*5.2*	*7.1*	*9.1*
Perimeter Development	*58.38*	*35.47*	*12.65*	*14.73*	*16.01*	*32.77*	*7.23*

The methods used for the control of aquatic weeds in Bayano have been mechanical, natural and chemical. The latter method has been used when the population density of macrophytes is high and the surface area involved is large. In the years 1976, 1977, 1978 and 1982 air fumigation was used because the population of weeds was great[52].

Therefore, it is believed that for the water options in the ROCC, even with cutting the majority of the arboreal vegetation, at the beginning there will be a proliferation of aquatic plants, which, as in case of Bayano, will have to be controlled until its surface and population have been reduced to manageable quantities. In the country, there is successful aquatic plant management experience.

4.3.3.1 Potential impacts during the Construction Phase

The impacts associated with the proliferation of aquatic plants are not expected to significantly appear during the construction phase, because their development requires the presence of the water body itself, which would not yet be present.

4.3.3.1.1 Potential direct impacts

It is considered that aquatic plants will not proliferate during the construction phase. As has already been mentioned, in Bayano the plants arose three weeks after the reservoir had formed.

4.3.3.1.2 Potential indirect impacts

The induced development that will occur in the watershed as a consequence of the construction of the project will not contribute to the proliferation of aquatic plants during this phase of the project. If there were significant changes in land use with resultant increases in the use of agrochemicals, these could introduce nutrients into the water bodies and favor the proliferation

of aquatic plants. Nevertheless, even in this case, the effects of this growth would be notable once the reservoir is formed.

4.3.3.2 Potential impacts during the Operation Phase

The incidence of aquatic weeds in the newly formed reservoirs is expected, especially during the first years of the operation phase. The possible direct and indirect effects related to this aspect are presented next.

4.3.3.2.1 Potential direct impacts

The uncontrolled proliferation of aquatic plants can create negative effects on the operation of the reservoir. This excessive growth of aquatic plants can go so far as to affect the intake of water for the diversion or ecological flow. Equally, the constant rain of vegetative material coming from these same plants, especially in the emergent macrophytes, provokes the accumulation of organic waste on the bottom, which also reduces the presence of oxygen, acidifies the pH of the surrounding water, and helps to accelerate the process of eutrophication.

It is probable that in the first years the system will be affected by floating plants (water lettuce and water hyacinth) that are dispersed easily by the action of the wind and are favored by the high levels of nutrients typical of the stabilization phase of the reservoir. Nevertheless, in the long term, if the process of eutrophication advances more or less slowly, a change would be expected towards a predominance of *Hydrilla*. With a quite transparent water column, it is possible that *Hydrilla* will become established in those areas of the reservoir with depths less than 10 meters.

Although the fluctuation of water levels in the reservoir could have a harmful effect on their growth, it is expected that the same ones should always be present. This is the case in Lake Gatún where the species is widely distributed. Nevertheless, in the specific case of Options 1 and 2, for which the structure of the intakes is known, it is not expected that *Hydrilla* can prosper in the surrounding area due to the depth of the water that would be well over 10 meters of depth for the greater part of the year, which constitutes the distribution limit of this species.

4.3.3.2.2 Potential indirect impacts

This excessive proliferation of aquatic plants can have negative consequences also on public health, human activities, and the aquatic fauna in general. A common effect of the weeds in the reservoirs is the obstruction of the navigation canals and the increase in the sedimentation. Some aquatic plants are vectors hosts of pathogenic organisms for humans; they increase the organic matter in decomposition and diminish the aesthetic value of the area where they appear. Once there is an uncontrolled increase of aquatic plants there is also an increase in their decomposition, through the action of aerobic bacteria, which results in the deoxygenating of large extensions of water in the reservoir, which reverberate negatively on the populations of fish and macro invertebrates.

Large quantities of weeds or aquatic plants can negatively affect tourist and recreation activities in reservoirs. For example, the formation of enormous masses of weeds such as water hyacinth, water lettuce and *Hydrilla* can prevent the free and rapid mobilization or navigation in the waters of the reservoir. The proliferation of aquatic plants can also result in, as a direct consequence, the increase of insect populations such as mosquitoes, sandflies and gadflies, which are an inconvenience during any recreational activity in these environments.

4.3.4 Fish and Aquatic Macro-invertebrates

Although in Panama they have built diverse reservoirs since the beginning of the last century, little is known about their impact on the aquatic fauna and flora that existed previously in the dammed rivers. The most outstanding, post-reservoir evaluations are the ones carried out on Lake Bayano[14] and Lake Fortuna[39], the work on the ecology of Lake Gatún published by Zaret and Paine (1973), and the study of the ichthyofauna of Lake Alhajuela and its tributaries realized by Briceño (1981). This information was used to evaluate the probable impacts on the aquatic fauna and flora of the water options currently under study.

The species of fish and macro-invertebrates reported in the Indio River and some of their characteristics are included in the Annex 3. All the species of fish can be found at diverse elevations in the Indio River and its tributaries, without showing definite patterns, with the exception that a great majority is found in the zones below 100 masl. Also is interesting that some species such as the *Poecilia gillii, Sycidium altum, Astyanax aeneus*, are found from 0 m up to altitudes above 1,000 m. In the Indio River 35 species were reported. The current approximate elevations of the dam sites are less than 10 masl for Indio River and Upper Indio,

less than 60 masl for Teriá, less than 200 masl for Upper Teriá and less than 260 masl for the Indio Headwaters.

The previous experiences at Bayano, Gatún, and Alhajuela demonstrate that the omnivorous families Characidae, Poeciliidae and Cichlidae, in contrast to other families present in the area, will rapidly increase their populations in the reservoir since they possess a high rate of egg production and usually spawn several times a year. The presence of the carnivorous *Gobiomorus dormitor* will turn out to be benefited by the increase of prey (minnows and young fish) in the shores of these lakes, for which its populations will also increase, but not in the same proportion or efficiency as the families mentioned previously, since they usually reproduce once per year. Of the species of fish that travel the rivers, it is believed that 23 species will remain in the Indio River reservoir and its tributaries.

On the Pacific as well as the Caribbean sides of Panama, there exist fish that travel the rivers to grow and then to return to the sea or brackish waters to spawn, among them can be counted the snooks (Centropomidae), the 'bocachicas' and dajaos (Mugilidae), the gobids (Gobiidae) and the grunts (Haemulidae). In the Indio River it is estimated that 4 species of fish will disappear upstream from the reservoir. The species that would disappear upstream from any of the options are Sycidium altum (Gobiidae) and *Agonostomus monticula* and *Joturus pichardi* (Mugilidae), and Centropomus sp. (Centropomidae). Although these species of fish do not constitute the primary source of protein for the inhabitants of the area, represent a supplementary source by the which are of alimentary importance moderate. Since the ecological point of view can be mentioned that these species are found in other basins of the Panamanian Caribbean for which the impact would not be considered as critical. Nevertheless, the disappearance of a species of a basin is not a desirable aspect in a water project.

In relation to the crustaceans, these are found from the lower zones up to the highest parts of the rivers of the ROCC; The palemonid shrimp and the pseudotelphusid crabs can be at all altitudes, from sea level to the highest parts of the region. On the other hand, the atyids, can be found in the lower areas (20 to 30 m) but never close to the estuaries zones. The snail *Melanoides tuberculata* is found at all elevations.

The impacts expected from the creation of one or more reservoirs in the Indio River Watershed on the populations of fish and aquatic macro-invertebrates will show up mainly over the long term during the operation phase of the selected water option. These are mainly associated with the physical barrier of the dam that restricts their movement above and below of the river and for the reduction in flow of the stretch of the river downstream from the dam. On the other hand, the

creation of a new environment provides additional habitat for some already existing species in the hydrographic system and others that surely will come.

4.3.4.1 Potential impacts during the Construction Phase

As was indicated previously, the majority of the impacts on populations of fish and aquatic macro-invertebrates are expected to occur during the operation phase. Nevertheless, during the construction phase it will be necessary to contain and divert the river, creating an obstacle that, in terms of the species mobility, is very similar to the presence itself of the dam. These effects are described next.

4.3.4.1.1 Potential direct impacts

The principal direct impact caused by the presence of a physical barrier that can be impassable for some migratory species is that these species disappear from the river upstream from the site where the barrier is located. This effect is expected to happen in the case of the execution one or more of the water options considered for the Indio River Watershed.

It is believed that 5 species of fish will disappear upstream in the Indio River partly due to the physical obstacle that will prevent their free upstream passage. The remaining species of marine fish reported in the rivers will not disappear since they will be downstream from the dam sites. In relation to the macro-invertebrates, five species of fresh water shrimps will be candidates for disappearing from the area of the reservoir and its principal tributaries: *Macrobrachium carcinus, M. crenulatum, M. acanthurus* (Palaemonidae), A*tya scabra,* y *Potimirim glabra* (Atyidae). Likewise to the fishes, these species represent a supplementary source of food for the residents of the area for which are alimentary importance moderate.

Based on previous studies, some of the species currently found would not be found beyond the dam site, partly due to the physical obstacle that will prevent their free upstream passage. The gobids species (*Sycidium altum* and *Awaous banana*), the mugilids (*Agonostomus monticola* and *Joturus pichardi*), and the haemulid (*Pomadasys crocro*) need to remain in brackish waters at periods in their lives, especially when they are larvae or postlarvae; if the connection of the river and the sea is interrupted, these fish will be adversely affected. It is clear, as the results from Bayano show, that the diadromous fish fauna (that move between the sea and the fresh water) in general tend to disappear from waters above dam sites. It is believed that 5 species will disappear upstream in the Indio River. The rest of the species of marine fish reported in the rivers will not disappear since they will be downstream from the dam sites.

Based on the experience of Bayano and having compared it with the macro-invertebrate found in the rivers of the ROCC, it is believed that the fresh water shrimp of the family Palaemonidae (*Macrobrachium carcinus*, *M. acanthurus* and *M. crenulatum*) and of the family Atyidae (*Atya scabra* and *Potimirim glabra*) will be candidate species for disappearing from the area of the reservoir and its principal tributaries.

The species of special interest to the scientific community, *Roeboides* sp. nov. and *Rivulus* sp. have been found in the rivers of the ROCC. These two species of scientific importance are associated with the small gorges and creeks located upstream, characterized by having crystalline waters and a river surface covered by gallery forests and with moderate currents and depths. These habitats will still remain even with the reservoirs, which will guarantee their existence.

4.3.4.1.1 Potential indirect impacts

There exists the risk of additional indirect impacts as result of such unsustainable activities as uncontrolled fishing, including the use of dynamite, which must be prevented at all costs. The induced development that the project will generate, especially during this phase, is also a threat for the aquatic fauna.

4.3.4.2 Potential impacts during the Operation Phase

The majority of the potential impacts on the populations of fish and aquatic macro-invertebrates would happen during this phase since they are mainly related to the presence of the reservoir and the reduction of flows associated with the water transferred to the Lake Gatún watershed.

4.3.4.2.1 Potential direct impacts

The direct effects of the execution of the water options on the aquatic fauna communities (fish and invertebrates) are discussed next, with priority given to the following aspects:

- species that would disappear upstream from the proposed reservoirs;
- species that would remain in the reservoir and its tributaries;
- effects on the populations downstream from the dams;
- effects on the fishing productivity; and
- effects on species of special interest.

4.3.4.2.1.1 Species that would disappear upstream from the proposed reservoirs

This topic has already been discussed in relation to the construction phase. The impact or impacts expected during the operation phase are similar to those previously described although perhaps with greater intensity because the physical barrier that the species would have to go over is of greater width.

4.3.4.2.1.2 Species that are expected to remain in the area of the reservoir and its tributaries

One of the most perceptible impacts of the creation of the reservoirs is a drastic decrease in biological diversity or number of fish species, which can be momentary or permanent. In reference to the Panamanian experience, it was shown that the creation of the Bayano reservoir had a negative impact on the community of native fish that inhabited the river. Before the flood, 26 families and 61 species of fish species were found; only 6 families and 13 species survived the change from lotic (river) to lentic (lake) habitat[11]. In other words, 79 % of the native river fauna disappeared or could not adapt to this change in ecosystems. Nevertheless, the fish species that are not found in the reservoir are still reported in the "periphery", which is to say, in its tributaries and downstream from the dam site.

Based on the evaluations carried out in Bayano, Gatún and Alhajuela lakes, it is believed that 23 species of the Indio River will remain in the resulting lacustrine zone and its tributaries. These species belong to the families Cichlidae (cichlids), Characidae (river sardines, 'sábalos pipones'), *Erythrinidae* (bodianus), *Loricariidae* (armored suckermouth catfish), *Poeciliidae* (livebearing tooth-carp), *Eleotridae* (sleepers), *Synbranchidae* (mud eels), *Hypopomidae* (knife fish), *Rivuliidae* (killies), and *Trichomycteridae* (parasitic catfish).

The species that will rapidly colonize or will adapt to the reservoir are characids including *Astyanax aeneus, Brycon chagrensis, Brycon obscurus, Compsura mitoptera, Gephyrocharax intermedius, Hyphessobrycon panamensis, Roeboides guatemalensis, and Roeboides sp* nov, the cichlid *Aequidens coeruleopunctatus*, the eleotridae *Gobiomorus dormitor*, and the poeciliids *Poecilia gillii* and *Brachyrhaphis cascajalensis*. The majority of these are omnivorous feeders and this presents a major advantage in the colonization of new environments because they use diverse sources of food and are capable of tolerating aquatic environments with very adverse conditions.

Of the 12 species believed to be able to colonize or adapt to the reservoir, 9 of them will be able to share the shores zones of little slope and medium depth (0.30 m to 2 m), generally covered by

aquatic and terrestrial weeds, and near the mouths of the gorges and rivers *(Astyanax aeneus, Brycon chagrensis, Compsura mitoptera, Gephyrocharax intermedius, Roeboides guatemalensis, Roeboides sp* nov, *Aequidens coeruleopunctatus, Poecilia gillii,* and *Brachyrhaphis cascajalensis).* On the other hand, *Gobiomorus dormitor* will associate with deeper zones (2 to 4 m) since it is a carnivorous species, but with benthic and cryptic habits, remaining hidden during the day. The species *Brycon obscurus, Bryconamericus emperor, Hyphessobrycon panamensis, Brachyrhaphis roswithae, Brachyhypopomus occidentalis, Piabucina panamensis, Synbranchus marmoratus* and *Trichomycterus striatus*, will live more associated with areas of the rivers and gorges with currents with slow to medium speeds and they will not enter the reservoir.

D'Croz and Del Rosario (1983) determined that the creation of Lake Bayano resulted in the disappearance of 10 of 12 species of benthic crustaceans and mollusks that existed in the fresh waters of the Bayano River. Only a species of palemonid shrimp *Macrobrachium tenellum* and a species of crab (*Trichodactylus sp.*) belonging to the family Pseudothelphusidae managed to survive the new reservoir. The first cause of their disappearance was the change in the flow and regime of the river, given that in the area of the reservoir the rapid and well-oxygenated currents, favorite habitat of shrimps, were eliminated. The second cause is related to the construction of the dam, since as in the fish, the shrimp that were upstream from the dam site could not get to the brackish, waters necessary to complete their life cycle.

Based on experience at Bayano, the only species of crustacean that is expected to survive upstream from the dam is the crab *Pseudothelphusa americana*, since its life cycle does not require salt water. Despite the reported presence of *Macrobranchium tenella* in the Bayano reservoir after the closing, it is believed that none of the shrimp species will survive in the reservoir since they need salt water to complete their life cycles. In case of the mollusks, the snail *Melanoides tuberculata* will see its populations affected in the zone of the reservoir, since its preferred habitat will be eliminated, which is the margins of the rivers. Nevertheless, due to its capacity for adaptation to different altitudes, it could be that populations *M. tuberculata* and *P. americana* establish in the zones beyond the maximum level of the new reservoir.

Possible effects from the fluctuations of the level of the reservoir

The water level fluctuations caused by dam operations are another important aspect that the ichthyofauna of the possible reservoirs will have to deal with. As a general rule, all the fish inside the reservoir are going to be negatively affected if the changes are very sudden, especially those that use the shores, submerged trunks and aquatic weeds to lay eggs, such as the characids and the cichlids, since their eggs or larvae can become exposed to the air and perish. An example of these changes can be observed in actuality in Lake Alhajuela where levels can drop as much

as 4 meters a month or raise 2 meters per month; In the 4-month dry season, the reservoir level drops about 10.5 meters, which are recovered in 8 remaining months. These changes turn out to be significant for the populations of fish that live there.

In the Indio River option, during the 4 months (February to May) of dry season, a water transfer of $43m^3/s$ into Gatún is estimated, which will cause the level of the reservoir to go down, and during the remaining rainy months the reservoir will be filled again. If the reservoir is at a level of 80 meters at the end of January, and if at the end of May it is to 45 meters, it is estimated that it would drop by 35 meters in 4 months, which would be equivalent to 9 meters per month or 30 centimeters daily, value that is much greater than reported for Alhajuela.

The changes in volume in the reservoirs will not greatly affect the macro-invertebrates, since in general they are not on the shores of the reservoir, but in the gorges or in the gorges' benthic zone.

4.3.4.2.1.3 Potential effects on the species downstream from the dam site

The consequences of the decrease and regime change of the flow downstream from the dam will affect species like *Agonostomus monticola, Joturus pichardi, Sycidium altum, Awaous banana, Brycon chagrensis, Ancistrus chagresi,* and *Pomadasys crocro*, which usually require a significant current, a situation that will force them to shelter in creeks or gorges downstream from the dam sites, or to go farther downstream where the flow comes closer at its original level. The only related experience from Panama is the ecological evaluation of the creation of Fortuna Lake on the Chiriquí River. Species diversity has not been affected in large proportions or notably modified. Common species such as the poecilids and erythrinids, and also some peripheral species, were still surviving in these sites five years after the closing of the dam.

Many species of fish will adapt and survive the consequences of the decrease and regime change of the flow downstream from the dam. The changes to populations of fish downstream from the dams are not anticipated to be drastic, since before reaching the mouth to the sea, there will remain between 31.2 km and 85.2 km of river habitat, a situation that will favor those species in search of survival alternatives. All the populations of shrimp species which live in water systems downstream from the dam will suffer the effects of the reduction and change of the downstream flow and will seek refuge in the gorges or rivers that drain into the principal river bed, and will re-colonize these waters once the normal flow of the river is established. Therefore, it is considered that downstream from the new reservoirs the situation will be similar to that indicated

for Fortuna, where the fish species previously mentioned apparently adapted themselves to the changes of flow.

The alteration caused to the fish populations downstream from the dams will be reduced as a smaller quantity of watershed water is regulated and transferred. That is to say, that the possible impact on these species is inversely proportional to the distance between the location of the dam and the sea and to the percentage of the entire watershed that would be isolated by the dam. The distance from the sea to the potential dam sites is 31.2 km at the site of Tres Hermanas (Options 1 and 2), 38.7 km in the case of Upper Indio (Options 3 and 4), 52.7 km for Teriá, 66.5 km for Upper Teriá and 85.2 km for the Indio Headwaters.

In case of the shrimps, the populations of all species that live in the water systems downstream from the dam will suffer the effects of the reduction and change in the flow regime. Goodyear (1982) reported the massive and disorientated migration of the species *Atya crassa* 1 km downstream from the Bayano dam, an event that was a product of the decrease of the flow from beginning of its filling. In spite of the temporary suspension that the ecosystems will suffer downstream, the species present in these ecosystems, such as the palaemonids and atyids, in the rivers of the ROCC will remain associated or will seek refuge in the gorges or rivers that drain into the principal river bed and will again re-colonize these waters once the normal flow of the river is established. This event was observed in the crustacean populations downstream from the Fortuna dam[27].

4.3.4.2.1.4 Effect on the fishing productiveness

If the reservoirs are well managed, fishing (traditional and commercial) in them can produce sustainable yields and simultaneously can be used to generate activities as the tourism (sports fishing) which would turn out to be beneficial to human populations. In this respect, it has been estimated that independently of their location, size, height, morphology, etc., Panamanian reservoirs can generate yields between 4.8 and 5.3 kg / ha / year. (Bayley, 1986; Maturell and Bravo 1994; Jackson and Marmulla, 2002). Taking these potential yields and multiplying them by the area of the future reservoirs gives and estimation of the productivity of the potential reservoirs; Indio (80-40) 4,560 hectares; Indio (45-40) 2,094 hectares; Upper Indio (50-40) 852 hectares; Upper Indio (45-40) 784 hectares; Teriá, 756 hectares; Upper Teriá, 817 hectares; and Indio Headwaters, 110 hectares.

Table 4-26
Potential Productivity of the Possible Reservoirs in Kilograms per Year

	Indio (80-40)	Indio (45-40)	Upper Indio (50-40)	Upper Indio (45-40)	Teriá	Upper Teriá	Indio Headwater
Yield (kg / year)	22,800	10,470	4,260	3,920	3,780	4,085	550

The introduction of exotic species such as tilapia (*Oreochromis niloticus*) and the peacock bass (*Cichla monoculus*) to the new reservoirs affects native fish, since these possess neither the reproductive potential nor the necessary rate of growth to assure considerable quantities of individuals. If the native species are analyzed, those that can be used for subsistence fishing and local consumption, they are very few and they include 'sábalo pipón' (*Brycon chagrensis*), and the sleeper (*Gobiomorus dormitor*). These species show many disadvantages (intramuscular spines, appearance of the fish, flavor of the meat and slow growth) compared with the exotic species, elements that would limit the potential use of the reservoir for fishing. Considering this reality, it is believed appropriate that, once the reservoirs are built, to incorporate in the management program the controlled sowing of tilapia (*Oreochromis niloticus*), an exotic species that has adapted well to Gatún and Alhajuela and where, in actuality, there are approximately 3,011 fishermen involved (Z. Trottman, personal communication DINAAC - MIDA, 2003). In this respect, since the year 1997 the capture of tilapia in the reservoirs of the country represents a growth activity for the national economy. In 1997, 63,339 kilograms of tilapia were exported, of which 95 % came from the Bayano and Alhajuela lakes[63].

4.3.4.2.1.5 Possible effects on species of special interest

According to the baseline study in the ROCC, there were 15 fish species reported that have some degree of nutritive importance in the Indio River. Nevertheless, the inhabitants have access to other sources of animal protein and do not completely depend on these aquatic resources for their survival. The greatest dependency on these resources (fish and macro-invertebrates) is accentuated during the period of Lent and Holy Week. It is not expected that the availability of these species will be negatively affected. On the contrary, the availability of fish can significantly increase with the introduction of species such as tilapia and peacock bass, previously discussed.

On the other hand, as it was previously indicated, two new species, *Roeboides* sp. nov and *Rivulus* sp. have been reported in the rivers of the ROCC. These two species of scientific importance are associated with the small gorges and creeks located up-stream, characterized by having crystalline waters and a riverbed covered by gallery forests with moderate currents and

depths. This habitat will still remain even with the reservoirs, which will guarantee their existence. A similar experienced was experienced in Lake Bayano with the endemic species of sardine *Eretmobrycon bayano* which was living in the gorges and rivers of crystalline waters. Although the majority of these areas were flooded or altered by the creation of the reservoir, in the actuality there are still populations in the tributaries of this reservoir.

4.3.4.2.2 Potential indirect impacts

The induced development that the project will generate even in this phase, although to a lesser degree than during the construction phase, might affect the aquatic fauna. On the other hand, the controlled sowing of tilapia can represent an income for the local and national economy.

This commercial fishing combined with the sports fishing can be a sustainable alternative production for those communities that will be relocated near the reservoirs. In this way, it is suggested that sport or recreational fishing be encouraged, using the peacock bass (*Cichla monoculus*) species that has been found in the canal reservoirs since 1967 and is a very profitable alternative, which simultaneously will help to control the excessive growth of tilapia in these reservoirs since the peacock bass is an efficient predator.

4.3.5 Comparison of the water options on the Biological Diversity

None of the anticipated impacts and potential risks on biological diversity is sufficiently significant to prevent the execution of the chosen alternative. Table 4-27 summarizes the impacts and potential risks to biological diversity, characterized by the terrestrial communities (vegetation and fauna) and aquatic communities (plants, fish and macro-invertebrates).

Table 4-27
Summary of the impacts on biological diversity by the different water options in the phases of construction and operation.

Options	Impact on terrestrial communities on:		Impact on aquatic communities on:		Total
	Vegetation	Fauna	Vegetation	Fauna	
1	3	3	3	2	11
2	1	2	2	2	7
3	1	1	1	2	5
4	1	1	1	2	5
11	2	3	2	1	8
12	3	2	2	1	8

1 = minor; 2 = medium; and 3 = major

The values assigned to each variable, in accordance with the criteria of URS specialists, show that option 1 is the one that presents the greatest potential impact, then options 12, 11 and 2; and the least potential impacts correspond to options 3 and 4.

In case of terrestrial communities, the comparative evaluation of the options suggests that Options 1, 11 and 12 would cause the greatest impact on the terrestrial fauna due to the levels of forest affected; Option 2 continues in importance due to the same reason of the area of forest that would be affected; and finally Options 3 and 4 are those which affect least amount of forest.

In summary, due to the fact that the direct impacts of the development of the water options would affect relatively small portions of degraded terrestrial habitat and only small areas of the ecologically valuable habitat, there are many opportunities to mitigate the direct effects of the development and to prevent, minimize and compensate the impacts and potential risks.

4.4 Potential Impacts on the Socioeconomic and Cultural Aspects

The precise estimation of the possible socioeconomic impacts from the execution of one or more of the water options considered in the watershed of the Indio River is important for several reasons. First, because the ACP has the intention and the responsibility for compensating and appropriately indemnifying the people displaced by the infrastructure and proposed flooded areas. Second, because the perception exists that the principal beneficiaries of the enlargement of the Canal are producers and urban consumers, completely leaving out the population directly affected by the above-mentioned expansion. Third, because there is the need to clarify the confusions that stem from the use of false or inaccurate information with regard to the negative impacts of the Canal Enlargement Plan, or on the distribution of the direct benefits of employment and revenue during the construction phase. Finally, the ACP needs to objectively estimate the socioeconomic impacts to be able to obtain external financing from development banks.

This section describes the socioeconomic potential impacts for each one of the six options that are being considered in the Indio River Watershed. The estimation calculated for these impacts is principally based on the information compiled from the following sources:

a. Information from the Department of Agricultural Development, CLICAC, the Institute of Agricultural Marketing, IDIAP and other institutions.
b. Information processed from the Agricultural and Economic Census and the Directory of Establishments.

c. The Social Accounting matrix for the Western Region of the Canal Watershed elaborated by URS[1].
d. Primary Information gathered in the ROCC by the URS team in 2003.
e. Information processed by the URS team from the calculation of the water surface and its geographical coverage.
f. Socio-cultural study of the zone elaborated by Abt Associates and Planet Panamá[2].

The general impacts of the water options that are being considered in the Indio River Watershed would be of the following principal forms:

a. Increase in the water supply and reliability of the Canal;
b. Impact on employment and revenue in the work zones of the water options;
c. Impact on commerce and marketing;
d. Impact related to population displacement;
e. Impact on social and community cohesion;
f. Reduction or elimination of agricultural production and services in the flooded areas;
g. Risks to public health; and
h. Impact on the demand for social infrastructure.

Some of these impacts can be favorable (positive) whereas others can be unfavorable (negative). The unfavorable impacts can normally be mitigated, but not eliminated completely. Nevertheless, considering the level of subsistence and poverty of the population, it is possible to propose levels of compensation and indemnity that allow the residents of the region to reconstruct their communities at a standard of living better than the current one. The principal aspects of each of these topics are described next.

Some of these impacts appear principally during the construction phase, others appear during the construction phase, but their effects continue during the operation phase, and others would appear exclusively during the operation phase of the chosen water option or options. Nevertheless, to facilitate their presentation, these are discussed by viewing them as continuous phenomena that really happen and then in later sections, their greater or lesser incidence is discussed for each of the construction or operation phase, or both.

[1] URS-damas y Moore, 2003. Western Region / Contract No. SSA-53-299. Compilation and Presentation of Socioeconomic Information of the Western Region of the Panama Canal Watershed. URS, Panama.
[2] Abt Associates/Planeta Panama, 2004. "Sociocultural study of Western Region of the Panama Canal Watershed." Consultancy Report presented to the Panama Canal Authority, Panama City.

4.4.1 Potential Impact on the Water Reliability of the Canal

From the point of view of the water reliability of the Canal, every option evaluated provides a different quantity of additional water for the operation of the Canal. It is necessary to compare this with the goal of increasing the availability of water for the navigation of approximately 15 lockages daily with a hydrological reliability of 99.6 %. Although only Option 1 manages to satisfy this demand, this evaluation will be realized when the final performance scores of all the alternatives are obtained. On the other hand, the options evaluated are very different with regards to financial cost, social cost, and excess water volume produced.

Evidently, the net profit of a greater water supply is positive because - as it will be seen further in this report - the social costs are relatively small in financial terms in relation to the total costs. Nevertheless, *it is very important to stress that, although the social costs are relatively small, they have to be compensated or appropriately indemnified, since there is a danger to the responsibility and image institutional and that could delay the execution timetable of the contemplated options.*

4.4.2 Potential Displacement of Population

The relative impacts of the six water options contemplated in the Indio River Watershed are not linear with respect to the social impact, since there is no arithmetical relation between the water surface and the affected population. This is due to the fact that the location of population centers depends on factors different from the factors that determine the flow produced by the analyzed options. Therefore, every option has different impacts that are not necessarily related to the water flow produced.

In terms of displacement, the impact of the options on the population is, in general terms, directly related to the water surface area (Figures 4-13 to 4-18) and indirectly related to the size of the existing communities that would absorb the displaced families. The biggest impact produced is by the Indio River 80-40 option that would displace a total of 1,568 people who inhabit 327 dwellings. Taking this impact as the upper limit of the options, it is possible to compare with other options to analyze the relative reductions associated with other evaluated options. The overlay of the descriptions of the alternatives considered on the population and infrastructure of the area can be seen in Figures 4-13 to 4-18.

The relative impact of the options indicates that it is necessary to evaluate which of the options meets the minimal requests of volume and reliability, in order to reduce an unnecessary impact

on the population. Using the option of greatest impact as the upper limit, an *ad hoc* indicator can be developed that allows the comparison of the options considered with Indio River 80-40 option as 100 %. The results of this comparison show, for example, that if the needs of expansion are covered by the Teriá catchment option, the impacted population would be a 43% less than the option that produces the greatest impact (Option 1).

Table 4-28
Population Directly Affected by the Water Supply Options

Option	Housings	Population	Comparative Population Impact Index
1. Indio River 80-40	327	1,568	1.00
2. Indio River 45-40	199	939	0.60
3. Upper Indio 50-40	72	316	0.20
4. Upper Indio 45-40	67	286	0.18
11. Teriá Catchment	174	900	0.57
12. Teriá 1 + Indio River Headwaters	181	950	0.61

4.4.3 Impact on Community Cohesion

The impact analysis of the options must include an approximation of the effect on community cohesion, given that once the population is displaced, it is very difficult to reconstruct a community that developed naturally over years. On the other hand, it is also difficult to incorporate a relatively large group of people inside relatively small nearby communities.

This problem of social absorption would become worse at the same time as the indemnities the displaced families receive placing them at a much higher standard of living than those not displaced. Such a potential disparity might generate social frictions that would harm the functioning of the project during the construction phase. Consequently, the indirect impact on the affected displaced communities is important even if, for the time being, it is difficult to estimate before hand. Nevertheless, this potential impact on the affected communities will be taken in account during the design of the mechanisms of compensation and mitigation.

Inside this frame of action, cohesion community would be favored to the degree that the ACP anticipates community preferences, which are highly related to their ethnicity ('cholo', 'sabanero' or African Caribbean, according to the socio-cultural study[3]). The agency in charge of

[3] Abt Associates / Planeta Panamá, 2004, *Op cit*

administering the relocation of the affected families must inform them, in advance, about the ethnic composition of the surrounding communities and provide them with information regarding the dominant religion, patron saints, patronal festivals, and other aspects of community life that would allow the displaced to better integrate themselves in the communities.

Although there is no way of exactly determining the direct impact of the options on community cohesion, it is possible to approximate through the number of settlements affected by each option (Table 4-29). Although the number of settlements is a rough approach to the possible impact of every option, the size of the village is also very important since it is much more difficult to reconstruct the social cohesion of villages as their size increases[4].

The field information indicates that the number of villages with more than 10 houses is relatively small, but significant. The town with the greatest number of dwellings to be affected would be that of Tres Hermanas, with 48 houses. Other towns with more than 20 dwellings are Teriá with 29 and Santa Rosa No.1 with 21 (Table 4-29).

Table 4-29
Impact of Options on Villages by Size

Alternative	Villages	Villages with 10 houses or more	Villages with 20 houses or more
1. Indio River 80-40	37	14	3
2. Indio River 45-40	23	9	2
3. Upper Indio 50-40	8	4	0
4. Upper Indio 45-40	7	4	0
11. Teriá Catchment	17	5	3
12. Teriá 1 + Indio River Headwaters	18	5	3

In summary, the number of towns with more than 20 houses that would be affected by the options is relatively small, which facilitates the compensation and indemnity, and the management of the prevention, reduction and impact mitigation programs. It is necessary to mention that, in global terms, the Indio River 80-40 option would directly affect 327 of the 1291 families in the watershed, which represents 25 % of all homes and 23 % of the population of the watershed. The possibility that the displaced families have to be absorbed locally is high for two reasons: (i) the familiarity of the displaced with the local ecosystem and the compatibility of their agricultural practices with the surrounding production patterns would create an incentive to

[4] Considering the isolation and lack of economical sustentability of the ROCC, cohesion community does not include paid employment or access to urban services as evaluation variables.

minimize the sudden changes in their life, for which they would prefer staying close to where they were earlier; (ii) although the displacement creates an opportunity to initiate other better remunerated activities - as with emigration from homes to urban centers or to places near to the construction of the dam - there is a tradition of diversification of activities among low income rural homes, that suggests that a part of every family would prefer minimizing the displacement distance and remain close to where they were living earlier.

For the time being, it is not possible to predict where displaced families will settle, but it is most probable that their houses will be located close to the surrounding communities; this must be taken in account during the administration of the mitigation component. Also, the consideration of the relative well-being of the absorbing communities is of particular importance for mitigation. If the displaced bring with them a greater quantity of money than the local economy can absorb, inflationary spirals would be created at the local level that would negatively affect the ones not displaced. Therefore, the gradual disbursement and the suitable administration of compensation funds will play a great role in the recovery of community cohesion.

4.4.4 Risks to Public Health

In relation to the health problems in the supplying watershed, it is necessary to consider both the current incidence of illnesses and the possible effects of the construction of the water option or options that should be selected. From the point of view of illnesses, one must consider illnesses already present in the zone, as well as others that could potentially appear, due to their relationship with the aquatic habitat that is significantly increased by the dam. Among these, one must consider the illnesses transmitted by vectors, among which Leishmaniasis stands out in importance in the watershed. This illness is directly tied to the water; the populations of etiologic agents, vectors or wild hosts, could be affected by the execution of the chosen water option. It is possible that the movement of populations towards other sites might put them into contact with areas of high incidence of infected hosts.

Other illnesses transmitted by vectors that must be considered for their relationship with water include malaria, Venezuelan equine encephalitis, yellow fever, and dengue. Although a notable incidence of these illnesses does not exist in the watershed, it is possible that these could appear and affect the population, especially during the filling phase. Others, such as onchocerciasis and schistosomiasis that have not been reported in the country must be kept under constant vigilance in order to rapidly detect them in case they appear.

Finally, it is also necessary to consider the rate of incidence of traditional illnesses that already

exist in the region since the population may be more vulnerable to them, especially during the period of displacement. Among these illnesses should be mentioned intestinal parasitosis which is caused by protozoan or helminthes parasites of the digestive system that are acquired without the intervention of a vector in the life cycle. Transmission is a direct result of human behavior, caused by deficient personal hygiene and low standards of environmental hygiene. Prevention consists in education, suitable water supplies, systems for the elimination of garbage, and the general improvement of standards of living. The incidence of intestinal parasitosis is not going to be modified by the presence of the dam and the associated reservoir, nevertheless, their evaluation is important because they significantly affect the quality of the life of the settlers of the area.

4.4.5 Potential Impact on Employment and Revenue

The level and type of employment among the families that inhabit the Western Region depends on three principal factors: 1) the level of access to land and personal productive goods, 2) the level of access to formal labor markets, and 3) the skills and education level of the members of the household who are economically active. According to the socio-cultural[1] study, the traditional labor of subsistence farming changes as the families increase their access to markets and to other sources of better-remunerated work. In the case of there being a construction project in the areas near the homes of the Indio River, there will be a displacement of local manpower towards the construction project that will be directly proportional to the local ability to compete for the jobs being offered, which need certain skills that are not easily available in the ROCC: drivers, bricklayers, carpenters, mechanics, and other forms of skilled labor. Therefore, the impact of the water options on employment will depend on the rapidity that the ACP has to install training centers to train the local manpower.

If and when there is an investment in training programs that allow the economically active population to acquire new skills and to increase their productiveness, all the options considered have the potential of generating much employment and revenue among the local population, especially in those towns that could be displaced,. An efficient way of facilitating the positive elements of this impact is through training carried out by independent entities under contract with the ACP. Although it is difficult to predict the proportion of manpower that could become qualified under this system, it is possible to predict the impact of the employment based on increasing proportions of participation by local manpower in the construction jobs of the different water options, as Table 4-30 shows.

[1] ABT Associates/Planeta Panamá, 2004. *Op. cit.*

Table 4-30
Potential impact of the local employment on the regional GDP

Option	Number of Families	% of labor participation			Impact on GDP[5]		
		10%	25%	50%	10%	25%	50%
1. Indio River 80-40	327	78,480	196,200	392,400	1.42%	3.54%	7.08%
2. Indio River 45-40	199	47,760	119,400	238,800	0.86%	2.16%	4.31%
3. Upper Indio 50-40	72	17,280	43,200	86,400	0.31%	0.78%	1.56%
4. Upper Indio 45-40	67	16,080	40,200	80,400	0.29%	0.73%	1.45%
11. Teriá Catchment	174	41,760	104,400	208,800	0.75%	1.88%	3.77%
12. Teriá 1 + Indio River Headwaters	181	43,440	108,600	217,200	0.78%	1.96%	3.92%

The effect of the additional employment among the displaced population on the regional GDP can be substantial. If one adult in 10% of the displaced families is used in the project with a salary of B/.200 monthly, the annual impact on the current regional GDP might come to an additional 1.42% under Option is 1. If 50% of the displaced families have an adult employed at the project, the additional impact might come to 7.08% under this same option.

4.4.6 Potential Impact on Commerce and Marketing Channels

The physical change that Indio River would experience because of the civil works construction associated with any of the options would alter the patterns of communication and commerce inside the area. This would affect the populations located along the river, which would experience a strong reduction in their commercial activities following a substitution of commercial river traffic by a terrestrial form. This transformation is to be expected due to the presence of the access highways included in the construction program of the options and the presence of the dam itself. Although it is still not possible to specify this impact in detail, it is necessary to take into account this variable in the future.

At present, the highest part of the ROCC is already connected with some centers of consumption such as Capira and El Valle. The marketing channels are already well defined and it is very doubtful that they will experience a radical transformation as a consequence of the construction activities. The families that inhabit these zones are already integrated into the sub-regional market. On the other hand, the zones that are located downstream from the dam would suffer a reduction in river flow and, as a result, would have to adopt new means of transportation.

[2] Evaluated under the GDP of the ROCC

Consequently, the presence of a dam would have negative consequences on the volume of aquatic transport that might be compensated by the creation of a highway parallel to the Indio River, which would permit the local change in the means of transport. This change does not have strong repercussions, given that - according to the socio-cultural study - this type of change has happened in several areas of the ROCC through the years without permanent negative consequences.

4.4.7 Impact on Local Infrastructure

Since the presence of infrastructure in a zone is directly proportional to its economic importance, it is not surprising to find that the infrastructure potentially affected by the water options is relatively modest. The social infrastructure (e.g., schools, health centers, recreation areas) is small and dispersed, which corresponds to the high dispersion of the population of the zone. The zone has few access routes, mostly being unimproved trails and commercial activity is based on a small number of kiosks located in the most important villages.

It should be observed that churches are the most numerous infrastructures, followed by cemeteries, schools, and communal centers. Health centers are not very numerous in comparison, which is an additional indicator of the low standards of living in the region.

It is important to mention that the impact discussed above only includes the infrastructure *per se*. Nevertheless, the population affected by the disappearance of the above mentioned infrastructure transcends the displaced population. Every social or economic infrastructure project has an area of influence that, in most cases, overlaps only partly with the flooded areas. In consequence, a school to be flooded might serve three towns, of which only one is going to be flooded. The real impact of the disappearance of this school would include the population of all three towns. This analysis will go into detail in the section on the prevention, reduction and mitigation of impacts.

This discussion must consider the need of the chosen water options to include the costs of replacing the social infrastructure that would serve the indirectly affected populations, that is to say, the populations that although would not be flooded, are inside the area of influence of the displaced infrastructure. For example, in case of the school in the previous example, it would be necessary to replace with two schools in order to appropriately mitigate the social impact; one for the displaced population and other one for the populations who were receiving school services but who are not displaced.

Table 4-31
Summary of the impact of the options on the local infrastructure

Infrastructure	Indio River 80-40	Indio River 45-40	Upper Indio 50-40	Upper Indio 45-40	Teriá Catchment	Teriá 1 + Indio Headwaters
Buildings	**No.**	**No.**	**No.**	**No.**	No.	No.
School	11	3	1	1	7	7
Health Center	3	1	0		2	2
Recreation Area	6	4	2	2	5	5
Cemetery	8	4	3	3	2	2
Church	15	6	2	2	5	6
Communal Building	9	4	1	1	3	3
Roads	**Km.**	**Km.**	**Km.**	**Km.**	**Km.**	**Km.**
Permanent	1.00	0.00	0.00	0.00	0	0
Summer	18.80	8.70	4.40	3.60	0	0
UnimprovedTrails	71.80	40.80	8.40	7.80	0	0
Facilities	**No.**	**No.**	**No.**	**No.**	**No.**	**No.**
Telephone antenna	3	2	0	0	1	1
Light Posts	0	0	0	0	0	0
Suspension bridge	0	7	3	1	5	6
Concrete Bridge	0	0	0	0	0	0
Wooden Bridge	8	0	0	0	0	0
Kiosk (Commercial)	16	7	1	1	4	4
Bus Stop	0	0	0	0	0	0
Telephone booth	3	0	0	0	0	0
Storage Tank	2	0	0	0	2	2

The costs of the affected infrastructure are calculated based on unitary costs for the region obtained during the study[6] phase, supplemented with qualified informants from the respective governmental entities. The nominal cost of the economic and social infrastructure of the areas affected by the water options (Table 4-32) ranges from B. / 242,000 for the case of Upper Indio 45-50 and B. / 2,166,240 for the Indio River 80-40 option which has the greatest geographical coverage. It should be mentioned that these costs refer to the direct costs of substitution and do not include the costs of compensation to the affected families, nor the costs of mitigation for the population that, although they do not live in the areas to being flooded, would be affected by the loss of access to the above mentioned services.

[6] URS-Dames and Moore, 2003. Occidental Region / Contract No.SSA-53-299. 'Recopilación y Presentación de Datos Socioeconómicos de la Región Occidental de la Cuenca del Canal de Panamá'. URS, Panamá

Table 4-32
Cost of the Infrastructure Affected by each Option (in Balboas)

Infrastructure	Indio River 80-40	Indio River 45-40	Upper Indio 50-40	Upper Indio 45-40	Teriá Catchment	Teriá 1 + Indio Headwaters
Buildings						
School	698,500	190,500	63,500	63,500	444,500	444,500
Health Center	151,500	50,500	-	-	101,000	101,000
Recreation Area	5,700	3,800	1,900	1,900	4,750	4,750
Cemetery	6,240	3,120	2,340	2,340	1,560	1,560
Church	485,250	194,100	64,700	64,700	161,750	194,100
Communal Building	135,450	60,200	15,050	15,050	45,150	45,150
Roads						
Permanent	90,000	0	0	0	0	0
Summer	376,000	174,000	88,000	72,000	0	0
Unimproved Trails	143,600	81,600	16,800	15,600	0	0
Facilities						
Telephone antenna	15,000	10,000	0	0	5,000	5,000
Light Posts	0	0	0	0	0	0
Suspension bridge	0	14,000	6,000	6,000	10,000	12,000
Concrete Bridge	0	0	0	0	0	0
Wooden Bridge	12,000	0	0	0	0	0
Kiosk (Commercial)	16,000	7,000	1,000	1,000	4,000	4,000
Bus Stop	0	0	0	0	0	0
Telephone booth	21,000	0	0	0	0	0
Storage Tank	10,000	0	0	0	10,000	10,000
Total Cost	**2,166,240**	**788,820**	**259,290**	**242,090**	**787,710**	**822,010**

The direct costs of substitution of the infrastructure that would disappear under each option already include the additional costs that arise from the construction of modernized infrastructure; it should be remembered that most of the existing infrastructure is of low quality. In the special case of the cemeteries, the direct costs refer to land costs and do not include the costs of transferring the existing graves to other locations. These costs will be included in the section on prevention and reduction of socio-environmental impacts and risks, and measures of compensation and indemnity for mitigation and mitigation compensation and compensation in another chapter of this report.

4.4.8 Potential Impact on Agricultural Production

The Indio River region, as is the rest of the ROCC, is poor and not self-sufficient. The regional production is considerably less than the total regional consumption. Nevertheless, the loss of production would represent - on average - 42 % of familiar consumption. Therefore, the cost of the agricultural production that would be lost from the floods is a very important component of the total regional revenue.

Since the dominant agricultural practice of the region is mainly subsistence-level shifting cultivation, it is very difficult to take into account agricultural production based on a snapshot inventory. Subsistence agriculture is seasonally shifting, that is to say, families cultivate different plots in different locations during the agricultural year. Therefore, for the purpose of evaluation, the total area suitable for cultivation is used as a point of reference to measure the total impact on production.

The local agriculture is seasonal with an initial cycle during which rice and corn are cultivated, as well as humid climate tubers such as manioc and yams. This first cycle is followed by a second cycle in the drier season including corn, either alone or in combinations with beans. The crops for home consumption (vegetables, fruit trees) and other marketable permanent crops (coffee, Guinea, plum palms) occupy small areas next to the family house.

Considering the low intensity of capital in subsistence agriculture, the biggest limitation for the producing families is the labor - especially during the periods of sowing and harvesting. This explains the fact that most families cultivate less than 1 hectare of land. Cattle and birds are used as food sources (milk, eggs) for daily consumption, and as capital storage.

In general, the families in the watershed that have cattle have come from other zones, especially from the peninsula of Azuero, and where there is cattle-based culture in which the creation of pastures and the expansion of the herd is an indicator of family success. According to the base study of the zone, the herds of local cattlemen range between 25 and 50 animals and these are stocked at a rate of 1 animal per hectare.

The impact of the water options on vegetation coverage and land use occurs mainly on pastures and areas in stubble (covered by bushes and fallow), which are usually resting (Table 4-33). The total value[7] of the displaced land ranges between B/. 876 thousand and B/. 6.1 million.

[7] This calculation is based on the following prices by hectare: Mature Forest: B/. 600; Secondary Forest: B/. 500; Pasture: B/. 3,600; Stubble: B/. 400; Crops: B/. 3,300.

The area under cultivation displaced by the options is quite small, which confirms the subsistence nature of the agriculture of the region, as well as the greater relative importance of cattle.

Table 4-33
Impact of the Water Options on the Vegetation Coverage and the Land Use

Vegetation Cover	Indio River 80-40	Indio River 45-40	Indio River 50-40	Indio River 45-40	Teriá Catchment	Teriá 1 + Indio Headwaters
Mature forest	62.2	32.3	14.8	14.2	33.75	34.09
Secondary forest	922.1	345.6	173.3	159	479.59	502.49
Pasture / cattle ranch	1,731.30	812.3	331.1	300.1	569.2	556.21
Stubble	1347.3	573.3	212.1	193.3	480.31	580.9
Crops	62.005	10.429	5.821	4.521	21.69	21.69
Approximate value (B./)	7,474,587	3,380,196	1,391,539	1,260,619	2,572,866.00	2,577,992.00

As for the value of the lost production, the estimates are approximate. According to the 2003 base study, a typical farm produces a gross revenue of B/. 232 per capita[8]. Therefore, *annually*, there would be a loss of production valued at between approximately B/. 66,000 and B/. 364,000in the areas directly affected by the options.

Table 4-34
Implied annual value of the production affected by the water options (B/)

Option	Population	Implied value
1. Indio River 80-40	1,568	363,776
2. Indio River 45-40	939	217,848
3. Upper Indio 50-40	316	73,312
4. Upper Indio 45-40	286	66,352
11. Teriá Catchment	900	208,800
12. Teriá 1 + Indio River Headwaters	950	220,400

As for the impact on cattle, it is difficult to estimate direct impact because the animals are semi-mobile. That is to say, they can move to zones located outside of the flood perimeter without lose of value. Nevertheless, we must consider the number of animals being displaced by the options. Table 4-35 shows an estimate of displaced animals; this enumeration of the animals to be

[8] This calculation is based on 42 % of the per capita revenue of B/. 547 observed in the region in 2003. The remaining 58 % comes from family remittances and from non-agricultural activities.

displaced is only an approximation, since current inventories move within several 'corregimientos'[9]..

Table 4-35
Approximate number of Animals in the Supplier Watersheds for Each of the Water options

	Cattle/[1]	Pigs	Aves
Indio Watershed	16,329	2,604	50,753
Indio	7,587	933	21,382
Upper Indio	6,153	720	19,807
Teriá	1,522	176	6,270
Upper Teriá	584	94	2,354
Indio Headwaters	750	122	3,026

[1] Horses and mules are also included in the cattle category.

4.4.9 Potential Impact on Mining Concessions

In the Western Region, including the area of the Indio River Watershed, there exist or existed numerous mining concessions for the exploration and development of metallic and non-metallic materials. These concessions were identified during the compilation study of socioeconomic information and they were entered into the geographical information system. The following table presents those concessions that would be affected by the water options under consideration.

Table 4-36
Affected Mining Concessions

Alternatives	Concession Code	Type	Current
1 - Indio 80-40	94-117	Metal	No
	94-85	Metal	Yes
	95-91	Metal	Yes
2 - Indio 45-40	94-85	Metal	Yes
	95-91	Metal	Yes
3 – Upper Indio 50-40	94-85	Metal	Yes
	95-91	Metal	Yes
4 – Upper Indio 45-40	94-85	Metal	Yes
	95-91	Metal	Yes
11 –Teriá Catchment	94-85	Metal	Yes
	95-91	Metal	Yes

[9] The cattle enumeration is based on the agricultural census for the following 'corregimientos' that are inside the catchments of this study: Cirí Grande, El Cacao, El Valle, La Encantada, Santa Rosa, La Laguna, Los Llanitos, Cirí de los Sotos, Indio River and Sorá

Alternatives	Concession Code	Type	Current
	95-17	Metal	Yes
	93-61	Metal	Yes
12 – Indio Headwaters - Teriá	94-85	Metal	Yes
	95-91	Metal	Yes
	95-17	Metal	Yes
	93-61	Metal	Yes

Source: Compilation Study Data base and ROCC Socioeconomic Information Presentation

As can be seen in the table, it appears that the majority of the exploration concessions are current. Because the information presented in the table above comes from a year 2000 survey, the status of the concessions was verified during the course of this study. The Department of Mineral Resources of the Ministry of Trade and Industry was contacted and indicated, however, that none of these concessions are currently valid. Since it was not possible to obtain an official document confirming this assertion, it will have to be confirmed in the future in order to proceed with any of the water options.

4.4.10 Potential Socioeconomic Impacts during the Construction Phase

As was indicated previously, the majority of the socioeconomic impacts would occur during the construction phase of the chosen water option, especially those that can negatively affect the inhabitants of the watershed and adjacent areas. These can be either directly attributable to the actions related to the construction of the water option or they can be consequences of the induced development that would probably happen in the area.

4.4.10.1 Potential direct impacts

Any of the water options that are selected for construction will generate a movement of local manpower towards the project, which will be directly proportional to the ability of the locals to compete for the jobs to being offered and to the size of the project (it is believed that the increased labor demand will last between three and five years). All the options considered have the potential of generating much employment and revenue among the local population, especially in those towns that could be displaced, if and when money is invested in training programs that allow the economically active population to acquire new skills and to increase their productivity for the kinds of jobs demanded during the construction of the projects.

The physical change that the Indio River would experience from the construction of the civil works associated with any of the options would alter the patterns of communication and

commerce inside the area. This transformation is to be expected due to the presence of the access highways included as part of the construction of the options and the presence of the dam itself. At present, the highest part of the ROCC is already connected with some consumption centers such as Capira and El Valle. Marketing channels are already well defined and it is very doubtful that they will experience a radical transformation as consequence of the construction activities. The families that inhabit these zones are already integrated to the sub-regional market.

In terms of displacement, the impact of the options on the population is in general directly related to the water surface area and indirectly related to the size of the existing communities that would absorb the displaced families. The biggest impact occurs in case of the Indio River option 80-40, where the above-mentioned option would displace a total of 1,568 persons, who inhabit 327 dwellings. Nevertheless, it is necessary to evaluate which of the options complies with the minimum requirements of volume and reliability, in order to reduce an unnecessary impact on the population.

Although there is no way of exactly determining the direct impact of the options on community cohesion, it is possible to make an approximation based on the number and size of the buildings affected by each option, since it is much more difficult to reconstruct social cohesion of establishments as they get larger. The number of towns with more than 20 houses that would be affected by the options is relatively small, which facilitates the compensation and management of the impact mitigation programs. Furthermore, the possibility that the displaced families have to be locally absorbed is high because of the familiarity of those displaced with the local ecosystem, the compatibility of their agricultural practices, the preference for minimizing the displacement distance and staying close to where they were living before. For the time being, it is not possible to predict where the displaced families will settle, but it is most probable that their homes will be located close to the surrounding communities. Furthermore, it is necessary to consider the relative well-being of the absorbing communities, since if those displaced bring with them a greater quantity of money than can be absorbed by the local economy, inflationary spirals would be created at the local level that would negatively affect those not displaced.

Given that the infrastructure potentially affected by the water options is largely relatively modest and of low quality, the impact on them will be small and it will be compensated by reconstruction. These costs will be included in the section on mitigation and compensation in another chapter of this report.

The region of the Indio River, as in the rest of the ROCC, is poor and not self-sufficient. Nevertheless, the loss of agricultural production is a very important component of family

revenue. Since the region's agriculture is mainly subsistence and of low capital intensity, the biggest limitation for producing families is manpower. This explains the fact that most of the families cultivate less than 1 hectare of land. The area under cultivation displaced by the options is quite small, which confirms the subsistence nature of agriculture of the region and the greater relative importance of cattle. As for the impact on the cattle, it is difficult to estimate a direct impact because the animals are semi-mobile and can move to zones located out of the flood perimeter.

4.4.10.2 Potential indirect impacts

The indirect impact on the communities affected by displaced is likely to be important, albeit difficult to estimate beforehand. Nevertheless, this potential impact on the affected communities will be taken in account during the design of the compensation and mitigation mechanisms. The possible development induced in the area as consequence of the projects that would be realized and the increase in economic activity makes it more difficult to quantify this impact, but it is highly likely to happen.

The compensation and mitigation mechanisms will have to include the social infrastructure that serves the indirectly affected populations, the populations, although not flooded themselves, that are inside the area of influence of the displaced infrastructure.

4.4.11 Potential Impacts during the Operation Phase

During the operation phase, the positive impacts which originated the conceptualization and possible execution of the water option will manifest themselves. Furthermore, some of the impacts whose effects began during the construction phase could continue to manifest themselves, especially those associated with the development induced in the area.

4.4.11.1 Potential direct impacts

The direct impacts are associated with the production of water for the operation of the canal and of the additional benefits such as the availability of electrical energy for the local communities. In terms of satisfying the additional water demand for the operation of the canal in the order of 15 additional locks, Option 1 is the only one that achieves this goal.

The local manpower that will be needed by any of the water options during the operation phase will be minimal, compared with the demand during the construction phase.

UNAUTHORIZED USE OR DUPLICATION IS PROHIBITED
PROHIBIDA LA REPRODUCCION SIN AUTORIZACION DEL AUTOR

CENTRO DE RECURSOS TECNICOS
AUTORIDAD DEL CANAL DE PANAMA

4.4.11.2 Potential indirect impacts

The construction of any of the water options will affect the populations located on the banks of the river, which will experience a strong reduction in their commercial activities after there is a replacement of the commercial river traffic by terrestrial traffic. On the other hand, the zones that are downstream of the dam would suffer a reduction of river flow and, as a result, would have to adopt new means of transportation. Consequently, the presence of a dam would have negative consequences on the volume of aquatic transportation that might be compensated by the creation of a highway parallel to the Indio River, which would permit a local change in the means of transport. This change does not have strong after effects, since – according to the socio-cultural study – this kind of change has already happened in several areas of the ROCC through the years, without permanent negative consequences.

4.4.12 Comparison of the Water Options on Socioeconomic Impact

As a way of comparing the water options, values from 1 to 3 were assigned to each of the variables that characterize the socioeconomic factors. The highest values indicate socio-environmental impacts and large potential negative risks. As shown in Table 4-37, in relation to the water produced and hydrologic reliability, a value of 0 was assigned to those options that achieve the 15 additional locks and those that do not, a value proportional to the quantity of water that each one contributes. If this last variable is not considered, the totals are shown between parentheses.

The Option 1 presents the greatest potential socioeconomic impact according to the stated criteria. This is followed by options 12, 11 and 2. Finally, options 3 and 4 are those that present the least socio-environmental impacts and potential negative risks. Nevertheless, it should be mentioned again that Option 1 is the only one that satisfies the additional water requirement for the operation of the canal.

Considering the poverty of the region and the dispersal of its population, the costs associated with the socioeconomic impacts are relatively small compared to the costs of the water options. The greatest costs are undoubtedly associated with the direct program of the resettlement of those displaced and, secondly, with the replacement of the social infrastructure, especially churches, schools, communal centers, and cemeteries. It is very important to clarify, nevertheless, that although the social costs are relatively small, they have to be handled in

appropriate manner, since they have a potential of becoming a high political cost that could derail the execution of any one of the options.

Table 4-37
Summary of the potential socioeconomic impacts of the water options

Options	Water Production	Jobs and Revenue	Commerce and Marketing	Population Displacement	Community Cohesion	Social and Local Infrastructure	Agricultural Production	Total
1	0	1	1	3	3	3	3	14
2	3	2	1	2	2	2	2	14(11)
3	3	3	1	1	1	1	1	11(8)
4	3	3	1	1	1	1	1	11(8)
11	2	2	1	2	3	2	2	14 (12)
12	1	2	1	2	3	2	2	13 (12)

4.5 Archaeological Resources

The objective of the cultural resources section of this study is to identify and to describe the possible impacts on the archaeological resources of the construction and operation of the possible water options in the Indio River Watershed. The work was based in part on a review of the available inventory of cultural resources and a brief field survey which permitted the identification of the possible archaeological impacts of each alternative. The impacts were quantified on the basis of a systematical review of the Alternatives planned in a map developed by URS. In addition, the cumulative archaeological impacts were calculated and compared on the basis of the number of sites that are impacted and the relative importance of each place according to what the existing inventory indicates.

The possible cultural resources impacts were evaluated following international methodologies complemented with the procedures of the Panamanian Institute of Culture. The methodology used was developed by the World Bank and has been used in many projects. The member organizations of the World Bank Group, including the International Financial Corporation (IFC), the International Bank of Reconstruction and Development (IBRD) and the International Development Agency (IDA), rely on detailed methodologies on the cultural resources, which also are incorporated as references by other organizations, including the Inter-American

Development Bank of (IADB), the Overseas Private Investment Corporation (OPIC), and many others. The requirements for the cultural resources were developed as part of the environmental safety and quality control program and it constitutes one of ten environmental guidelines that are demanded by these banks for any investment.

The following approach to the Management of Cultural Resources is described in the standards of the World Bank (World Bank 1999). The procedures of the standard are found in a document titled "Cultural Resources in Environmental Assessments" (World Bank 1994). Both documents identify the following procedures in order to implement the policies of the Bank:

- Check the existing cultural resources information for the project area;
- If the review is positive, carry out a rapid survey by a specialist; and
- If the survey is positive, implement mitigation measurements including changes in the design of the project, compile information and rescue excavations before the construction as well as monitoring activities during the construction.

With respect to the global approach regarding cultural resources, the same international standard suggests the following principles:

- Reduction of the significant impacts, re-designing the project (which is preferable to mitigating the impacts), recovering data and rescue;
- Procedures for the protection of cultural resources is of primary importance at a national level; and
- Aspects of cultural resources must be taken into account in the context of the environmental evaluation (EA), planning processes or other environmental documentation.

The methodology used to evaluate the cultural resources is compatible with the standards of UNESCO, the European Community and the International Council on Monuments and Sites (ICOMOS). The World Bank guide on cultural resources is more specific than that of these organizations. For this reason, some of the elements used to evaluate the cultural resources of the water options are based on projects that have been recently developed and that have been subject to review on behalf of the World Bank and other agencies that share this guide. Some of these projects:

- The gas pipeline between Brazil and Bolivia whose construction began in 1997 with funds from the World Bank and the IFC;

- The integrated energy project of Cuiabá between Bolivia and Brazil, whose construction began in 1998 with funds from the OPIC;
- The exportation project of Chad, between Chad and Cameroon, built in 2000 with funds from the World Bank and IFC; and
- The BTC oil pipeline between Azerbaijan, the republic of Georgia and Turkey, build in 2002 with funds from the IFC.

The water options that are currently being evaluated have the potential of affecting sites and archaeological artifacts that are a part of the cultural heritage of Panama and whose scientific and cultural value would be diminished. If some of the options were carried out, the following impacts would occur:

- Excavation activities in borrow pits that contain archaeological sites;
- Dam construction sites directly on an area that contains archaeological sites; and
- Flooding of archaeological sites for raising water levels inside the area of the retention dam.

The first three types of activities could cause physically irreversible damage to the sites by themselves, and the third (flood) would make the site to be inaccessible to archaeological investigation in the near future.

The impacts of the options on archaeological resources are irreversible in the majority of cases, but are limited spatially to the zone of physical activity that causes the impact. In comparison to the social- environmental impacts and risks caused by the project, the archaeological impacts are atypical. The archaeological sites, although they do not have equal importance, are all unique and they cannot be recreated. Furthermore, although it is possible to prevent, reduce and mitigate the impacts by means of investigation and study before a construction project, archaeologists maintain that the sites must not be completely excavated in order to preserve information for future investigation. For this reason, avoidance is always considered to be the preferable way to prevent, reduce and mitigate impacts on archaeological resources. This point will be discussed in the section on the Environmental Management Plan.

It should also be considered that the archaeological impacts of the water options in the Indio River Watershed would not necessarily all be negative. The compilation of information, studies and the transmission to the public of archaeological information made possible by a large construction project could represent a valuable cultural and scientific contribution, all the more

so when it is considered that the funds for such studies are often seriously limited by inadequate public financing.

4.5.1 Potential Impacts during the Construction Phase

It is expected that the majority of the potential impacts to the archaeological sites identified in the area of influence of the considered water options, would happen during the construction phase of the projects.

4.5.1.1 Potential direct impacts

For the identification of specific impacts on archaeological resources, the available information about the 6 alternatives, including principal elements such as the dam, reservoir, borrow pits, and principal roads was used. This information was overlaid on a map of known archaeological sites identified by the survey. Table 4-37 summarizes the impact of each one of six alternatives. The impact sites that the inventory study (Cooke *et al.* 2001) considers to be of average and high importance are identified according to their site code (for example, Pn-50) in Table 4-38; the sites of low importance are counted according to their total number only.

4.5.1.2 Potential indirect impacts

There exists the risk of indirect additional impacts as a result of plundering or looting of ruins, which must be avoided at all costs. The induced development that the project will generate, especially during this phase, is also a threat to the cultural resources of the ROCC.

4.5.2 Potential impacts during the operation phase

During the operation phase of the water option that is carried out, the possible impacts to cultural resources, especially archaeological, are principally associated with the development that is likely to be induced in the area.

Table 4-38
Summary of Possible Archaeological Impacts by Alternative

Alternatives	Archaeological places with Potential Impact			Score of Expected Impact
	High Importance (1 Site = 10 points)	**Moderate Importance** (1 Site = 5 points)	**Low Importance** (1 Site = 1 point)	
Option 1	1 Site (Pn-50)	1 Site (Cp-37)	14	***29***
Option 2	1 Site (Pn-50)	1 Site (Cp-37)	5	***15***
Option 3	No Sites	1 Site (Cp-37)	3	***8***
Option 4	No Sites	1 Site (Cp-37)	3	***8***
Option 11	No Sites	3 – (Cp-35; Cp-43; Cp-44)	15	***30***
Option 12	No Sites	3 – (Cp-35; Cp-43; Cp-44)	2	***18***

4.5.2.1 Potential direct impacts

The operation and maintenance activities of the project during this phase will not create socio-environmental impacts or potential risks to cultural resources.

4.5.2.2 Potential indirect impacts

The induced development that the project will generate even in this phase, although to a lesser degree than during the construction phase, might affect cultural resources due to the plundering of archaeological remains. On the other hand, communication to the public of the archaeological information gathered by the project might represent a valuable cultural and scientific contribution for the country.

4.5.3 Comparison of the Potential Impacts to the Cultural Resources by Option

In an effort to judge the relative severity of the possible archaeological impact for each alternative, a scoring system was developed where a distinct numerical weight was given to each site. A score of "10" was given to sites of great importance; sites of moderate importance were given a score of "5", and sites of little importance a score of "1". According to this system, the sum of the scores of all the sites subject to impact for the alternative in question represents a measure of the severity of the archaeological impact that the selection and implementation of this alternative would cause, given the absence of any mitigation measure. The greater the score for an alternative, the greater is the potential for a negative impact of the implementation of the

alternative. The weighted impact score for each one of six alternatives is shown in the right column of Table 4-37.

The review of the weighted impact scores for each alternative show a substantial difference between them. The alternatives of least impact are 3 and 4 with an Impact Score of "8", whereas the greatest impact would be caused by the alternative 11, with a weighted impact score of 30.

This summary of potential impacts will offer an archaeological basis for considering the possible impacts of the alternatives with respect to the project's value for these options. Even more impacts information shown in the table will offer a basis for the planning and measurement of the usefulness of the different mitigation options. The last process offers additional information to backup the selection and possible refinement of the available alternatives.

4.6 Landscape and Scenic Resources

The study area is dominated by intense and nearly constant rains and by much cloudiness and diffuse light at the highest elevations, for which reason runoff channels dominate. In general, it is an area where waters flow continuously with a dense, dendritic drainage (Riparian Zone). The area is extremely sensitive to anthropic intervention due to the predominance of steep slopes, the rough micro-relief and intense rains, putting into danger its original stability (Ecologically Sensitive Zone).

The studied landscape consists of a low percentage of primary forests, typically fragmented, and with a consistent tendency to turn into a relictual and degraded landscape (Zone with Fragmented Landscape). The indiscriminate deforestation to which the Western Region has been subjected, in addition to such practices as burning and fires of woods and pastures is diminishing the recreational-ecotourism potential of the study area. Occupation has been disorderly, benefiting the extensive cattle ranching over other more diverse uses in agreement with the diversity of natural environments found there.

The evaluation of possible impacts on landscape resources was based principally on the information produced during the Compilation and Presentation of Socioeconomic Information of the ROCC. During this project numerous polls were carried out, including polls designed to identify sites of landscape and/or recreational interest to the communities. The types of sites that the communities reported included:

- Rivers, for their recreational value;

- Hills, for their recreational and cultural value;
- Chapels, for their religious value;
- Waterfalls, for their recreational value;
- Forests, for their natural value;
- Stone Writings, for their cultural value; and
- Beaches, for their recreational value.

The resources described earlier provide the population of the area diverse activities such as swimming, trips by boat, and trips on horseback, fishing, hunting and walks, among others. To identify those towns that might see their landscape and/or recreational resources affected, the GIS database of socioeconomic information was used to overlay these on the coverage of the different alternatives. The principal sites and facilities identified in each case are summarized in Table 4-39.

Table 4-39
Number of Towns with Scenic Resources (Reported by the Communities) Affected by Alternative

Alternative	Type of Work					Total
	Quarries	Dam	Tunnel / Channel	Trail	Reservoir	
1 - Indio 80-40	0	0	0	0	11	11
2 - Indio 45-40	0	0	0	0	7	7
3 - Upper Indio 50-40	0	0	0	0	3	3
4 - Upper Indio 45-40	0	0	0	0	3	3
11 –Teriá Catchment	0	0	0	0	0	0
12 – Indio Headwaters - Teriá	0	0	0	0	0	0

Source: Elaboration by the authors with information from the socioeconomic database of the ROCC

In the following table, some of the sites of major importance for the communities are indicated, according to the option that would affect them:

Table 4-40
Scenic Resources Potentially Affected by Option

Alternative	Town	Place of Local Interest	Type of Associate Activity
1 - Indio 80-40	Boca de Uracillo	Indio River & Uracillo Meadows	Boat trip & swimming
		Indio River, Ponds, Waterfall	
	San Cristóbal	Stones / Indigenous writings	Trip, fishing, hunting
	La Conga Abajo	Indigenous stones, Waterfall	Trip
	Tres Hermanas		Trip
2 - Indio 45-40	Boca de Uracillo	Indio River & Uracillo Meadows	Boat trip & swimming
		Indio River, Ponds, Waterfall	
	San Cristóbal	Stones / Indigenous writings	Trip, fishing, hunting
	La Conga Abajo		Trip
3 - Upper Indio 50-40	San Cristóbal	Indio River, Ponds, Waterfall	Trip, fishing, hunting
	La Conga Abajo	Stones / Indigenous writings	Trip
4 - Upper Indio 45-40	San Cristóbal	Indio River, Ponds, Waterfall	Trip, fishing, hunting
	La Conga Abajo	Stones / Indigenous writings	Trip

Source: Elaboration by the authors with information from the socioeconomic database of the ROCC

4.6.1 Potential Impacts during the Construction Phase

Considering the nature of the potential impacts to the sites and recreational facilities identified in the area of influence of the considered water options, it is expected that the majority should happen during the construction phase of the projects.

4.6.1.1 Potential direct impacts

During this phase of the project, the construction and associated activities such as the roads, will negatively affect landscape in the watershed that has already been deteriorated. Also it is anticipated that the loss of recreation facilities and sites referred to by the population would occur during this phase.

4.6.1.2 Potential indirect impacts

The induced development generated by the project in this phase might affect fragmented landscape even more due to increased deforestation and fires in the woods and pastures.

4.6.2 Potential Impacts during the Operation Phase

During the operation phase, any of the options that are actually carried out will bring an important new element to the regional landscape, being the infrastructure itself or the reservoirs

associated with the chosen alternative. This introduces an element of increased diversity and at the same time provides opportunities for recreational activities that are currently not available.

4.6.2.1 Potential direct impacts

The implementation of any of the alternatives related to the water options in the Indio River Watershed will undoubtedly have an effect on the landscape of the region. This effect takes principally results from the presence of a water body that earlier was not present in the area. Equally, the protection and restoration of the wooded zones and of the water corridors would promote an important and positive landscape change. The presence of reservoirs in the area would give impulse to new recreation activities.

4.6.2.2 Potential indirect impacts

The induced development generated by the project in this phase, although in lesser scale to that during the construction phase, might affect the existing fragmented landscape.

4.6.3 Comparison of the Water Options

The overlay of the coverages of the different alternatives on the towns with sites of interest produced the results shown in Table 4-39. As it can be appreciated in the table, the alternatives located in the upper parts of the Indio River Watershed tend to affect a smaller number of inhabited sites that reported resources of interest for their communities. Alternatives 1 and 2 would affect the highest number of towns that reporting sites of scenic interest for their communities.

Table 4-41 summarizes the impacts of each of the options and their corresponding mitigation measures. As the table shows, Option 1 was the one that received the greatest score (99), since the values that it received in the geologic and seismic impacts, in soils, in the air quality, the terrestrial and aquatic communities, and in the socioeconomic aspect were the highest; in some cases its scores were double the value of the other options. Option 11 followed with a score of 84, suggesting the greatest potential impacts of this option on hydrological resources, air quality and noise. Option 12, with a score of 75 points, has a very similar tendency to option 11, with regard to the environments to being affected. Option 2 would potentially alter the air quality and the aquatic communities and would increase noise. Options 3 and 4 obtained scores of 45 and 46, respectively; these are the two options that would least affect the physical environment, biological diversity and the socio-economic and cultural aspects. It is important to highlight that

this chapter only took into account the impacts produced by the options, independently of the benefit (water production) that they generate. To make a comparison between alternatives it is necessary to take into account this "benefit" factor. In Chapter 6.0 of the study, the comparison of the options taking into consideration the cost (investment and environmental, social, economical, cultural impacts) and the benefit (water production in locks) is presented.

Table 4-41
Summary of the Potential Socio-environmental Impacts and Mitigation Measures of the Indio River Watershed Water Options

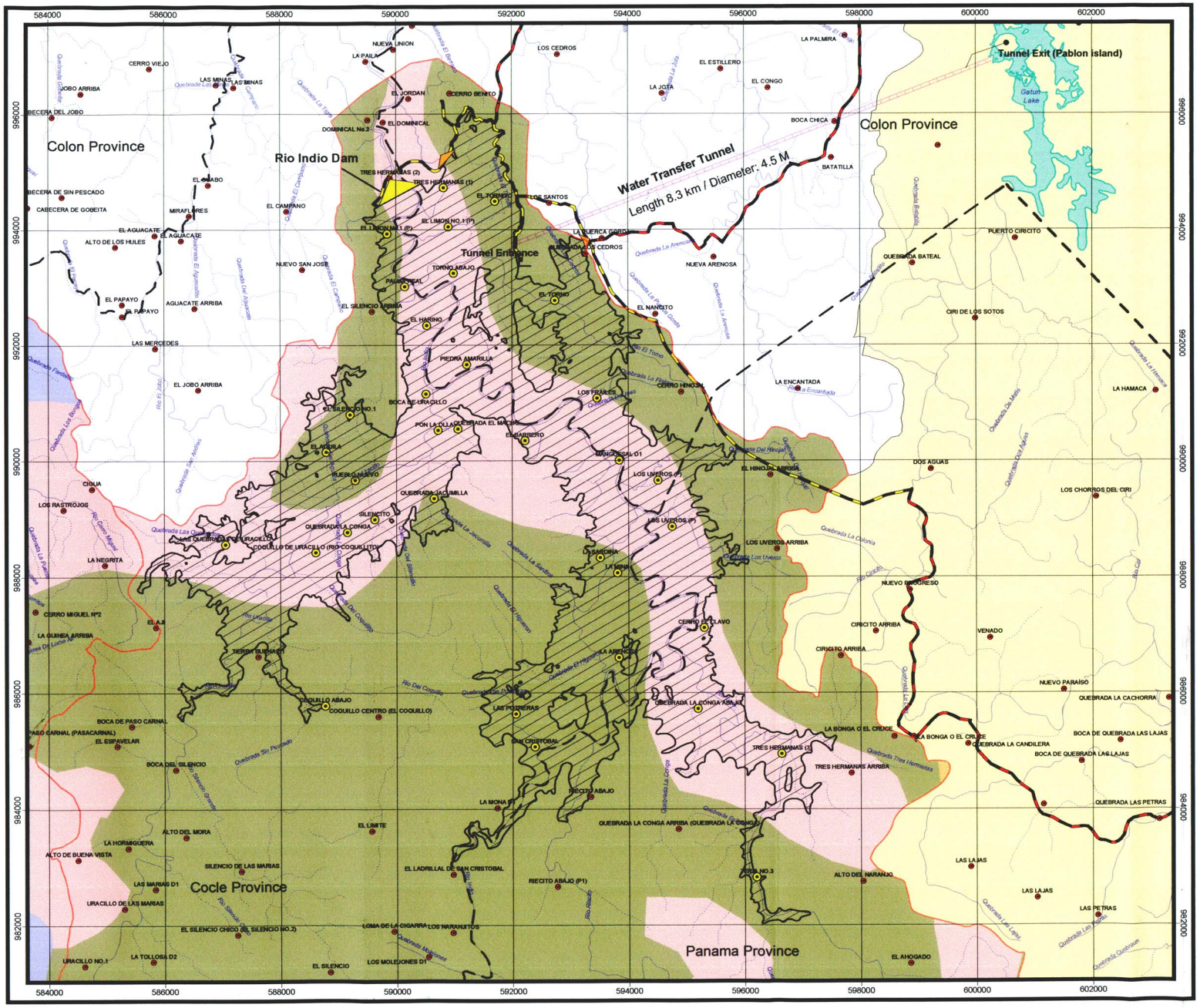
Potential Socio-environmental Impacts	Option	Value	Accumulated value
A. Impacts on the Physical Environment			
1. Geology and Seismology The geologic and geotechnical characteristics of the watershed do not present any adverse condition that could not be mitigated by means of a conventional design and appropriate construction methods. In addition, in the dam site of options 1 and 2, no active faults were detected nor materials capable of liquefaction during an earthquake. - in the construction phase the risks will be due to: landslides: i) roads (greater risk in options 11 and 12 due to steeper slopes); and ii) in the other projects. The construction of the tunnel with a concrete covering to avoid water filtrations and the presence of dangerous gases. Inadequate disposal of waste material (greater volume with the largest option: 1, 12, 2, 11, 3 and 4, respectively). - in the operation phase the risks will be for: landslides: i) roads (greater risk in options 11 and 12 due greater fluctuations in elevations: option 1, 12, 11 and the rest). Earthquake: the possibility that an earthquake affects the project is relatively small. Water filtration through, below or around the dam: i) filtration is considered to be minimal; ii) in the event of a failure, the greatest damage (downstream) would be caused by options 11 and 12 because they are higher up in the watershed.	1	10	
	2	5	
	3	5	
	4	5	
	11	9	
	12	9	
2. Soils The majority of the soils of the watershed have little agricultural value (classes VI and VII). - The greater the size of the project (reservoir) the bigger impact to the soil (1, 12, 2, 11, 3 and 4). - Development induced by the project can provoke deforestation and greater agricultural activity.	1	8	18
	2	5	10
	3	4	9
	4	4	9
	11	7	16
	12	7	16
3. Hydrological Resources The hydrological resources in the watershed are of good quality, but will deteriorate during the project construction, if measures are not implemented to minimize runoff and spills and to treat wastewaters. During operation, the water quality of the reservoir will be monitored to determine changes and eutrophication risk in order to take the necessary preventive and corrective measures.	1	5	23

Potential Socio-environmental Impacts	**Option**	**Value**	**Accumulated value**
A. Water level and flow, waters below the dam: - During operation the maximum resultant water flow under the dam will have a significant attenuation (about 85 to 90 %; HEC-5), therefore, a reduction in floods (negative effects on terrestrial and aquatic ecosystems but minor damages to goods and loss of human lives). - During operation there will be an attenuation of the riverbed downstream. The riverbed is composed of thick materials (me=16.5 mm). The degradation of the bed will be insignificant (stabilization efforts are not needed). The reduction of flow of water in the fluvial channel manifests itself in the degradation of the mouths of the tributaries; The reduction in transported sediment loads manifests itself in the increase in erosion of the canal; The reduction of the capacity of the river to transport sediments will manifest itself in the accumulation of sediments at the mouths of the tributaries. This might affect navigation due to the reduction of water flow and deposition of materials.	2	5	15
B. Erosion and sediment transport: - During construction there will be deterioration in water quality due to the sediments of the earth movement. - During operation sedimentation of the reservoir will not be a problem and, therefore, it will not be necessary to dredge; The capacity of the reservoir will be affected by no more than 1 or 2 % at the age of 50 and 100 years, respectively (1.4 mm / year; 1.04 ton/m^3).	3	6	15
C. Quality of the water and eutrophication risk: - During construction, deterioration in water quality due to the contribution of sediments (erosion), residual waters and hydrocarbon spills. - During operation, the concentrations of *dissolved oxygen* will be: i) water below the dam sites: lower concentrations in the layers near to the bottom and more than anything, when the reservoir is filling, affecting ecosystems and water quality; This situation can be alleviated by changing the depth of the water exits;	4	6	16
ii) Gatún: will not affect water quality of the lake due to the transfer of water from any of the Indian River options; it will not be necessary to change the depth of the intakes. - During operation, *temperature* or thermal stratification will be more or less stable, this thermal stratification that will be influenced by the presence of winds, especially during the dry season; Water options 3, 4 and the reservoir at the Indian River Headwaters, the water will circulate with certain frequency partly due to its comparative low average depth. The thermocline will be between 10 and 15 meters deep.	11	7	23
Light penetration will be up to 15 meters deep. - During operation, the risk of *eutrophication* is low. Concentrations of phosphorus and chlorophyll in the water options, in ascending order, the following: 12, 11, 1, 2, 3 and 4.	12	7	23
4. Air Quality The most important impacts on air quality are principally related to the emission of	1	6	29

Potential Socio-environmental Impacts	Option	Value	Accumulated value
dust from the areas devoid of vegetation and by the traffic of trucks that transport material on the tertiary roads.	2	5	20
- During construction, more than during operation, options 1 and 2 would affect the air quality of a slightly greater number of towns, but options 11 and 12 would affect the largest number of sensitive receptors (schools, churches and health centers), compared to the other alternatives.	3	3	18
- During construction, laborers will be exposed to dust and possibly other substances.	4	3	19
- During operation, the area of the reservoir would not be susceptible to forest fires (positive impact). But better access to the area might intensify the alteration of the vegetation coverage and to contribute to more zones with fires.	11	5	28
	12	6	29
5. Noise	1	5	34
The most important impacts of noise are principally related to construction activities of and by the traffic of trucks that transport material.	2	5	25
- During construction, more than during operation, options 1 and 2 would affect the air quality of a slightly greater number of towns, but options 11 and 12 would affect the largest number of sensitive receptors (schools, churches and health centers), compared to the other alternatives.	3	3	21
- During construction, laborers will be exposed to noise, which will exceed safety levels.	4	3	22
	11	3	31
	12	5	34
B. Socio-environmental Impacts and potential risks to Biological Diversity			
6. Terrestrial communities	1	6	40
Because of the high rate of existing human intervention, biological diversity has a value relatively low in the Indian river watershed. The construction of any of the options will inevitably result in the removal of permanent vegetation. The greater the area of the reservoir, the greater the loss of vegetation; None of the socio-environmental impacts and potential risks are significant enough to prevent the execution of the project.	2	3	28
	3	2	23
	4	2	24
	11	5	36
- During the construction phase, there would be cutting to construct roads, other projects and the reservoir between 110 (option 4) and 460 hectares (option 12) of mature forest.	12	5	39
- During the construction phase, the majority of terrestrial fauna species would be negatively affected by the loss of the habitat, especially the slightly disturbed forest.			
- During the operation phase, additional habitat will be provided for waterfowl.			
7. Aquatic communities	1	5	45
The experience regarding the growth of aquatic weeds in Panamanian reservoirs indicates that these will invade any of the proposed reservoirs.	2	4	32
- During construction, even if the majority of the arboreal vegetation is cut, *aquatic weeds* will proliferate.	3	3	26
- During operation, experience in the country in the control of the aquatic weeds can be leveraged.	4	3	27
	11	3	39

Potential Socio-environmental Impacts	Option	Value	Accumulated value
During the operation phase of the reservoir, fish will be subject to a new regime: from lotic to lentic. The experience in the reservoirs of the country indicates that the introduction of peacock bass and tilapia generates an important fishing activity for the riverside communities. - During operation, the *fish and macro-invertebrates* present the following characteristics: 23 species of fish will remain in the lacustrine zone and tributaries; 4 species will disappear upstream; Population alterations will not be as drastic downstream from the dam; Rapid fluctuations of reservoir level affect the fish that use the banks to lay their eggs (trunks and weeds), since they would become exposed; 2 species of scientific importance are associated with upstream streams and that will still remain with the reservoir;	12	3	42
C. Socio-environmental Impacts and potential risks on Socio-economic and Cultural Aspects			
8. Socio-economic: **Socio-economic:** The Indio river watershed, as with the whole ROCC region contains family nuclei and small communities that mainly live in extreme poverty. - During construction, the following socio-environmental impacts and potential risks that are proportional to the size of every option will appear: It will be necessary to displace between 286 (option 4) to 1,568 persons (option 1); There will be an impact on community cohesion, since once displaced it will be difficult to reconstruct, even more when the settlements are larger; There will be a strong reduction in the commercial activities of populations located along the river bank; There will be a loss of infrastructure; There will be a loss of agricultural production that represents 42% of family consumption; There will be increased local employment and income, if and when the population is trained. Considering the poverty of the region and the dispersion of its population, the direct costs of replacing the economic and social infrastructure are relatively small. The biggest costs are associated with the costs of compensation to the displaced families and the mechanisms for lessen the impact on family and communal cohesion	1	14	59
	2	11	43
	3	8	34
	4	8	35
	11	12	51
	12	12	54
9. Cultural resources The current archaeological inventory in the ROCC indicates that 20 archaeological sites of different levels of importance are known to exist. Valuable scientific and cultural information will be lost due to the flood. - The archaeological sites that would be affected have been qualified as high, moderate and low importance. Options 1 and 2, report 1 site of high importance and the rest of the options none. Nevertheless, the option reports the highest total value, because it reports more moderate's sites (3) and 1 lower (15) importance.	1	29	88
	2	15	58
	3	8	42
	4	8	43
	11	30	81
	12	18	72

Potential Socio-environmental Impacts	Option	Value	Accumulated value
10. Scenery and scenic resources - Water options 1 and 2 tend to affect a greater number of inhabited sites that report resources of community interest.	1	11	99
	2	7	65
	3	3	45
	4	3	46
	11	3	84
	12	3	75



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 1: RIO INDIO 80-40

SOILS POTENTIAL IMPACTS

ACP

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Saddle Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer tunnel Rio Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio 80-40 Reservoirs
- Oriental Basin

Soils Types

- Arable: very severe limitations in choice of plant, requires very careful management or both
- Non Arable: very servere limitations, suitable for grassland , forests reserves
- Non Arable: with limitations preventing its use for commercial
- Non arable: low risk of erosion but with other limitations, suitable for forests and grassland

Source: Panama Canal Authority (ACP), Contraloria General de la Republica, IGN "Tommy Guardia", and URS Holding.

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Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

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REGIONAL LOCATION

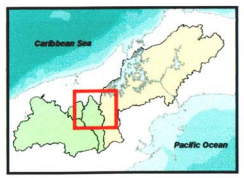

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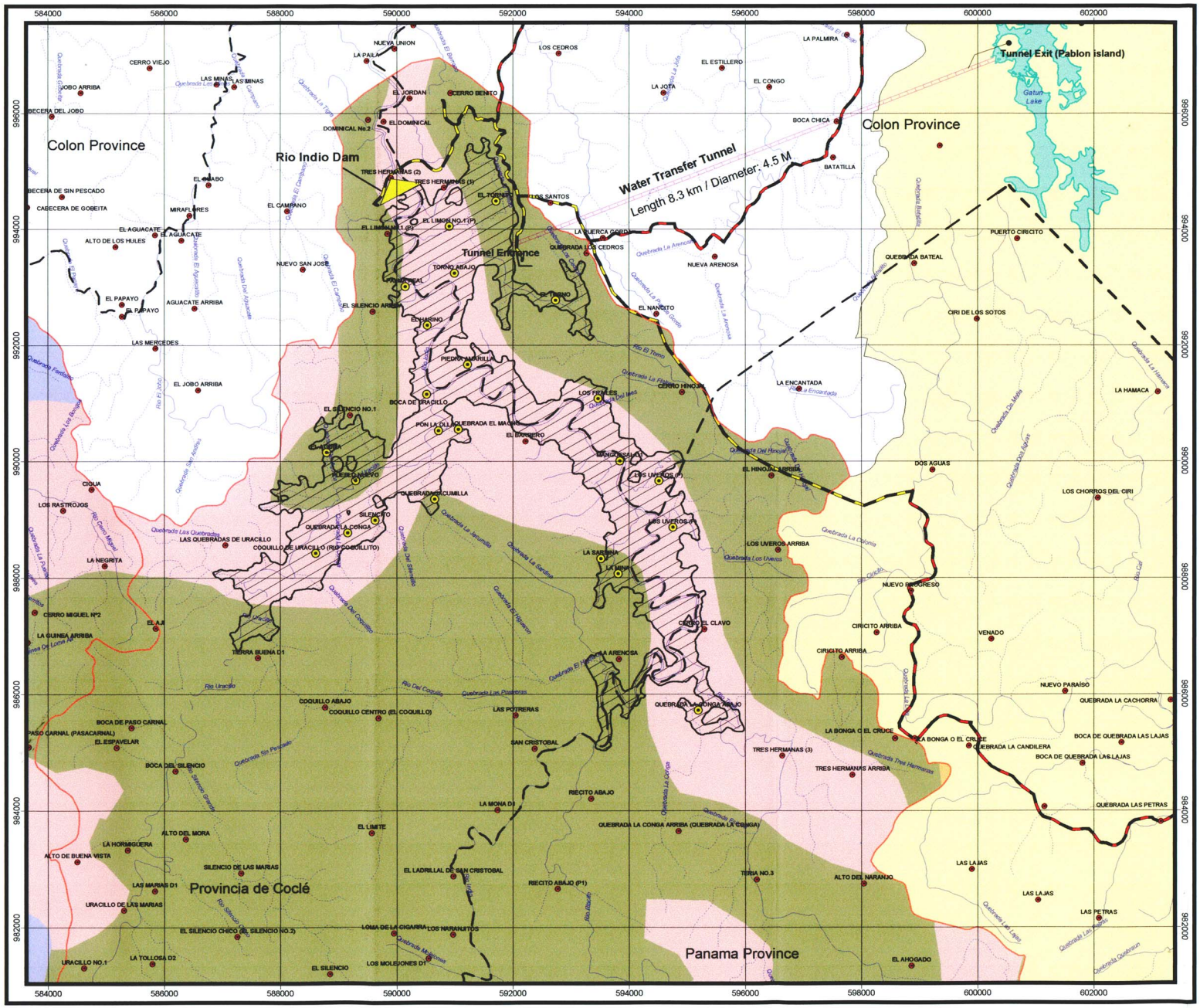
Figure N° 4-1



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 2: RIO INDIO 45-40

SOILS POTENTIAL IMPACTS

ACP

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Saddle Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer tunnel Rio Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio 45-40 Reservoirs
- Oriental Basin

Soils Types

- Arable: very severe limitations in choice of plant, requires very careful management or both
- Non Arable: very servere limitations, suitable for grassland , forests reserves
- Non Arable: with limitations preventing its use for commercial
- Non arable: low risk of erosion but with other limitations, suitable for forests and grassland

Source: Panama Canal Authority (ACP), Contraloria General de la Republica, IGN "Tommy Guardia", and URS Holding.

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Norte de Cuadrícula U.T.M.
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Datum NAD 27
Zona 17

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REGIONAL LOCATION

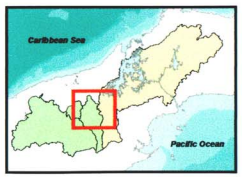

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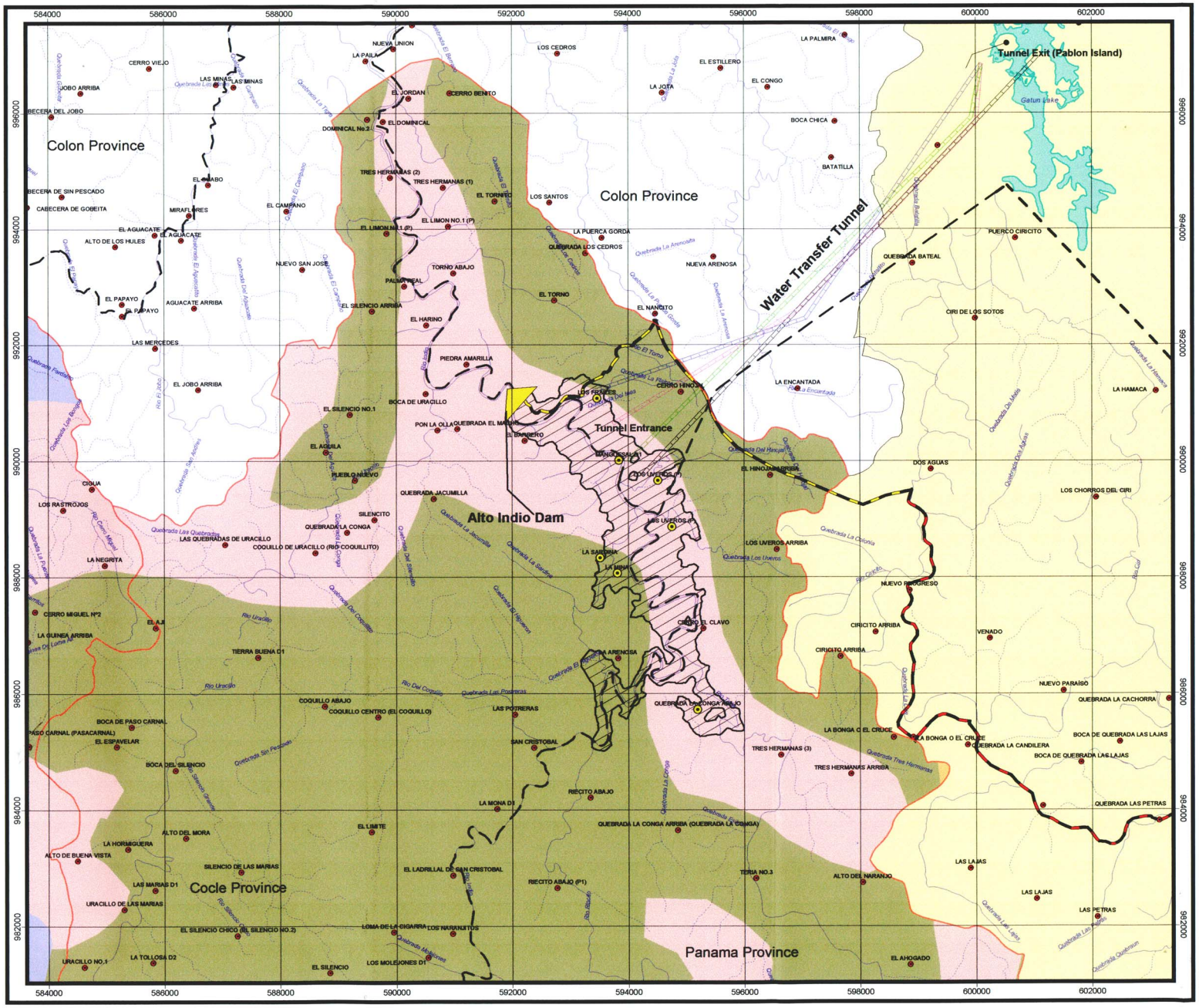
Figure N° 4-2



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 3: ALTO INDIO 50-40

SOILS POTENTIAL IMPACTS

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Saddle Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Tunnel Options Alto Indio - Lago Gatún
- Province Boundary
- Existent Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio 80-40 Reservoirs
- Oriental Basin

Soils Types

- Arable: very severe limitations in choice of plant, requires very careful management or both
- Non Arable: very servere limitations, suitable for grassland , forests reserves
- Non Arable: with limitations preventing its use for commercial
- Non arable: low risk of erosion but with other limitations, suitable for forests and grassland

Source: Panama Canal Authority (ACP), Contraloria General de la Republica, IGN "Tommy Guardia", and URS Holding.

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Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

2 0 2 Km

REGIONAL LOCATION

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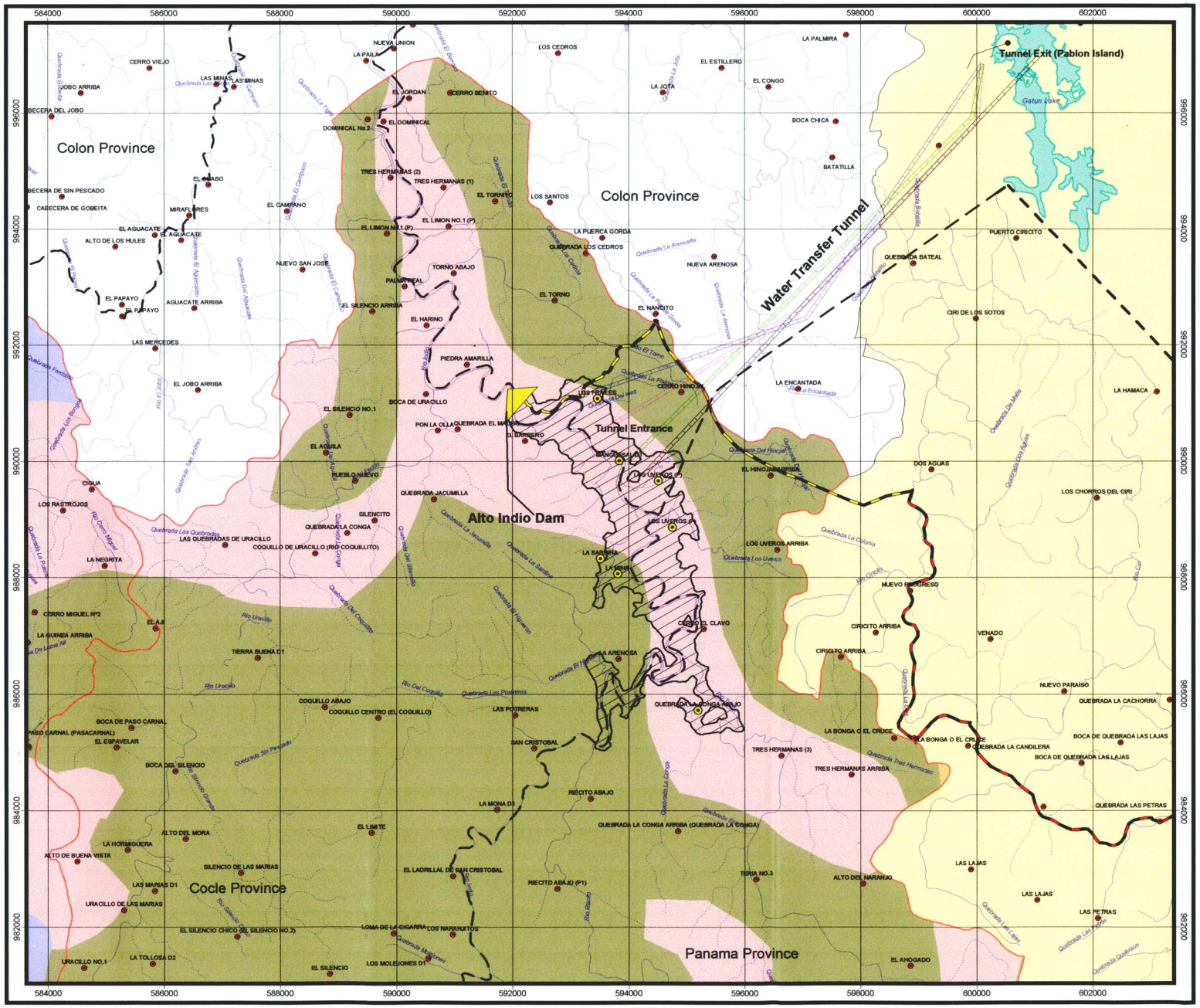
Figure N° 4-3



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 4: ALTO INDIO 45-40

SOILS POTENTIAL IMPACTS

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Saddle Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Tunnel Options Alto Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio 80-40 Reservoirs
- Oriental Basin

Soils Types

- Arable: very severe limitations in choice of plant, requires very careful management or both
- Non Arable: very servere limitations, suitable for grassland , forests reserves
- Non Arable: with limitations preventing its use for commercial
- Non arable: low risk of erosion but with other limitations, suitable for forests and grassland

Source: Panama Canal Authority (ACP), Contraloria General de la Republica, IGN "Tommy Guardia", and URS Holding.

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Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

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REGIONAL LOCATION

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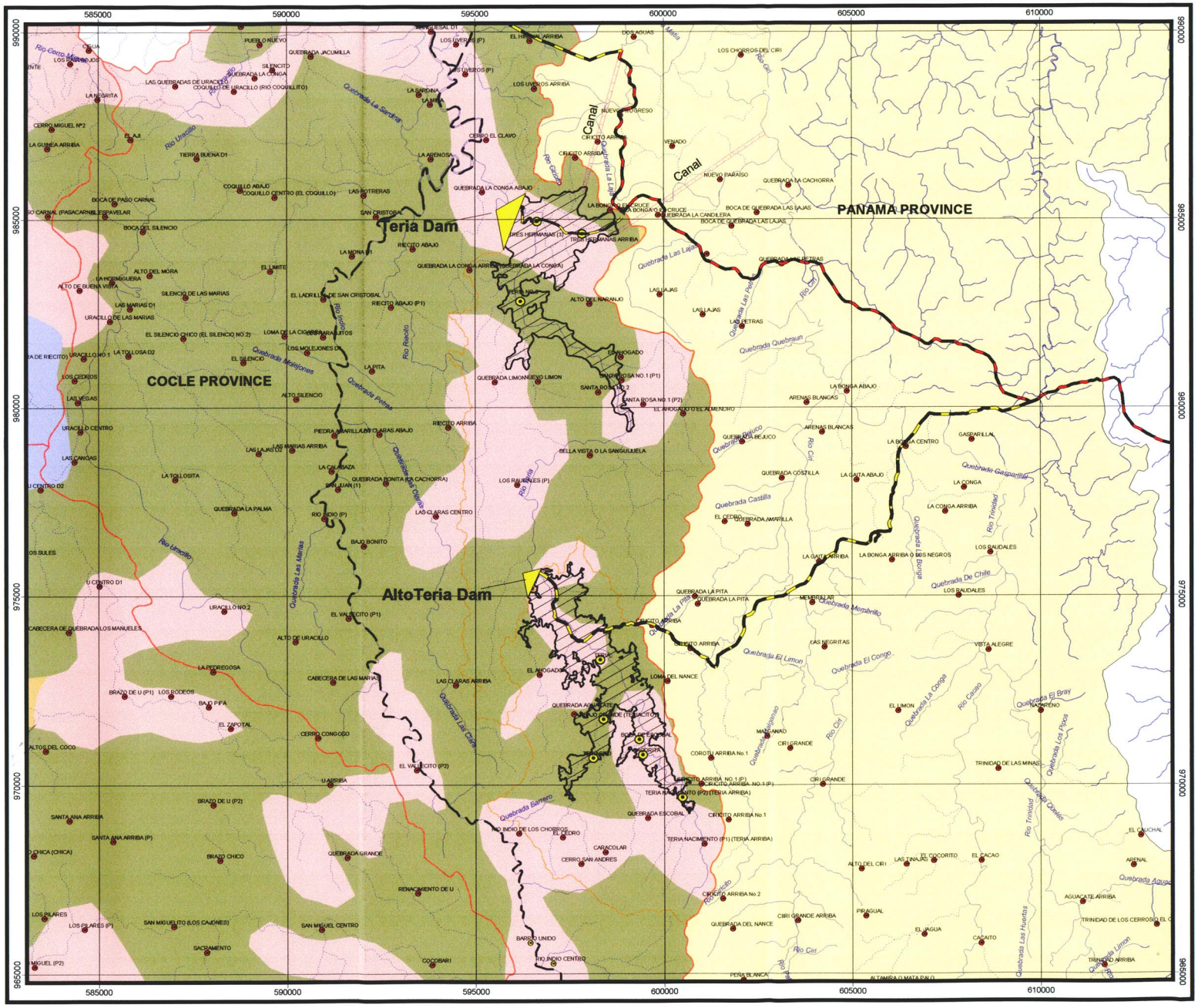
Figure N° 4-4



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 11: TERIA RIVER BASIN

ACP

SOILS POTENTIAL IMPACTS

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer Tunnel
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- ROCC Subbasin Boundaries
- Teria and Alto Teria Reservoir
- Teria and Alto Teria Basin
- Oriental Basin

Soils Types

- Arable: very severe limitations in choice of plant, requires very careful management or both
- Non Arable: very servere limitations, suitable for grassland , forests reserves
- Non Arable: with limitations preventing its use for commercial
- Non arable: low risk of erosion but with other limitations, suitable for forests and grassland

Source: Panama Canal Authority (ACP), Contraloria General de la Republica, IGN "Tommy Guardia", and URS Holding.

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1927 North American Datum
UTM Zone 17

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REGIONAL LOCATION

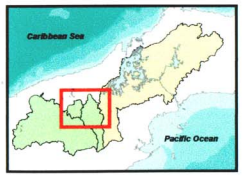

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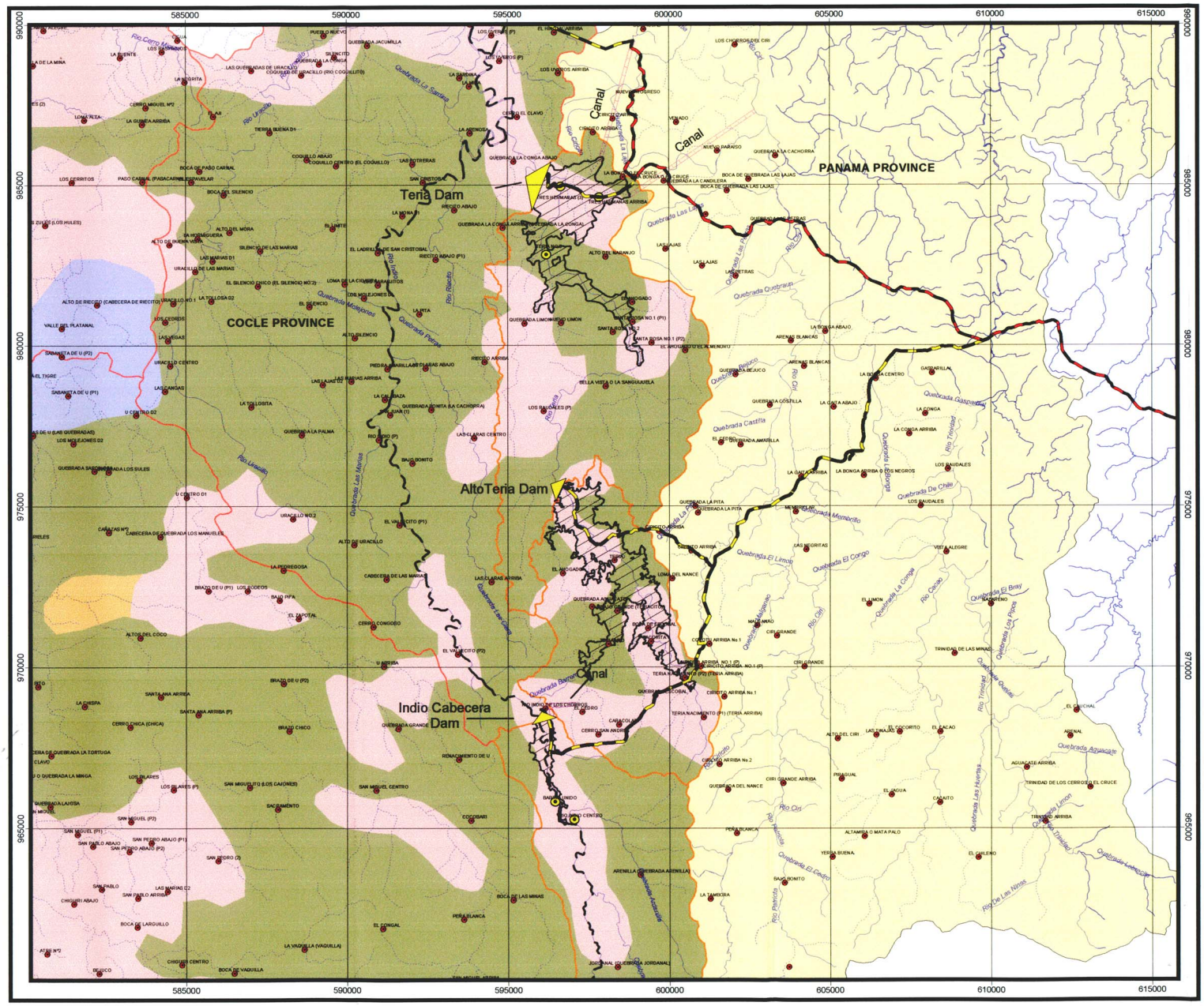
Figure N° 4-5



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 12: INDIO CABECERA, ALTO TERIA, AND TERIA RIVER BASIN

SOILS POTENTIAL IMPACTS

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer Tunnel
- Transfer Tunnel
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio Cabecera, Teria and Alto Teria Reservoir
- Indio Cabecera, Teria and Alto Teria River Basin
- Oriental Basin

Soils Types

- Arable: very severe limitations in choice of plant, requires very careful management or both
- Non Arable: very servere limitations, suitable for grassland , forests reserves
- Non Arable: with limitations preventing its use for commercial
- Non arable: low risk of erosion but with other limitations, suitable for forests and grassland

Source: Panama Canal Authority (ACP), Contraloria General de la Republica, IGN "Tommy Guardia", and URS Holding.

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1927 North American Datum
UTM Zone 17

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REGIONAL LOCATION

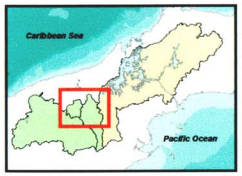

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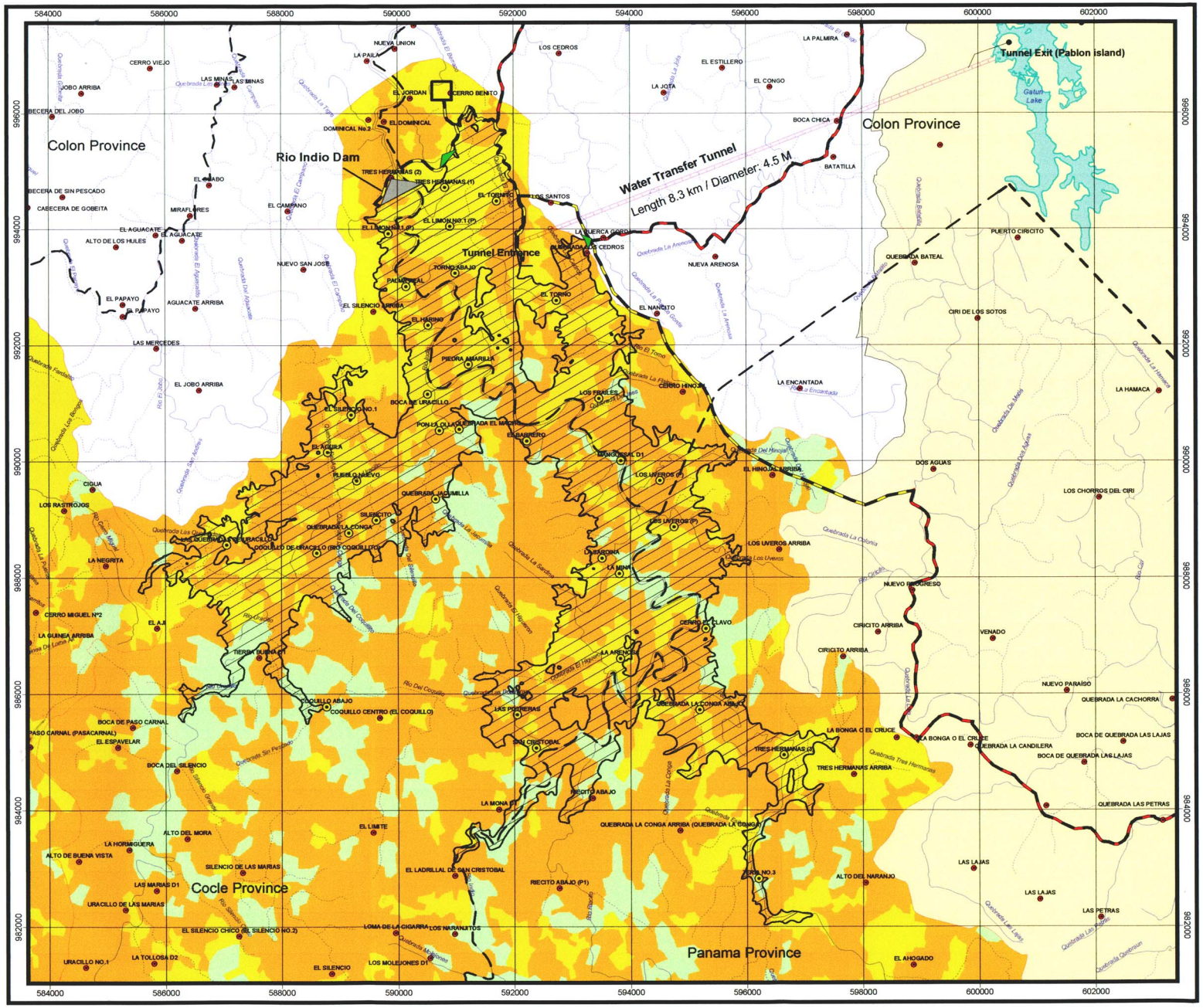
Figure N° 4-6



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 1: RIO INDIO 80-40
VEGETATIVE COVERAGE
POTENTIAL IMPACTS

ACP — PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Saddle Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer tunnel Rio Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase Main and Secondary Rivers
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio 80-40 Reservoirs
- Oriental Basin

VEGETATIVE COVERAGE

- Lowland tropical ombrophilous evergreen forest
- Montane Tropicalombrophilous evergreen forest
- Submontante tropical ombrophilous evergreen forest
- Grassland or productive system with significant natural spontaneous woody vegetation
- Shrubland or productive system with significant natural spontaneous woody vegetation

Source: Panama Canal Authority (ACP), Contraloría General de la República, IGN "Tommy Guardia", and URS Holding.

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Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

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REGIONAL LOCATION

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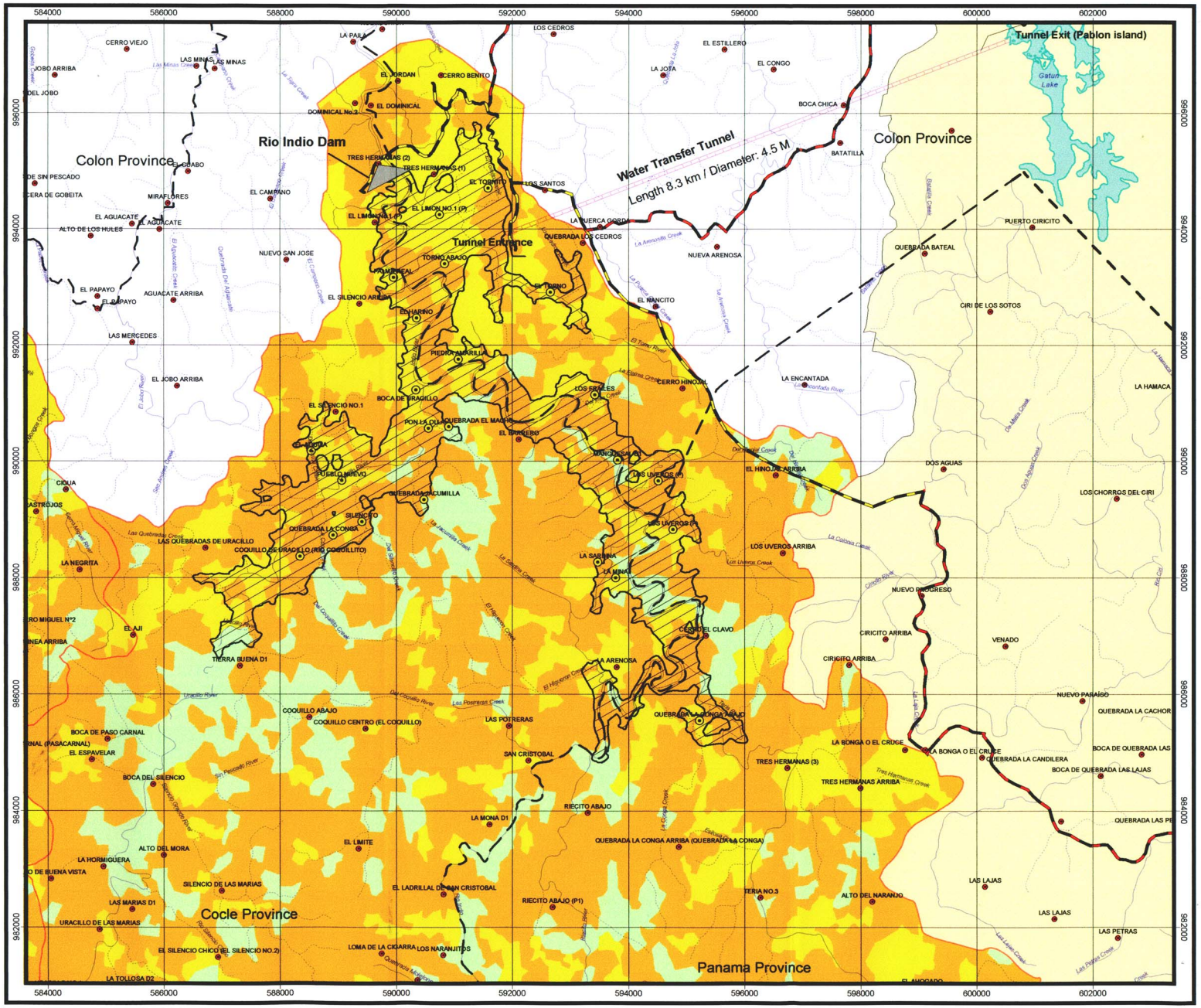
Figure N° 4-7



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 2: RIO INDIO 45-40

VEGETATIVE COVERAGE POTENTIAL IMPACTS

ACP

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Saddle Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer tunnel Rio Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio 45-40 Reservoirs
- Oriental Basin

VEGETATIVE COVERAGE

- Lowland tropical ombrophilous evergreen forest
- Montane Tropicalombrophilous evergreen forest
- Submontante tropical ombrophilous evergreen forest
- Grassland or productive system with significant natural spontaneous woody vegetation
- Shrubland or productive system with significant natural spontaneous woody vegetation

Source: Panama Canal Authority (ACP), Contraloría General de la República, IGN "Tommy Guardia", and URS Holding.

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Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

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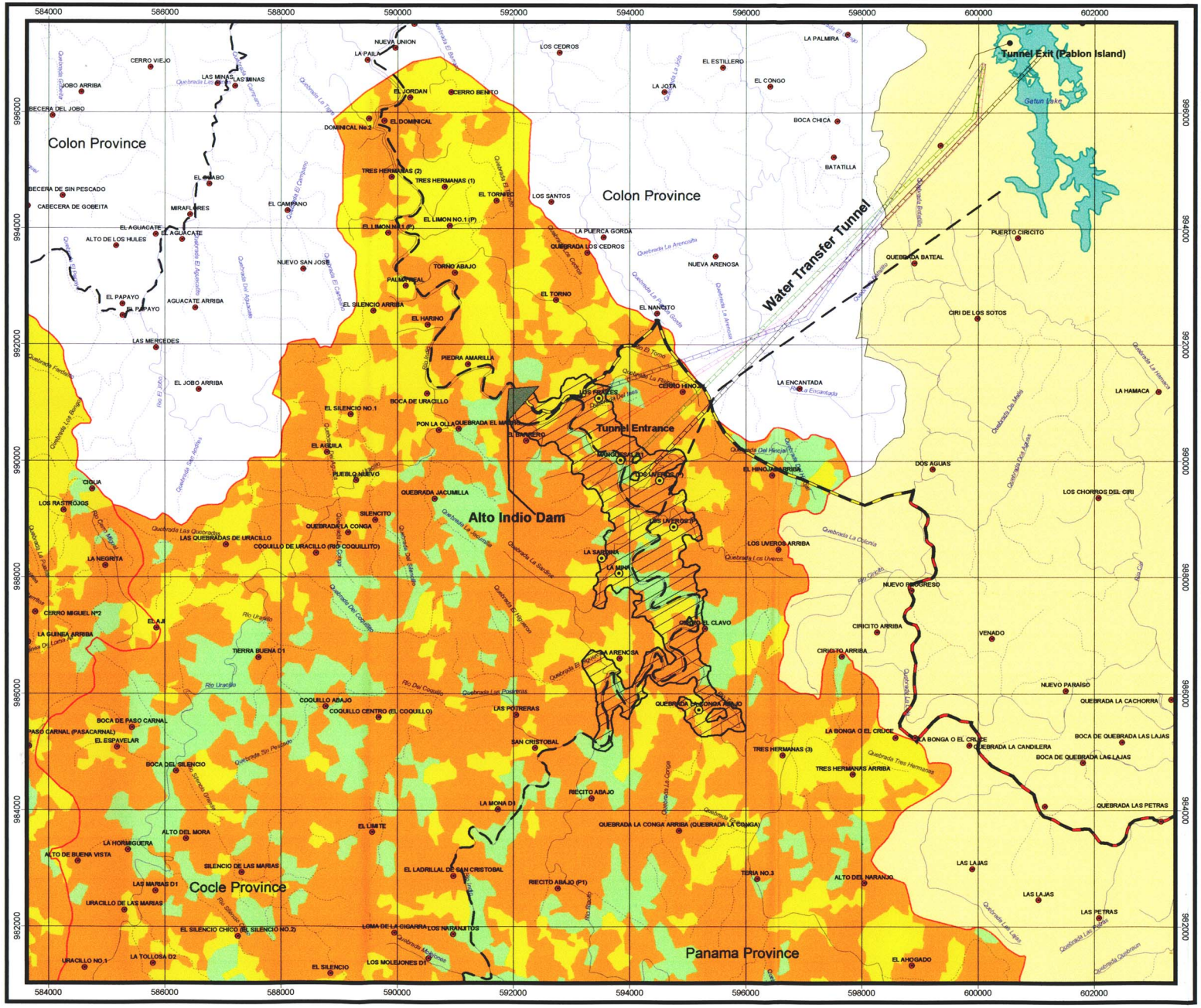
REGIONAL LOCATION

SCALE: 1:65,000

Figure N° 4-8



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 3: ALTO INDIO 50-40 VEGETATIVE COVERAGE POTENTIAL IMPACTS

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Saddle Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Tunnel Options Alto Indio - Lago Gatún
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase Main and Secondary Rivers
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Alto Indio 50-40 Reservoirs
- Oriental Basin

VEGETATIVE COVERAGE

- Lowland tropical ombrophilous evergreen forest
- Montane Tropicalombrophilous evergreen forest
- Submontante tropical ombrophilous evergreen forest
- Grassland or productive system with significant natural spontaneous woody vegetation
- Shrubland or productive system with significant natural spontaneous woody vegetation

Source: Panama Canal Authority (ACP), Contraloría General de la República, IGN "Tommy Guardia", and URS Holding.

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Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

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REGIONAL LOCATION

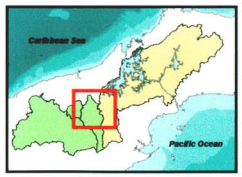

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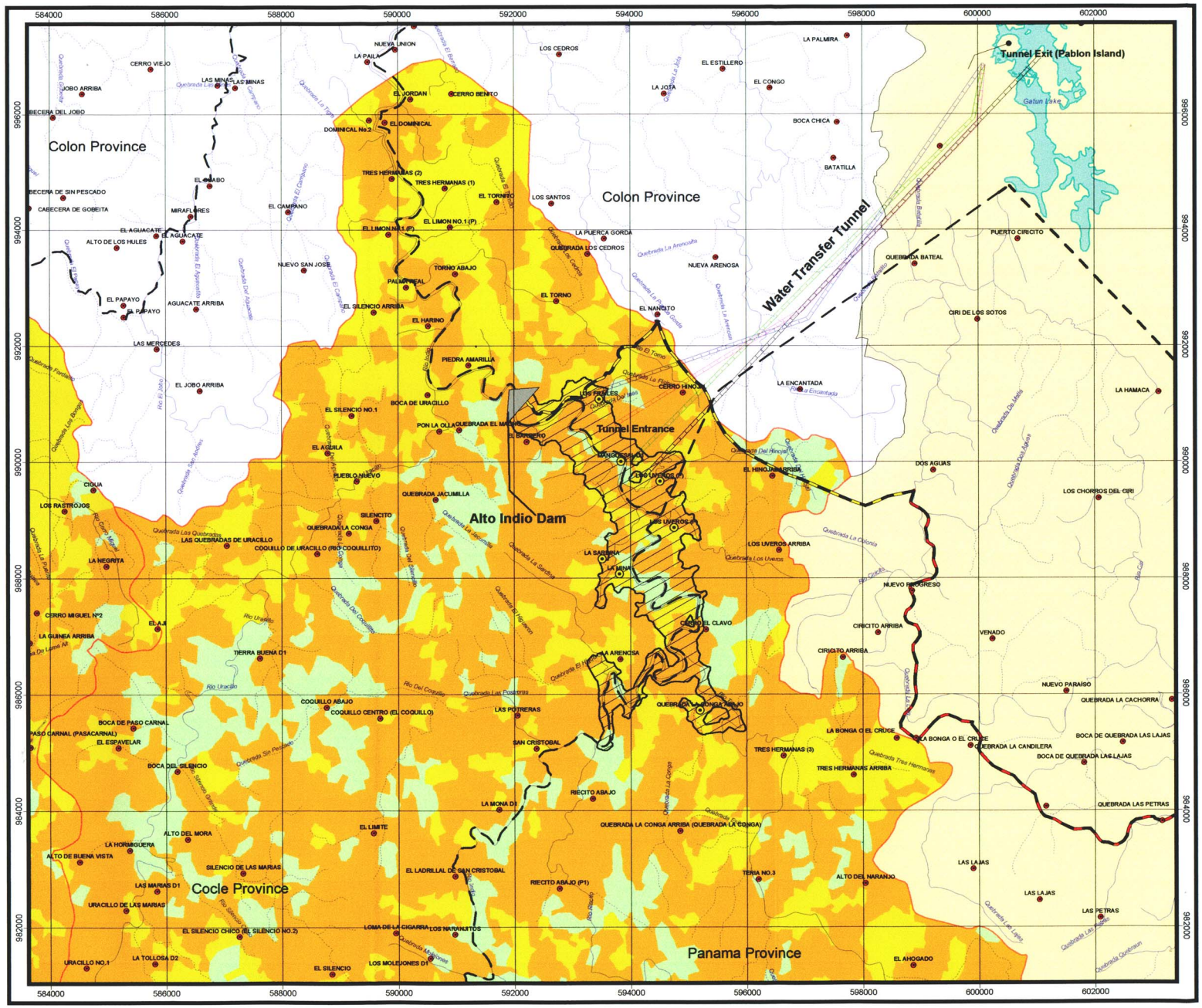
Figure N° 4-9



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 4: ALTO INDIO 45-40

VEGETATIVE COVERAGE POTENTIAL IMPACTS

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Saddle Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Tunnels Options Alto Indio - Lago Gatún
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase Main and Secondary Rivers
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Alto Indio 45-40 Reservoirs
- Oriental Basin

VEGETATIVE COVERAGE

- Lowland tropical ombrophilous evergreen forest
- Montane Tropicalombrophilous evergreen forest
- Submontante tropical ombrophilous evergreen forest
- Grassland or productive system with significant natural spontaneous woody vegetation
- Shrubland or productive system with significant natural spontaneous woody vegetation

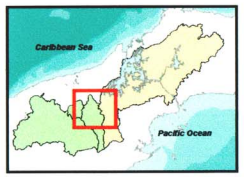
Source: Panama Canal Authority (ACP), Contraloría General de la República, IGN "Tommy Guardia", and URS Holding.

N W E S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

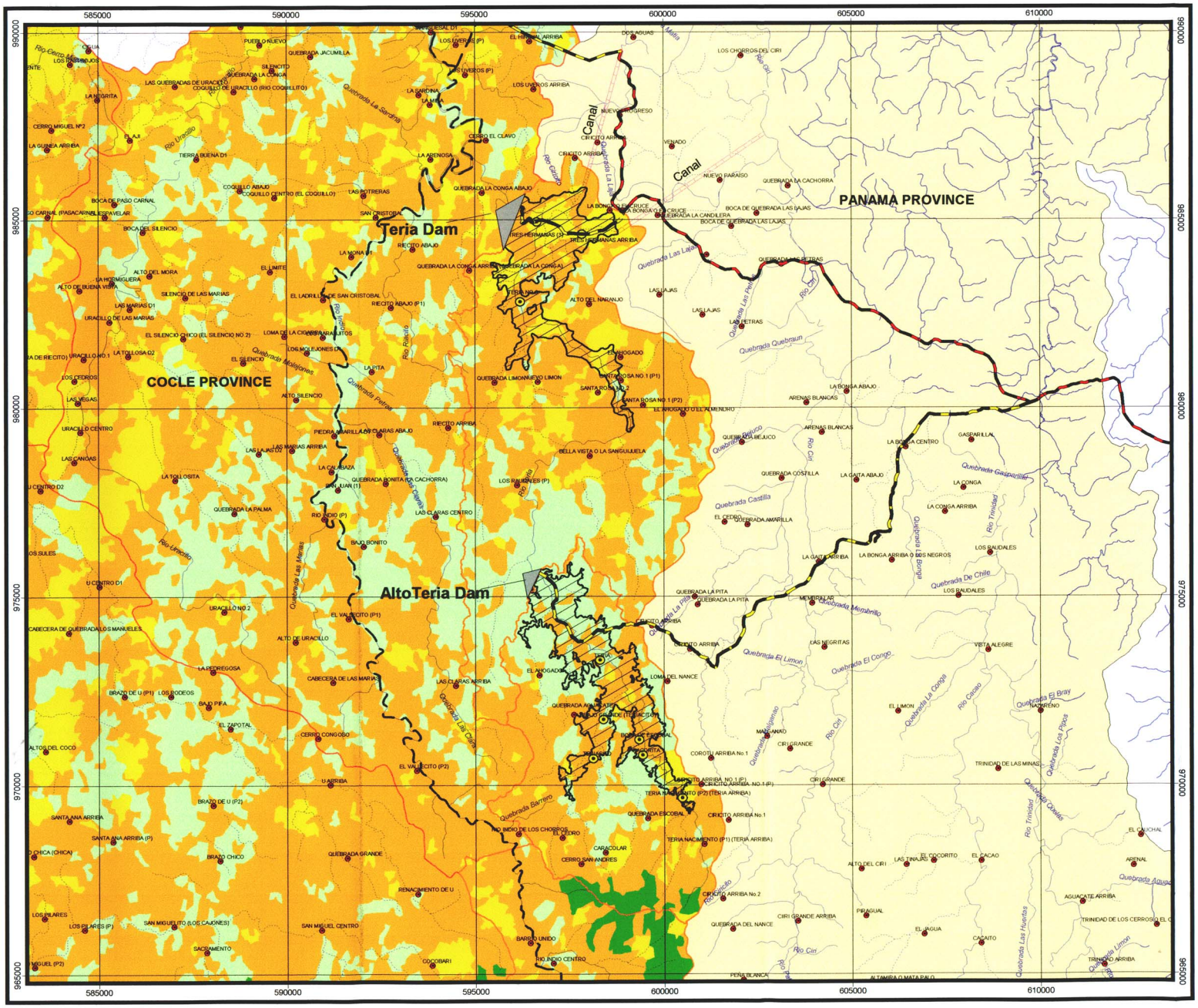
2 0 2 Km

REGIONAL LOCATION



SCALE:1:65,000

Figure N° 4-10



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 11: TERIA RIVER BASIN

VEGETATIVE COVERAGE POTENTIAL IMPACTS

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer tunnel
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Teria and Alto Teria Reservoirs
- Teria River Basin
- Oriental Basin

VEGETATIVE COVERAGE

- Lowland tropical ombrophilous evergreen forest
- Montane Tropicalombrophilous evergreen forest
- Submontante tropical ombrophilous evergreen forest
- Grassland or productive system with significant natural spontaneous woody vegetation
- Shrubland or productive system with significant natural spontaneous woody vegetation

Source: Panama Canal Authority (ACP), Contraloria General de la República, IGN "Tommy Guardia", and URS Holding.

N
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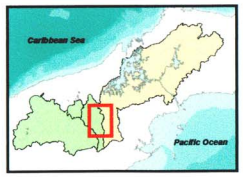
Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

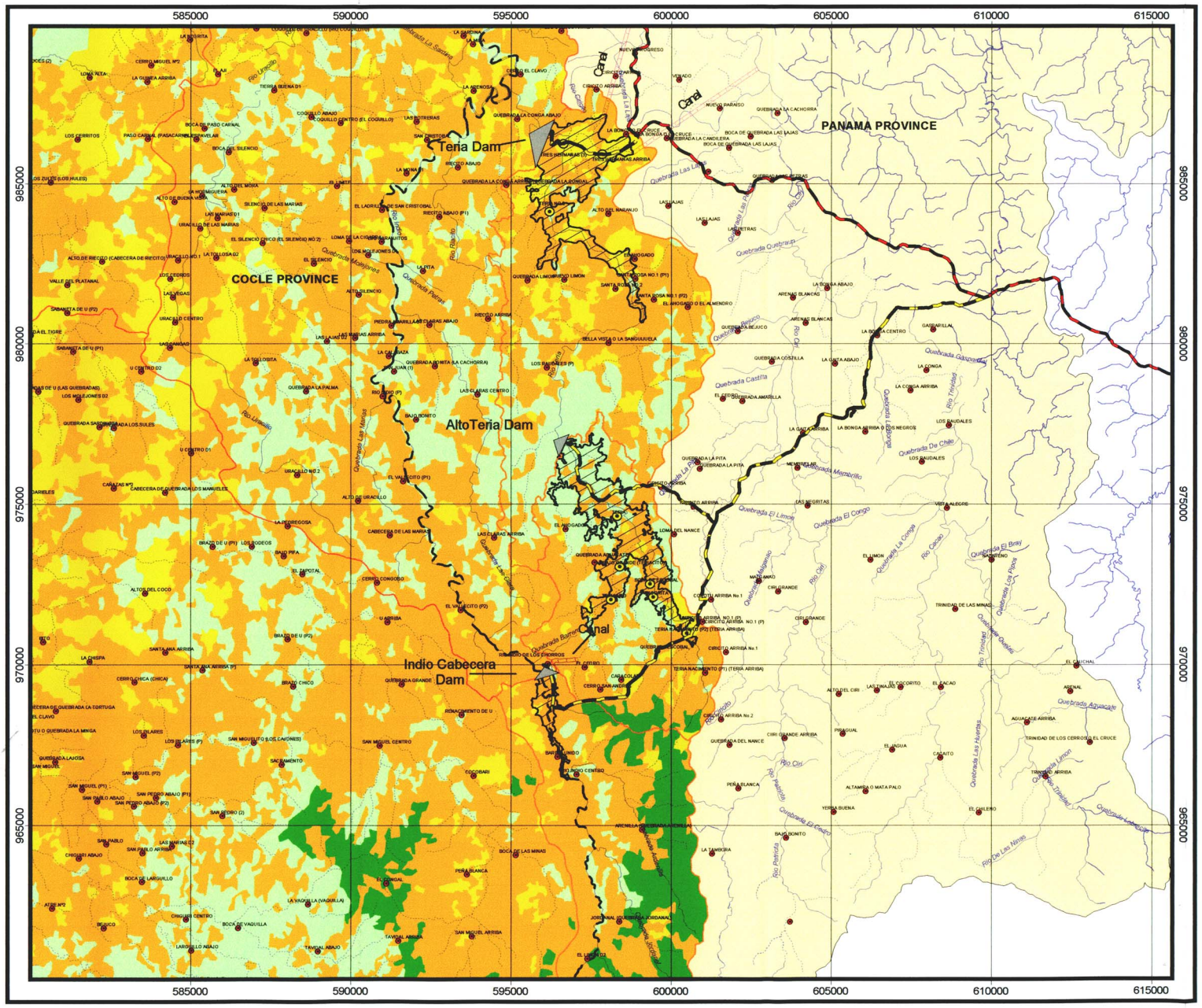
2 0 2 Kilometers

REGIONAL LOCATION



SCALE. 1:100,000

Figure N° 4-11



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 12: INDIO CABECERA, TERIA AND ALTO TERIA RIVERS BASIN

VEGETATIVE COVERAGE POTENTIAL IMPACTS

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Towns inside the Reservoir
- Towns outside the Reservoir
- Transfer tunnel
- Transfer tunnel
- Province Boundary
- Existent Access Roads to Reservoir
- Temporary Roads During Construction Phase Main and Secondary Rivers
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio Cabecera, Teria and Alto Teria Reservoirs
- Indio Cabecera, Teria and Alto Rivers Basin
- Oriental Basin

VEGETATIVE COVERAGE

- Lowland tropical ombrophilous evergreen forest
- Montane Tropicalombrophilous evergreen forest
- Submontante tropical ombrophilous evergreen forest
- Grassland or productive system with significant natural spontaneous woody vegetation
- Shrubland or productive system with significant natural spontaneous woody vegetation

Source: Panama Canal Authority (ACP), Contraloría General de la República, IGN "Tommy Guardia", and URS Holding.

N
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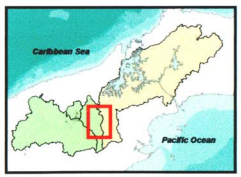
Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

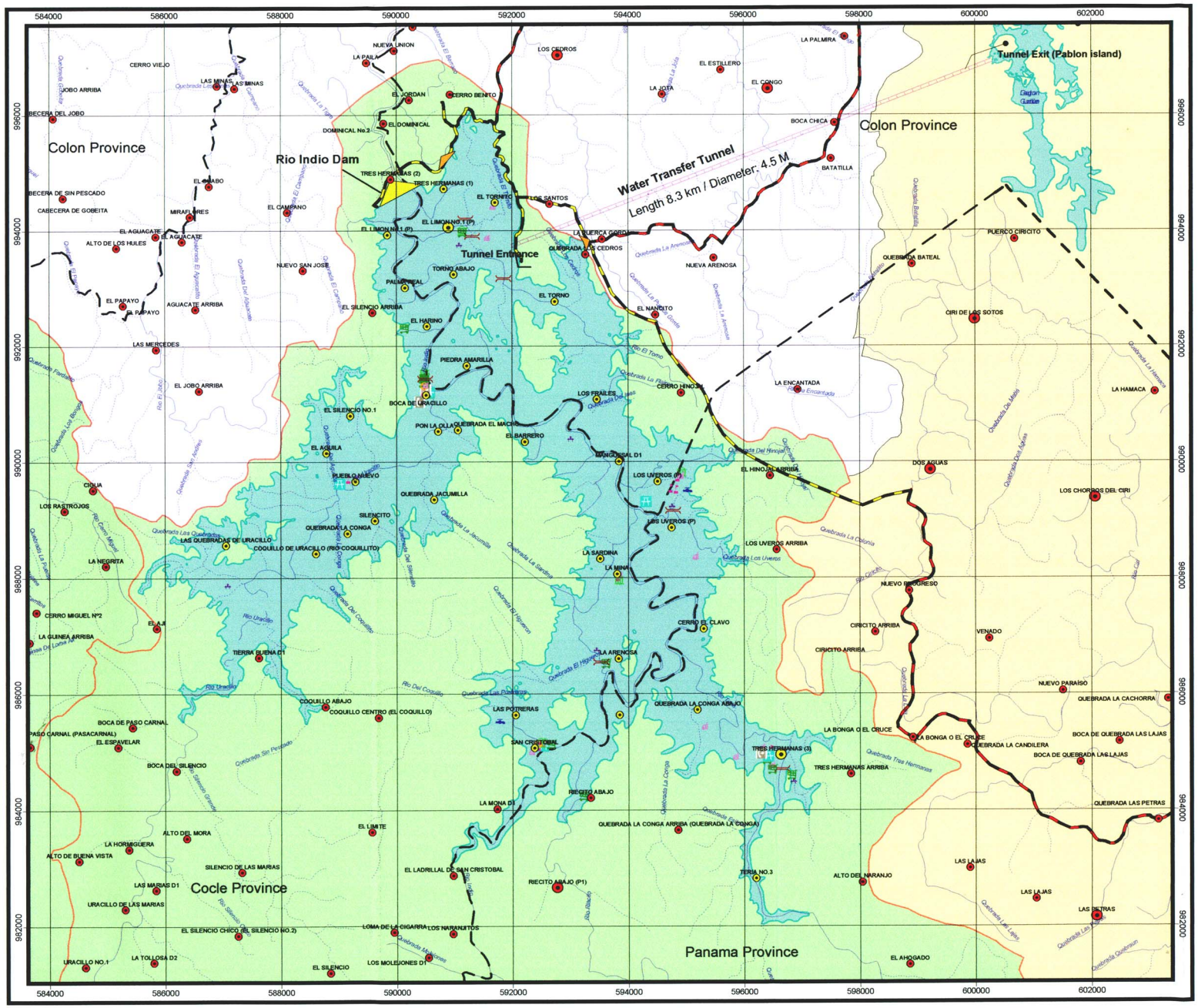
2 0 2 Km

REGIONAL LOCATION



SCALE 1:120,000

Figure N° 4-12



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 1: RIO INDIO 80-40

TOWNS AND INFRASTRUCTURE POTENTIAL IMPACTS

ACP PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Saddle Dams
- Transfer tunnel Rio Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio 80-40 Reservoirs
- Occidental Basin
- Oriental Basin

NUMBER OF INHABITANTS

I. Direct	I. Indirect
1 - 107	1 - 107
108 - 357	108 - 357

Infrastructures

- 2 Potable Water, Distribution, Storage, Source, Reserve Tanks
- 6 Recreational Area
- 8 Cemetery
- 3 Clinic or Health Stand
- 16 Commerce/Industrial/Agroindustrial
- 11 School
- 9 Goverment
- 15 Church
- 8 Bridge
- 3 Telecommunications

Source: Panama Canal Authority (ACP), Contraloria General de la República, IGN "Tommy Guardia", and URS Holding.

N W E S

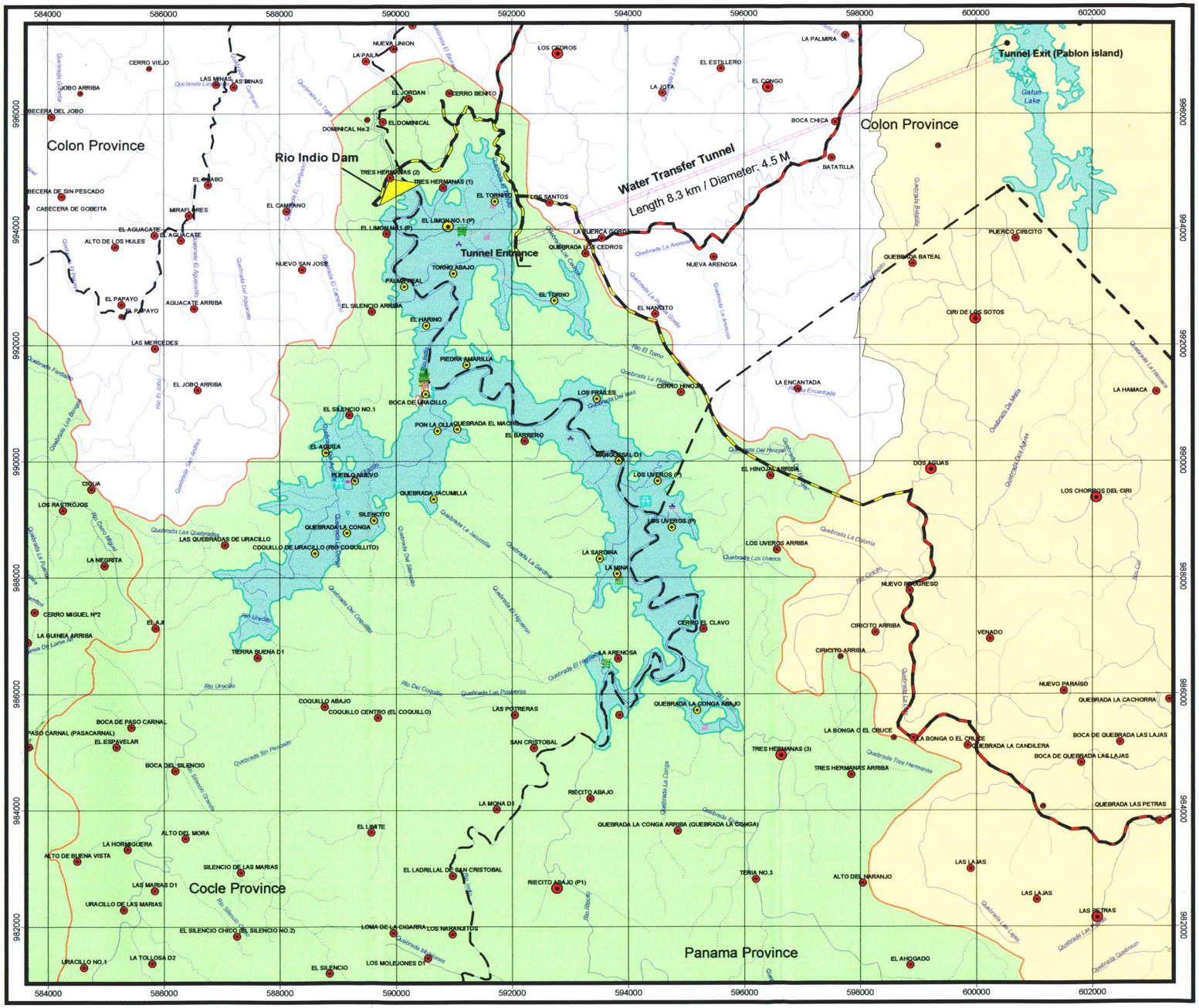
Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

2 0 2 Km

REGIONAL LOCATION

SCALE: 1:65,000

Figure N° 4-13



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 2: RIO INDIO 45-40

TOWNS AND INFRASTRUCTURE POTENTIAL IMPACTS

ACP PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Transfer tunnel Rio Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio 45-40 Reservoirs
- Occidental Basin
- Oriental Basin

NUMBER OF INHABITANTS

I. Direct	I. Indirect
1 - 107	1 - 107
108 - 357	108 - 357

Infrastructures

- 2 Potable Water, Distribution, Storage, Source, Reserve Tanks
- 6 Recreational Area
- 8 Cemetery
- 3 Clinic or Health Stand
- 16 Commerce/Industrial/Agroindustrial
- 11 School
- 9 Goverment
- 15 Church
- 8 Bridge
- 3 Telecommunications

Source: Panama Canal Authority (ACP), Contraloria General de la República, IGN "Tommy Guardia", and URS Holding.

N W E S

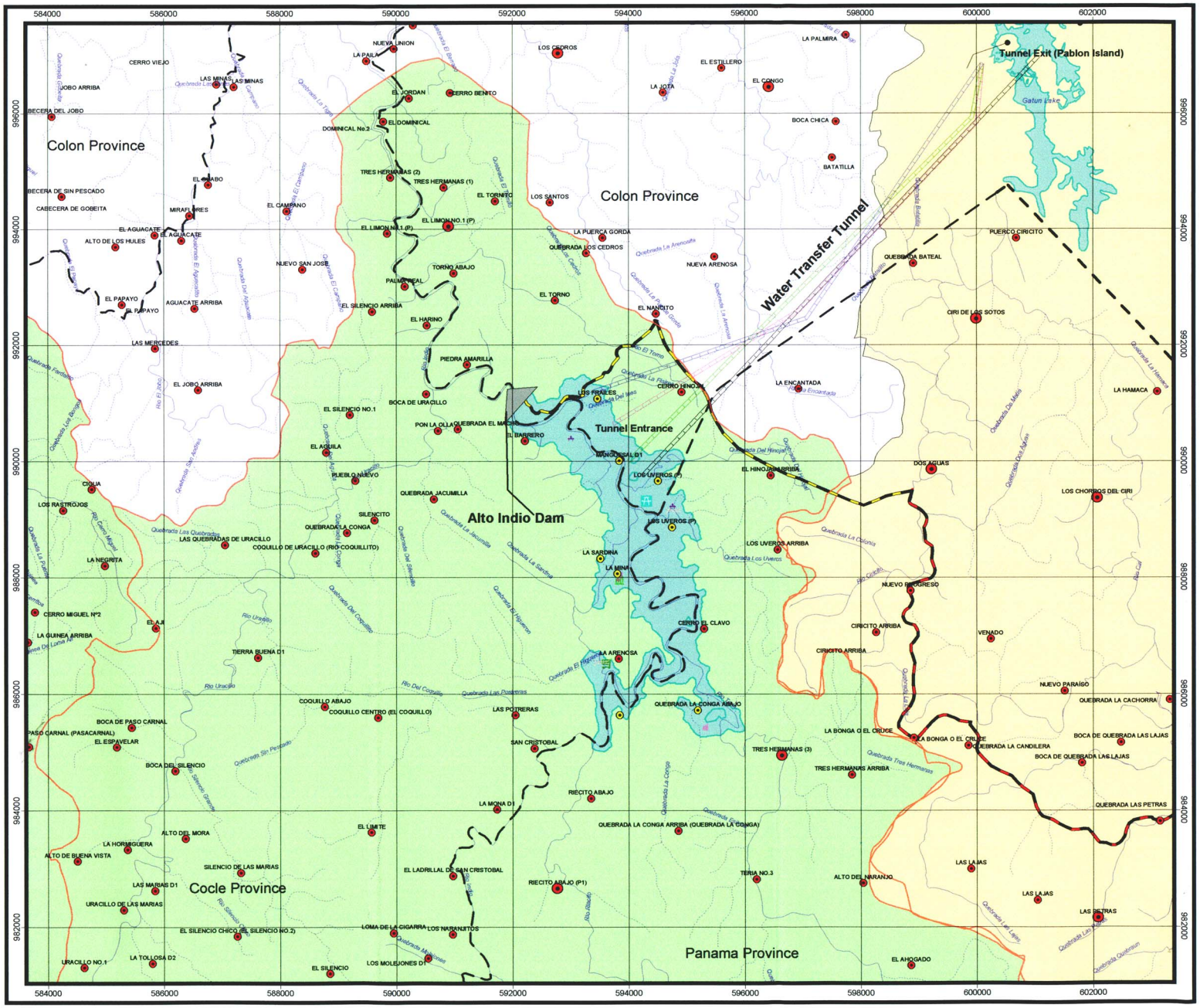
Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

2 0 2 Km

REGIONAL LOCATION

SCALE. 1:65,000

Figure N° 4-14



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 3: ALTO INDIO 50-40

TOWNS AND INFRASTRUCUTURE POTENTIAL IMPACTS

ACP

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Tunnel Options Alto Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Alto Indio 50-40 Reservoirs
- Occidental Basin
- Oriental Basin

NUMBER OF INHABITANTS

I. Direct	I. Indirect
1 - 107	1 - 107
108 - 357	108 - 357

Infrastructures

- 2 Potable Water, Distribution, Storage, Source, Reserve Tanks
- 6 Recreational Area
- 8 Cemetery
- 3 Clinic or Health Stand
- 16 Commerce/Industrial/Agroindustrial
- 11 School
- 9 Goverment
- 15 Church
- 8 Bridge
- 3 Telecommunications

Source: Panama Canal Authority (ACP), Contraloría General de la República, IGN "Tommy Guardia", and URS Holding.

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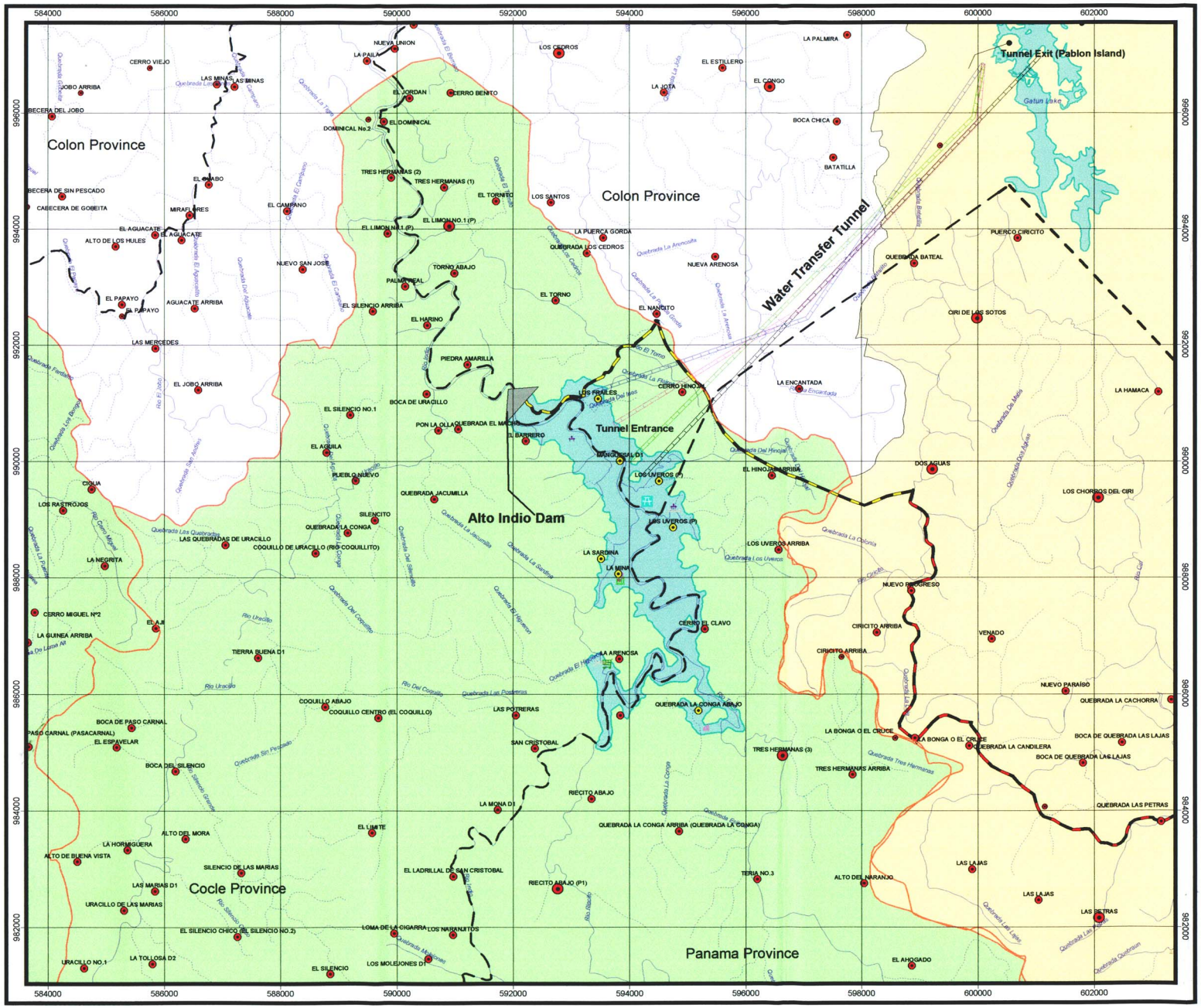
Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

2 0 2 Km

REGIONAL LOCATION

SCALE. 1:65,000

Figure N° 4-15



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 4: ALTO INDIO 45-40

TOWNS AND INFRASTRUCUTURE POTENTIAL IMPACTS

ACP PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Tunnel Options Alto Indio - Gatun Lake
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Alto Indio 45-40 Reservoirs
- Occidental Basin
- Oriental Basin

NUMBER OF INHABITANTS

I. Direct	I. Indirect
1 - 107	1 - 107
108 - 357	108 - 357

Infrastructures

- 2 Potable Water, Distribution, Storage, Source, Reserve Tanks
- 6 Recreational Area
- 8 Cemetery
- 3 Clinic or Health Stand
- 16 Commerce/Industrial/Agroindustrial
- 11 School
- 9 Goverment
- 15 Church
- 8 Bridge
- 3 Telecommunications

Source: Panama Canal Authority (ACP), Contraloria General de la República, IGN "Tommy Guardia", and URS Holding.

N W E S

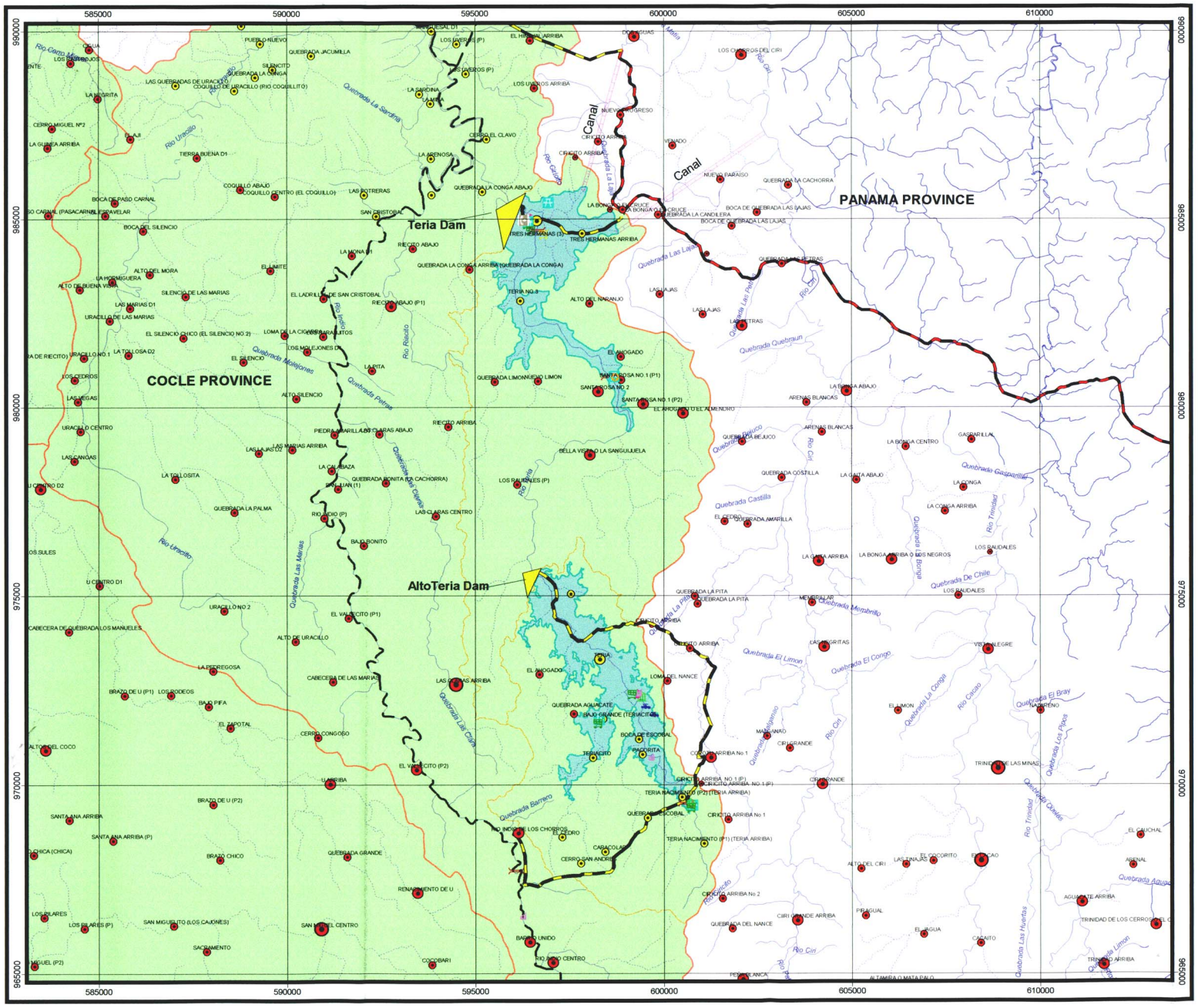
Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

2 0 2 Km

REGIONAL LOCATION

SCALE: 1:65,000

Figure N° 4-16



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 11: RIO TERIA BASIN

TOWNS AND INFRASTRUCTURE POTENTIAL IMPACTS

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Transfer tunnel
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Teria and Alto Teria Reservoirs
- Teria and Alto Teria Basin
- Occidental Basin
- Oriental Basin

NUMBER OF INHABITANTS

I. Direct	I. Indirect
1 - 107	1 - 107
108 - 357	108 - 357

Infrastructures

- 2 Potable Water, Distribution, Storage, Source, Reserve Tanks
- 6 Recreational Area
- 8 Cemetery
- 3 Clinic or Health Stand
- 16 Commerce/Industrial/Agroindustrial
- 11 School
- 9 Goverment
- 15 Church
- 8 Bridge
- 3

Source: Panama Canal Authority (ACP), Contraloria General de la Republica, IGN "Tommy Guardia", and URS Holding.

N
W E
S

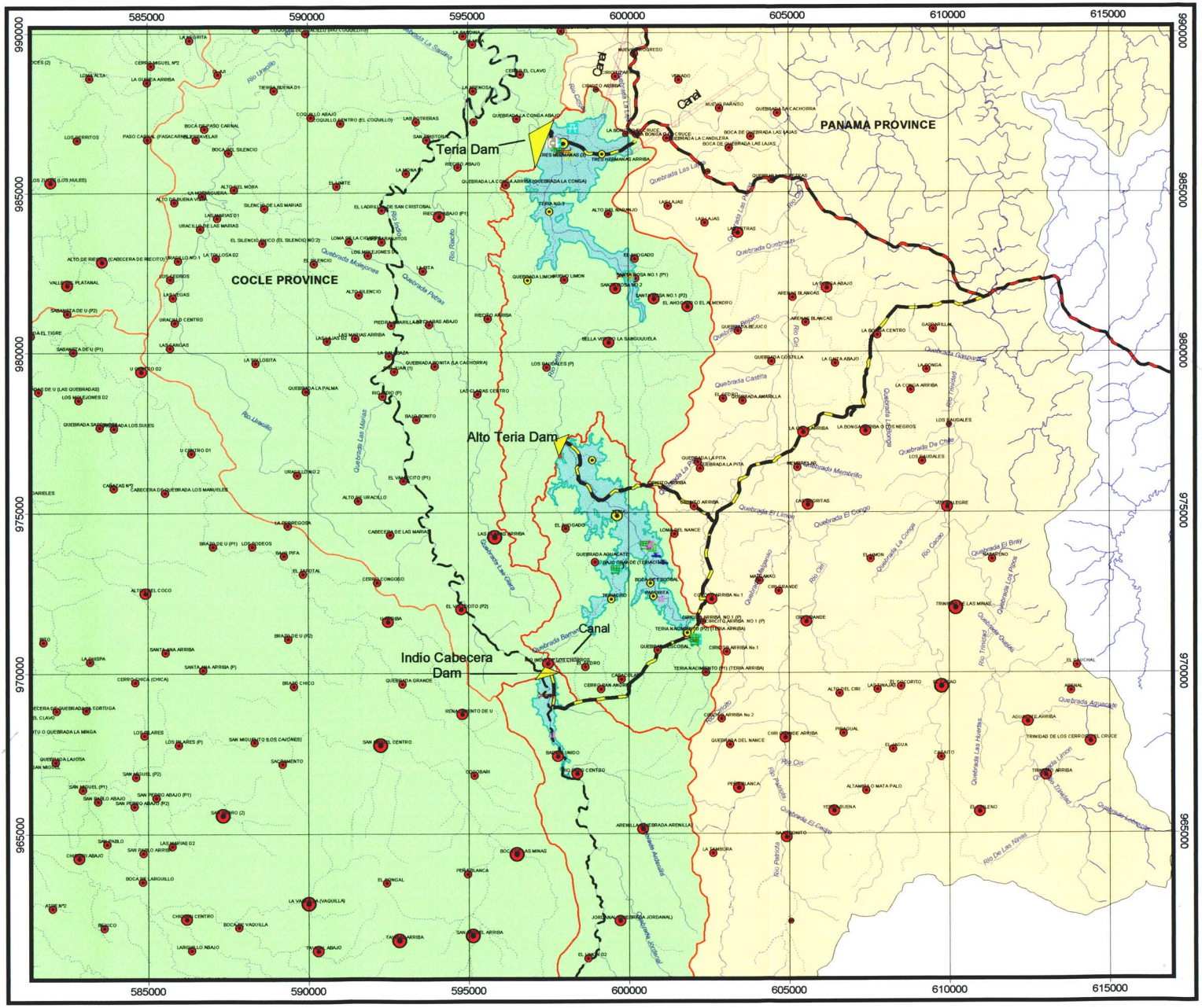
Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

2 0 2 Kilometers

REGIONAL LOCATION

SCALE. 1:100,000

Figure N° 4-17



ENVIRONMENTAL EVALUATION OF WATER RESOURCES OPTIONS FOR INDIO CAÑO SUCIO AND TOABRE RIVERS

OPTION 12: INDIO CABECERA, ALTO TERIA AND TERIA RIVER BASIN

TOWNS AND INFRASTRUCTURE POTENTIAL IMPACTS

PANAMA CANAL AUTHORITY (ACP)

LEGEND

- Dams
- Transfer tunnel
- Transfer tunnel
- Province Boundary
- Existing Access Roads to Reservoir
- Temporary Roads During Construction Phase
- Main and Secondary Rivers
- Creeks
- ROCC Subbasin Boundaries
- Indio Cabecera and Teria Reservoirs
- Teria, Alto Teria and Indio Cabecera Rivers Basin
- Occidental Basin
- Oriental Basin

NUMBER OF INHABITANTS

I. Direct	I. Indirect
1 - 107	1 - 107
108 - 357	108 - 357

Infrastructures

- 2 Potable Water, Distribution, Storage, Source, Reserve Tanks
- 6 Recreational Area
- 8 Cemetery
- 3 Clinic or Health Stand
- 16 Commerce/Industrial/Agroindustrial
- 11 School
- 9 Goverment
- 15 Church
- 8 Bridge
- 3

Source: Panama Canal Authority (ACP), Contraloria General de la República, IGN "Tommy Guardia", and URS Holding.

N W E S

Clarke 1866 Spheroid
1927 North American Datum
UTM Zone 17

2 0 2 Km

REGIONAL LOCATION

SCALE. 1:120,000 | Figure N° 4-18

Even though existing conditions are appropriate to implement any of the considered water alternatives, conducted analyses indicate that, with current erosion rates and nutrient export, sedimentation risks and accelerated eutrophication of the possible reservoirs are small. Nevertheless, it should be considered that if there are not current important risks to the projected useful period of the reservoir and to water quality due to sedimentation, this situation could deteriorate if there is an increase of the land use intensity that is not in accord with limitations imposed by the biophysical conditions previously described.

Based on the previous considerations we concluded that in order to make the execution of any water option feasible from the social and environmental standpoint an environmental management plan (EMP) is needed to work primarily in two main axes: the adequate relocation and the improvement of the living conditions of the local communities; and the recovery, improvement, and conservation of the environmental goods and services associated with the watershed's original ecosystems. Therefore, the two main components of the EMP are:

- A **resettlement human development plan** that properly compensate fro the losses and difficulties, and that particularly improve the living conditions of the communities, families and people that could be affected by the implementation of the water option(s), which may be selected; and
- A **recovery and protection of the biophysical conditions plan** for the Rio Indio watershed, with the purpose of fully reestablishing the environmental goods and services, thus reducing the environmental risks for the operation of the Canal.

These two main components of the EMP include a set of measures for the prevention, reduction and control of the potential socio-environmental impacts and risks, which are directly aimed to avoid and minimize the effects of the potential negative socio-environmental impacts and risks and maximize the positive ones. In essence the plan includes actions oriented to prevent the socio-environmental impacts and risks that can be prevented, reduce those that cannot be prevented, compensate for the net effects that could not be prevented or reduced, and maximize the potential directs and indirect benefits.

In Addition to these two main components, in order to complete the EMP it is necessary to include other plans and programs, which will facilitate the EMP meeting its main goals and objectives. Among these the more important include:

- A **socio-environmental monitoring plan** with the parameters and indicators that shall be measured and the frequency of information gathering for each one of them. The monitoring

activities seek a double purpose; on one hand periodically verify that the measures for prevention, reduction and control are meeting their objectives; and for the second part document the state of socio-environmental "health" in the area of influence.

- A **program for verification and control**, with its execution mechanisms including activities with a structure similar to those of the monitoring plan, with the purpose of demonstrating and documenting that the planned actions that are effectively being executed. Rather than to determine the environmental "health" of the region, this program aims to measure the effectiveness of the environmental management and the administrative procedures in place. The National Authority for the Environment (ANAM) will be, by law, responsible for this program and the ACP must coordinate with this institution to find the mechanism to execute this program.
- A **contingency plan,** which include the measures to prevent, reduce, control, or respond to any emergency conditions. The plan includes the prevention and control measures for spills of hazardous substances such as oil, fuel, and paints, amongst others; as well as any other contingencies particularly during the construction phase. During the operation phase and evacuation and protection plan for the communities downstream the dam shall be available, in case of dam failure.
- A **proper budget,** which shall cover the costs of the measures for the prevention, reduction and control of the socio-environmental impacts, the monitoring, and verification and control activities that together conform the EMP.

Finally, the costs that represent the execution of the Environmental Management Plan are included. When preparing the cost estimates the disbursement both for prevention, reduction and control activities as well as the ones for monitoring, and verification and control were considered.

5.1.1 EMP Objectives

The EMP seeks that the selected water alternative is executed and operated without the occurrence of adverse environmental and social impacts that have not been considered. For this purpose several components (programs) have been organized considering the nature of the actions and the requirement of the specialized personnel in them.

The EMP objectives include the following:

1. Provide the ACP with a document where the required measures to prevent, minimize, mitigate and compensate or indemnify the current and potential socio-environmental

impacts derived from the execution of one or more or the considered water alternatives are provided;

2. Identify important topics for which more information is required to define the required management;
3. Define the parameters and variables that will be used to determine and improve environmental quality in the project's influence area through monitoring;
4. Establish mechanisms so that pertinent authorities can provide follow up to the project's environmental consequences and implement required controls;
5. Define the measures to prevent and reduce and control and/or provide response in urgent situations; and
6. Provide detailed costs to implement the EMP.

5.1.2 Responsibilities and Execution Mechanisms for the EMP

The EMP describes the programs that should be performed or accomplished by ACP and/or contractors to prevent and minimize the socio-environmental impacts during the conceptualization, design, construction and operation and maintenance phases of the option or water options, that become selected for the Master Plan to expand and modernize the canal.

Before the prevention, minimization, reduction and control and compensation of the socio-environmental impacts, ACP and/or the contractor must have a responsible person to assure the full compliance with the programs. Specific responsibilities of the Socio-environmental Coordinator in the Environmental Management Plan will be:

- Assure the fulfillment of the environmental requirements established in the EMP's programs and of the contracting conditions imposed to the project;
- Guarantee that the project's EMP is appropriately implemented and monitored;
- Prepare weekly reports regarding the compliance with environmental measures;
- Provide information to ACP, ANAM and other organisms of the Panamanian State, when they require them;
- Periodical inspections of work areas to verify the compliance with the EMP;
- Provide immediate response to urgent situations through the Contingency Plan; and
- Interact with local communities to keep them informed of the project's events and to discuss in time any aspect of interest.

In section 5.5 the foreseen organization to execute the Environmental Management Plan is described, including the respective administrative structure.

5.2 Resettlement And Human Development Plan

The resettlement and human development plan includes actions to prevent, reduce and control socio-environmental impacts and potential risks that could be directly and indirectly affecting the population in the case that any of the considered water alternatives is developed. The plan includes specific activities organized by programs with related topics and for each of them there are justifications, objectives and descriptions of impact prevention, reduction and control measures. These measures are grouped by phase of construction and final design, operation and an eventual abandonment/close out.

The Indio River watershed, as well as all the Occidental Region of the Canal Watershed (ROCC), contains family nuclei and ties and small communities that mainly live in extreme poverty. When facing the possibility of displacing families that currently inhabit the proposed zones for the canal water alternatives, ACP is correctly considering all elements so that it is successful. The resettlement and human development plan is based on the assessment of the potential socio-economic impacts and associated risks and costs that the Indio River watershed population, and that from adjacent areas, would confront in the case that one of the considered water alternatives is carried out. The main objective of the plan is to prevent, reduce and control socio-environmental impacts and potential negative risks, maximizing the positive ones and to improve the local socio-economical infrastructure to leave inhabitants of the influence area in the selected option in better living conditions than before the displacement.

The execution of any of the water options under consideration would have directs and indirect impacts on the population currently living in the areas of potential flooding. At the family level those impacts include the displacement from those areas of the affected families, its belongings, production and subsistence means, and their communities' social and cultural web. At the communal level the impacts include the loss of the social and economic infrastructure, the displacement of the nucleus of commercial activity and the informal institutional network in which the every day life of the community goes about.

On the other hand, the execution of any of the water options would also have positive impacts, such as the generation of paid employment in one of the poorest regions of the country, as well as the opportunity to acquire new and enhanced productive skills, which could generate a greater permanent income to the affected families. Finally, the execution of the water options provides an opportunity to improve the level of regional development and the public socioeconomic infrastructure, supported by the scale economies that the construction activities for any of the

options would bring about. The potential impacts and risks on the socioeconomic and cultural aspects were described in the section of impacts.

It is certain that the water options under consideration would have directs and indirect impacts on the population of the Rio Indio watershed. To minimize those impacts at least the following three main factors shall be taken into account:

a. **An appropriate estimation of the compensation for the affected population**. The compensation figures, the administration and payments of those values and the minimization of the local inequalities that these compensations may cause are of great importance to reduce the social impact and to improve harmony among the displaced and the non-displaced citizens. Primarily, the program shall avoid the over heating of the local economy, which may occur as a result of the sudden injection of cash resources to a reduced population group. This possible over heating could lead to high levels of local inflation, which would harm the population in the receptor communities, giving rise to a local discord factor. As will be shown below, the compensation should avoid the generation of winners and losers within the local communities.
b. **Create an environment of opportunity.** When the extreme poverty conditions are suddenly disrupted by a high level of social and economic assistance an incentive for aid dependence may be created. In other words there is a risk for creating a dependence attitude that will not lead to local development. Therefore, the compensation mechanisms shall be aimed to the construction of opportunities (vg: development of the local economic infrastructure and local training and education) and no to the mere and simple transfer of money.
c. **Provide public goods**. To avoid resentment from the non-compensated families, the mitigation program must emphasize the provision of public goods, such as electricity, potable water, basic education, good quality of public health services, and those communication and transportation means that would benefit the displaced as well as the non-displaced sectors of the regional population. In this way there is significant consistency in the distribution of the benefits amongst both groups, providing at the same time the local share of the canal expansion benefits[1].

[1] These three points are critical factors and are completely consistent with the lessons learned on the subject of involuntary displacement and the resettlement of families in conditions similar to those of the Rio Indio watershed, which are summarized in: World Bank, 1996. "Resettlement and Development: The Bankwide Review of Projects Involving Involuntary Resettlement 1986-1993." Environment Department Paper No. 032, Washington DC. Those lessons indicated that the **proper estimation** of the compensation, together with the constant supervision and **enforcement of the agreements** with the displaced are of outmost importance for the success of the resettlement program.

In the same manner as the rest of the ROCC, the Indio River watershed is a very poor region; in fact the region is not self sufficient, the average per capita income is 21 times smaller than the average national income and the income received by people working is lower than B/. 70 per month[2]. Thus, the total cost of replacing family property and existing infrastructure is small with respect to the total cost of any of the considered options. Nevertheless, *because these are poor families that have been historically isolated and that they would capture a minimum portion of the direct benefits of the Canal expansion, the image risk linked to the process of prevention, reduction and control of socio-environmental impacts is extremely high.* In fact, the final success of the resettlement and human development plan will translate rapidly in an administrative and managerial success for PCA and the Government, which will favor the support of all Panamanians to the canal modernization program, while —conversely—*if the plan is managed in an inappropriate manner, the negative impact on the institutional image could slow the execution schedule of the considered options.*

5.3 Objectives of the resettlement and human development plan

The main objective of the plan is to prevent, reduce and control direct and indirect negative impacts that the water alternatives will cause on social and economic aspects of the families that inhabit the direct and indirect influence area. Its purpose is to satisfy the needs of the affected families with regard to material, social and emotional losses that will occur with the execution of the options considered by ACP. In the same level, its purpose is to define the opportunities that a canal modernization and expansion program could have to improve life conditions among the affected families to compensate or indemnify the families due to the negative impacts, even when there may be a direct replacement for the affected goods.

To fulfill these objectives this section relies on learned lessons from involuntary resettlement in other countries – summarized from World Bank and specialized author's documents[3]. These lessons include specific aspects regarding content and logistics of the process of redevelopment, as well as healthy warnings on the obligation to emphasize equity in the process, both among resettled people and among resettled people and the receiving community.

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[2] See Table 4.7.4 de URS-Dames and Moore, 2003. Western Region/ Contract No.SSA-53-299. Recopilación y Presentación de Datos Socioeconómicos de la Región Occidental de la Cuenca del Canal de Panamá. URS, Panamá.

[3] World Bank, 1996. *Op. cit.*; Cernea, Michael M., 1988. "Involuntary Resettlement in Development Projects: Policy Guidelines in World Bank-financed Projects." World Bank Technical Paper No. 80. Washington D.C.; Hansen, Art y Anthony Oliver-Smith, eds., 1982. *Involuntary Migration and Resettlement: The Problems and Responses of Dislocated People.* Boulder, Colorado: Westview Press.

5.3.1 Components of the Resettlement and Human Development Plan

For the Indio River watershed, the plan to resettle and generate human development in the communities of the influence areas of the considered water alternatives has four main components, which together should improve socioeconomic conditions of these communities and should be reflected in a relatively short period of time in the quality of life indicators. These main components of the plan are described as follows:

- **Program to Resettle the Communities.** Prevention, reduction and control of direct impact of displacement of affected families in the flooding areas. This component has as an objective to replace goods and family properties that would disappear due to flooding, as well as compensating or indemnifying affected families due to the damages and discomfort produced by their relocation in other place in the region. The replacement of family goods is required but insufficient. A cost to compensate emotional damages and discomfort experimented by families when displaced from their households has to be added. The compensation and indemnifying will occur in two ways: one monetary to alleviate the discomfort during the transition[4] stage and the other of an institutional type, through training programs and other manners of acquiring new labor skills to increase the capability to be employed and local productivity. Within this component —and related with the mitigation program to maintain community cohesion— a management rule is included: reduction of the distance between current sites of agricultural activities and the resettlement places, within possibilities. Distance reduction between the current location and the resettlement area— including production lands— is very important as a compensation factor and must be considered in detail once ACP decides on the option to develop[5]. Also minimization of the resettlement distance should be accompanied by an effort to resettle the displaced families to compatible communities in ethnic, cultural and social terms.

- **Program to Compensate Production Losses.** Direct impact prevention, reduction and control of the production loss for self-consumption and for commercialization. The objective of this component is to compensate or indemnify affected families for the value of their lost production as a consequence of the displacement. This includes the loss of annual

[4] The use of calculation methods for the compensation, such as evaluation of the disposition to accept losses, or the contingency assessment, will be described in the monitoring section of this document.

[5] Other countries experiences indicate that the payment to replace lost goods is required but insufficient. To this the strong equity criteria has to be added as mitigation to avoid the presence of winners and losers within a community due to a project. The movement of complete groups of a same location to a same nearby location, and its accompaniment with a strong community investment that benefits the receptive community, is fundamental for the success of the project. See Resettlement News, No. 4, January 2003.

commercial crops, as well as the costs to reestablish perennial crops and the non-perceived productive income during the transition period in the new resettlement zone.

- **Program to Protect Community Cohesion**. Prevention, reduction and control of the impact of the loss of community and social cohesion. The resettlement of the communities creates special circumstances that do not allow the exact replacement of the existing communities. Although there is a good possibility that a resettlement program well conducted improve community cohesion in the resettlement area, also there is a risk that existing communities will not resist the period and will disintegrate under the displacement pressures. According to recent studies[6] families in the region have a marked preference to move in group and prefer the shortest possible distance from their current village location. This is due in part to the fact that most of the communities contain less than 10 houses and group a nuclei of people conformed by related people or that consider themselves as effective clans, which function as families or multiple households. Also the socio-cultural study underlines that cultural affinity (Vg. Customs, music, patron festivities, etc.) can be a powerful cohesive helping to insert displaced families into receptive communities with similar cultural values. The objective of this component is to replace, widen and improve social infrastructure of the displaced communities and households: Schools, Health Centers, Churches, Cemeteries and Community Centers. The replacement will be accompanied by compensation and indemnifying communities through the improvement of quality and capability of replaced infrastructure — better Schools, better Health Centers, etc.

- **Program to Replace and Improve the Economic Infrastructure.** Prevent, reduce and control the impact of loosing the economic infrastructure, including roads and bridges, local nuclei of commercial activities and land and water transportation infrastructure. The objective of this component is to replace and improve the regional economic infrastructure with the projection to generate a better access to commercial activity centers out of the flooding zones. Within the component attention will be given to the provision of road infrastructure for communities downstream of the dam/s whose capacity to move by boat will be affected including their capacity for commercial exchange. The compensation for this impact will include the replacement of commercial stands, restoration and improvement of access roads to the perimeter of the flooding zone, and improved access roads in the perimeter of the zones located downstream of the dams.

[6] Abt Associates/Planeta Panamá, 20004. *Op. cit.*

- **Technical Assistance Program for Sustainable Development.** It is certain that the well being of the populations around the water alternative constitute the best guarantee to recover and maintain the ecological equilibrium in the Indio River watershed and neighboring areas. Thus the management plan should be designed in terms of the well being of these populations that traditionally have been isolated and have received low attention from the Central and Local Government. Only in this manner population's participation and cooperation in the plan implementation can be obtained, which is basic for its success. To guarantee a larger local capture of the benefits of the expansion of the water alternatives, this component includes agriculture and livestock local programs that will emphasize commercialization. This last focus is fundamental to guarantee that technical assistance and the new offered practices by the Ministry of Agriculture and Livestock Development and the IDIAP that have economical validity will be adopted voluntarily by producers. This means that all technical assistance offered should be economically advantageous for the producers, if not it will be ignored. Obviously that the conceptualization of a long term sustainable development program is out of the contract scope, but the main elements for one are here provided.

5.3.2 Direct Impact Prevention and Control in the Construction Phase

Most of the impacts of economic and social nature, and all those that have a high risk of negatively affecting local dwellers and communities will be evident in the construction phase. Thus the measures to prevent, reduce and control these effects, guiding them to promote the sustainable development of the communities in the area will also happen during the same phase. In the following sections the main measures destined to make feasible, from the economic and social point of view, the execution of the water alternative that results selected in the Indio River watershed are provided.

5.3.2.1 Program to resettle displaced communities

In general terms displaced families due to the proposed dams should have the option to receive the total equivalent of all compensations and indemnifying in cash from the program to modernize and expand the canal. This focus, although feasible as part of the implementation plan, is considered only in an implicit manner within the analysis.

To be able to consider the actions that ACP and the program to modernize and expand the canal should implement so that affected communities effectively maintain or improve their living conditions, it is necessary that the relocation of affected communities is conducted in very

similar areas to the ones they currently inhabit. This is a clear and simple manner to diminish the negative direct impact of displacement over the family well being, because it minimizes the number of variables that are modified during the change and adaptation process. In this sense, some neighboring areas have been identified in the feasibility study conducted for Option 1 (Figure 5-1), which could be also considered by the other options considered as possibilities for the required resettlement.

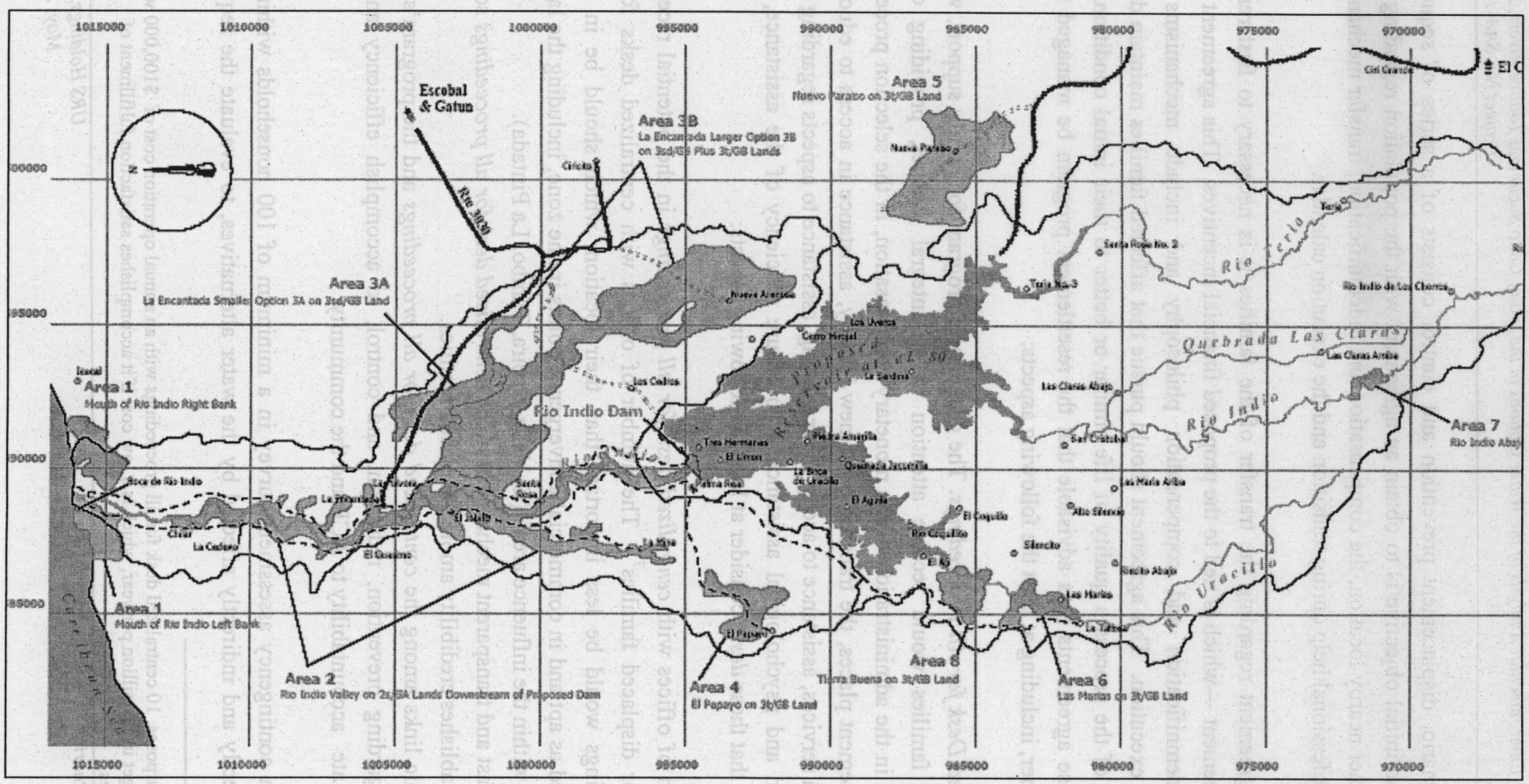
High poverty and low education level of the affected population indicates that a market focus, where families are free to select their own direction, is fairly simplistic and can easily lead to the failure of the project due to the lack of knowledge of urban life among the affected families; their lack of labor skills and appropriate productivity and the lack of financial discipline required to manage compensation funds in an appropriate manner.

Although the option of leaving the rural environment should exist among affected families, ACP and the Government have the joint responsibility to help the families in the transition process. Therefore, this option should only be considered in special cases, for instance when a considerable part of the family group already is settled in an urban area. This is a feasible situation presented with some frequency among affected families because the Indio River Watershed is characterized by migration of population to areas outside of the region.

Also, it should be considered that the main cause for opposing the expansion, by some residents of the watershed, is the generalized perception of a large disproportion in the distribution of benefits from the program to modernize and expand the canal, in which the displaced families will only receive direct negative impacts. This perception would disappear with the implementation of an effective prevention and control plan for the socio-environmental impacts and reasonable and responsible compensations or indemnifications, managed through offices of direct aid to the population in the potential resettlement areas.

Although the analysis assumes that the displaced families would again restart their activities that preceded the displacement, a large part could migrate to urban zones. In both cases, ACP would have to establish support offices for the affected families to aid them in the transition process to their new locality. Even more, these offices should be a source for resources and access to institutional services, so that the displaced families feel protected during the transition.

Figure 5-1: Potential Areas for Resettlement Identified in the Feasibility Study of the Option 1.



Under this scenario, displacement prevention and control consists of a series of sequential activities, whose initial objective is to obtain an agreement with the population regarding their transfer to another nearby location, the compensation and indemnification, transfer mechanisms, the access to professional help during transition and the execution calendar.

To reach an agreement regarding the transfer of the families it is necessary to first reach a conceptual agreement —which is tied to the proposed financial incentives. This agreement must reflect the indemnification and compensation philosophy and include mechanisms and alternatives for execution. This agreement should pursue that affected families maintain during and at the end of the process a quality of life similar or better to their initial condition. To accomplish these agreements it is advisable that the resettlement program be managed in an integrated manner, including at least the following aspects:

i. *Centralized Desk for All Proceedings*. The design of a program for family support, where displaced families would receive attention in an integral manner, providing direct assistance in the administration of the monetary compensation, in the selection process of the resettlement places, the transfer to the new locality, assistance in access to education and health services, assistance to access labor training, assistance to aspects regarding labor orientation and psychological assistance. To ensure efficiency of the assistance, it is important that these *desks* consider at least the following aspects:

- Location of offices with *centralized desk for all proceedings* in the potential reception areas for displaced families[7]. The number of offices with centralized desks for all proceedings would be less important than their location, which should be in areas identified as apt and in commercial convergence points in the zone, including the largest villages within the influence area (El Valle, Capira, Tambo, La Pintada).
- Use of fast and transparent mechanisms in the *centralized desk for all proceedings* so that ACP establishes credibility among displaced families.
- Electronic links among the *centralized desk for all proceedings* and the program's data base regarding prevention, reduction, and control, to accomplish efficiency and an appropriate accountability to ACP and the community.

ii. Conduct a contingency assessment survey in a minimum of 100 households within the zones directly and indirectly affected by the water alternatives, to evaluate the required

[7] For budgetary purposes, 10 centralized desk for all proceedings with an annual operation cost of $100,000 would increase the budget in $1 million per year, which is a low cost if it accomplishes satisfaction fulfillment of displaced families.

compensation to mitigate the disturbance implied by the involuntary resettlement of affected families and due to the disturbance suffered by receptive and neighboring communities[8].

iii. Contract a *non-governmental organization* or an independent firm to negotiate the agreements with the affected communities and families, within realistic budgetary limits[9]. Costs presented in this report can be considered as an initial approximation to these budgetary limits. Compensation amounts should be made based on a study of the willingness to accept the transfer (contingent evaluation). This type of evaluation would enable ACP to systematically obtain first hand knowledge of the amount per person that would persuade a family to move from a place, taking into account the replacement and improvement of their living conditions and access to social and economic infrastructure.

iv. Once the amount of replacement and compensation for transfer has been agreed upon, negotiation of the potential resettlement zones with the community may be initiated. During this process, special care must be given to minimizing the distance between the current location and the proposed sites.

v. Negotiate a transfer calendar, emphasizing the need to execute the work during the dry season, to ensure a fast resettlement. The calendar should consider the time required for the replacement homes to be available before the families leave their current homes.

vi. Prepare and sign the contracts between ACP and the families, with approval from an honorable national institution (for example, an Episcopalian Council or an Inter-ecclesiastic Committee) and proceed with the execution of the relocation program.

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[8] The duration of this type of survey would be of approximately 6 months (2 months for planning and field tests; 2 months to conduct the study and 2 months to analyze and report writing), at an approximated cost of $ 120,000. This cost is higher than normal due to the specialized nature of the survey, which requires professional personnel at the field level.

[9] During the negotiation, there is always the possibility of complicity among the members of the affected communities to oppose it to obtain higher compensation amounts. In this scenario, it is necessary to maintain as a context the level of well-being and income of the non affected households and use that as a reference point. The main idea is that the received benefit will not create economical and moral unbalance among the households of the communities. Thus the main focus of the negotiation should be the maintenance of an equity climate within the receptive community to ensure the restoration of social cohesion. Thus the equity criteria and its discussion and internalization among the affected ones, should be one of the main components in the negotiation to reduce overpricing.

vii. Contract an independent firm so that — together with the municipalities— it identifies and acquires the needed land for the resettlement of the families, using a price scheme that reflects local real estate market.

viii. Work together with municipalities, the judiciary system and the police to avoid the resettlement of families in the abandoned areas and in the land acquired for the replacement. This can be accomplished through the establishment of a surveillance perimeter paid by ACP in the reservoir areas, and through an agreement with authorities to rapidly displace those illegally settled on replacement lands. This surveillance will be conducted by personnel hired by a private independent firm, operating with the approval of the community.

ix. Establish agreements with public and private entities to provide labor training to the displaced families, emphasizing the acquisition of abilities that later can be used in the construction of the selected water alternative.

Table 5-1 shows the costs for prevention, reduction and control of the direct impact of displacement from households as a consequence of the flooding in the 6 options considered in Indio River watershed. The cost of replacing a house is estimated at B/. 10,000 per house[10]. This cost includes only the direct cost of replacing affected houses, taking into account the use of better and more durable materials. A unit cost between B/. 125 and B/. 140 was applied to an average house of 70 to 80 m^2 including the cost of the land. Such costs are a little higher than local construction costs with improvised materials but are appropriate to plan and build replacement houses[11].

[10] To estimate costs, the household is used as a unit of measure. Although a house can host more than one household —as defined by the National Census of the Republic— the cost of replacing and transferring those physical goods is more appropriate for these circumstances.

[11] The study by Abt Associates is also derived from the possibility of building wide houses with more modest materials, since rural families are not used to live in spaces similar to those in urban areas. Nevertheless, this is a detail that must be considered in the following phase of the project development.

Table 5-1

Indio River Watershed Population Displacement Mitigation Costs, by Water Option

Option	Number of houses	Population	Replacement of the house (B./)	Compensation for Damages and Inconveniences (B./)	Training (B./)	Totals (B./)
1. Indio 80-40	327	1,568	3,270,000	1,568,000	327,000	5,165,000
2. Indio 45-40	199	939	1,990,000	939,000	199,000	3,128,000
3. Upper Indio 50-40	72	316	720,000	316,000	72,000	1,108,000
4. Upper Indio 45-40	67	286	670,000	286,000	67,000	1,023,000
11. Teriá Basin area	261	1,386	2,610,000	1,386,000	261,000	4,257,000
12. Teriá +Indio (head)Basin area	271	1,511	2,710,000	1,511,000	271,000	4,492,000

Note: *Simulated* costs used in the Table are: B. /10,000 per replaced house; B./1,000 per person as compensation for the disturbance due to transfer (provisional), and B./500 per trained person, with an average of 2 trained people per household.

The cost of the replaced houses is for a house of 100 m^2 in an area of 300 m^2 at a cost of $ 1,000 for the land and a net construction cost of $ 90 per m^2, including the cost of transferring the materials. This is a very generous budget, but it is included as a reference because the accelerated construction of several houses at the same time in small communities results without a doubt in the temporary inflation of materials and construction costs, especially when the receiving communities know that the funds are guaranteed[12].

Compensation for damages and disturbances is not estimated with precision, it is presented as an initial estimate. To estimate with precision a compensation that will satisfy affected families it is necessary to use estimation methods that will determine the compensation that would be accepted by a family to be voluntarily displaced[13]. These estimation methods have not been done in the field, thus the figures in the previous Table are mere speculation. As an initial value, B/.1,000 per person is used, which is equals 1.8 times the per capita income in the zone (B/. 547).

[12] The house costs are close to three times the local costs for self construction (materials and land), which are estimated approximately in $ 2,000 in total for a house of 60 m^2. These costs were collected by URS in situ in April 2004.

[13] The most accepted method is contingency valuation where through a systematic survey the willingness to accept a bad thing in exchange for a monetary compensation is determined. It is considered that the environmental impact study of the selected option should include an estimate of these costs. Together with them the disposition and interest of the communities to be resettled to the potentially identified areas should also be evaluated.

Finally, the costs of prevention, reduction and control in the Indio River watershed include the expected expenses in labor training. Assuming that an independent entity will be hired to develop labor training, a cost of B/. 500 per person is assigned, per training, at a maximum of 2 people per house as training clients.

The total cost of this program to prevent, reduce and control in the Indio River watershed ranges between 1 and 5 million Balboas approximately, depending on the selected option. All previous costs are realistic and have been estimated considering the need to avoid the injection of more money than the local economy can handle. These costs do not include operation costs of the centralized desk for all proceedings previously mentioned.

5.3.2.2 Program to compensate production losses

Compensation for production losses must be done in a transparent manner. Each family to be displaced should go through a short in situ auditing done by an independent organization hired by ACP and externally approved to account family possessions and seasonal and permanent production. Based on this auditing each family would be paid their corresponding amount upon reaching their new house. Land cost of territories owned by the families in the area was already estimated in the impact section and will be accounted at the end of this section.

To diminish claims risk and other related problems, ACP should contract another independent institution to make semester payments to the compensated families, during a three-year period. Such payments would be phased to reflect the cash flow of displaced permanent crops avoiding at the same time problems that could result from providing a poor and non-educated family with too much money in one payment and forgetting about them.

This component includes the valuation of displaced production of annual and perennial crops[14]. Approximately 46% of the agricultural production in the Indio River watershed is in perennial crops of which coffee, oranges and pineapple are mainly used for commerce while plantain, peach palm fruit and bananas are mainly used for household consumption (Table 5-2).

[14] Compensation does not include the value of cattle and domestic animals as these can be transferred to the new location without loss in production as the case of the crops. Nevertheless, land use for cattle raising is directly compensated in another part of the program.

Table 5-2
Composition of areas in production (hectares) in ROCC and in Río Indio watershed

	With seasonal crops	With permanent crops	% Permanent
Western Region	11,045	8,857	44.50%
Río Indio watershed	2,656	2,235	45.70%

Source: Censo Nacional Agropecuario 2001.

For compensation purposes, cash flow from permanent crops should be discussed in a different form from annual crops since for the firsts there is a waiting period of 3 to 4 years for the first harvest. Thus, the estimate for Río Indio includes 55% of the annual value as the value of annual crops and 3 times the annual value of the perennial production, to compensate or indemnify producers for the growth period of the perennial crops to be replaced (Table 5-3).

Table 5-3
Río Indio watershed. Annual implicit value of the production affected by the water alternatives (B./)

Option	Annual crops	Perennial crops	Total Value
Río Indio 80-40	197,530	498,737	696,267
Río Indio 45-40	118,291	298,670	416,961
Upper Indio 50-40	39,808	100,511	140,319
Upper Indio 45-40	36,029	90,969	126,998
Teriá catchment area	174,603	440,848	615,451
Teriá + Indio (river source) catchment area	190,350	480,607	670,957

Based on most recent estimates on annual and perennial production composition, the implicit value of production —including the value of the years required to recover the perennial production— ranges between B/.126 thousand in the case of Upper Indio 45-40 and B/. 696 thousand for the case of Río Indio 80-40 option. As expected, more than 70% of the value is assigned to perennial crops, since production would be affected for 3 or 4 years, while the impact of annual lasts one year only.

5.3.2.3 Program to protect community cohesion

The loss of social infrastructure —Schools, health centers, Churches, Cemeteries and community centers— is an important factor in the loss of social cohesion. Although the emotional cost of this loss is already included in the individual monetary compensation shown in previous Tables,

the replacement cost of the improved social infrastructure should be considered in a separate manner.

Replacement social infrastructure should be done by direct acquisition of services between PCA and the corresponding institution. Thus for schools, an agreement must be signed with the Ministry of Education so that they build the new school with funds from PCA. The same must be done with the Ministry of Health and any other ministry according to the case. Replacement of Churches must be hired with each of the displaced Churches, since their formation and daily operation is highly linked to community participation and teachings and administrative characteristics of each congregation. This is particularly important with non-Catholic denominations, for which community participation in the construction phase is a manner of consolidating their community labor.

In regard to the case of Cemeteries, a private firm must be hired to conduct required exhumation fast and with respect. This is a very important aspect, since it has emotional aspects that should be managed with great care. In accord to field information, the cost to exhume a grave and transferring it to a new location is approximately of $ 50 per grave[15].

Most of the replacement costs for social infrastructure is assigned to Schools, followed by the costs to replace Churches. The last one is a strong indication of community cohesion and the role that it can develop in the dialogue with Churches to grant the political support required to conduct the water alternatives.

It should be mentioned that the replacement cost refers to the construction of the improved infrastructure, which will greatly help in the improvement of the community well being and in the restoration of community social cohesion. In the case of the health centers it is different. In Upper Indio there are no health centers. Nevertheless, a replacement cost is assigned to compensate or indemnify the families for its absence.

Replacement costs for social infrastructure reach B. / 1.5 Millions in the case of Río Indio 80-40, diminishing as the geographical area of the other options is reduced accordingly (Table 5-4). These costs include the elements to replace the affected infrastructure and to improve it in the same areas of settlement including the receiving communities.

[15] In accord to data supplied by a private funerary firm, the costs are divided as follows: exhumation costs $ 25; cleaning of bones $ 10; box for the bones $15.

In terms of health it has been considered that the presence of a reservoir as part of the options, could increase the incidence of sicknesses transmitted by insects associated with aquatic habitats. The population movement to the settlement areas could increase the incidence of other parasite-related diseases, especially leishmaniasis. In the same manner the strengthening of health services in the area has been considered, which are known to be deficient still for prevention and treatment of most common local affections.

Table 5-4
Replacement Cost of Social Infrastructure, by Water Option in the Indio River Watershed (B./)

Infrastructure	Río Indio 80-40	Río Indio 45-40	Upper Indio 50-40	Upper Indio 45-40	Teriá catchment area	Teriá+Indio (head) catchment area
Schools	698,500	190,500	63,500	63,500	381,000	317,500
Health centers	151,500	50,500	0	0	101,000	151,500
Recreational areas	5,700	3,800	1,900	1,900	4,750	3,800
Cemeteries	18,720	9,360	7,020	7,020	4,680	4,680
Churches	485,250	194,100	64,700	64,700	194,100	161,750
Community meeting areas	135,450	60,200	15,050	15,050	45,150	30,100
Total	1,495,120	508,460	152,170	152,170	730,680	669,330

Note: Unit costs used for infrastructure are presented in Annex 5. Cemeteries costs include: 25% for the replacement land and 75% for transfer costs of the human remains to the new location.

5.3.2.4 Economic Infrastructure Improvement and Replacement Program

This component includes roads and bridges, as well as local commercial centers and terrestrial and fluvial transportation infrastructure. The replacement costs of these economic infrastructure should be interpreted cautiously since they only reflect the cost of the existing poor infrastructure in the region of interest. Evidently the displaced families would be transferred to zones with better access, and where infrastructure would be better in quality and capacity, therefore more costly then the existing one.

Nevertheless, the replacement costs presented in Table 5-5, as follows, serve to determine the minimum cost that should be considered to comply with the objective of minimizing the negative impact of displacement on the livelihood of the residents. On the other hand, economic infrastructure especially roads and bridges are conditioned by the geography of the resettlement zones and by the investment that has to be done by ACP at the dam site and areas neighboring the flooding perimeter. Thus, economic infrastructure costs are not a guide to replace but an accounting unit to be able to provide follow up on investment directed towards the community

and not to the construction of the options themselves. Existing infrastructure is so scarce in this watershed that in no case the total cost is greater than B/.700 thousand.

In summary, the previous costs only indicate the replacement of what was lost, but do not reflect the real cost of what needs to be done since these costs are difficult to isolate from the construction of the alternatives, and from the existing infrastructure in the resettlement zones. In fact, in the feasibility study for Option 1 additional costs are considered to provide for transportation, irrigation and commercialization required to support production.

5.3.3 Impact Prevention and Control in the Construction Phase

Induced development effects during the construction phase are associated with the increase of the population and larger demand of services. Since the demanded services by the added population are similar to those required by local population, actions are similar and associated costs to them are included in the programs previously described. Nevertheless, besides this, it is convenient that during the construction phase special programs be developed to support of the improvement of life conditions in the watershed and in all the ROCC. Taking into consideration suggestions made up to now by the inhabitants of the region, the improvement of the transportation infrastructure in the ROCC and solving other basic needs of the community could be part of the support to be provided.

Table 5-5
Replacement Value of the Current Economic Infrastructure, by Water Option (B./)

Infrastructure	Río Indio 80-40	Río Indio 45-40	Upper Indio 50-40	Upper Indio 45-40	Teriá catchment area	Teriá+Indio (head) catchment area
Roads						
Permanent	90,000	0	0	0	0	0
Summer	376,000	174,000	88,000	72,000	0	0
Dirt	143,600	81,600	16,800	15,600	0	0
Facilities						
Telephone antennae	15,000	10,000	0	0	5,000	5000
Lamp posts	0	0	0	0	0	0
Suspension bridges	0	14,000	6,000	6,000	6,000	8000
Concrete bridge	0	0	0	0	0	0
Wooden bridge	12,000	0	0	0	0	0
Kiosk (Commerce)	16,000	7,000	1,000	1,000	7,000	5000
Bus stop	0	0	0	0	0	0
Telephone booth	21,000	0	0	0	0	0
Storage tank	10,000	0	0	0	10,000	0
Total	683,600	286,600	111,800	94,600	28,000	18,000

Note: Unitary costs used for infrastructure and facilities are presented in Annex 5.

5.3.3.1 Improvement of highways and roads

In accord to community needs presented in several meetings and workshops, we recommend that the repair of highways and roads be done at the starting point of the improvement of life conditions. It is not a matter of adding asphalt to roads but rather improving highways and roads to allow vehicles to pass through them all year round. Whenever possible, labor should come from the communities.

The selection of priority highways and roads should be done in consultation with the communities. Due to strategic reasons, in several areas of the watershed, a road must be selected. Obviously, the purpose of improving road infrastructure is not only to improve land transportation but also to strengthen community organizations, something that would not be feasible if this work is simply subcontracted by ACP or MOP. Community organizations could be involved in the process, and residents could participate in coordination of work, and in the verification that progress goals are met by contractors.

Activities should be conducted in a way in which two objectives are performed simultaneously: the improvement of communication routes and the strengthening of the local institutions.

Activities should not be performed in a manner that they accomplish only the first objective. Besides, there is a third objective: credibility in the modernization and expansion program for the canal. It must be stressed that the road improvement in the zone comes from the Panama Canal's income and that it constitutes only the first of many activities projected. Then, activities will have three related functions among them: (a) road improvement; (b) strengthen local community organizations; and (c) establish credibility for ACP and its contractors as serious actors that fulfill the agreements.

5.3.3.2 Other development programs

If activities with the highways and roads are successful, procedures must be established for communities to select another or several development projects compatible with the needs pointed out by the residents in the consultation performed by ACP. For the execution of community improvement projects, it is recommended that a promotion fund for human development be established in the Indio River watershed.

This Fund must have three essential features: (a) enough money to provide support for several simultaneous projects, (b) flexibility in terms of the items that can benefit from this money, for which each community has the option of identifying their own priorities; and (c) quickness in disbursement, this is, administrative arrangements that allow disbursement within one or two weeks of signing an agreement with a community. Probably, the best scheme to manage this Fund is a private organization under contract with ACP or CICH (Interinstitutional Commission for the Watershed).

5.3.4 Indirect Impact Prevention and Control during the Operation Phase

Once the infrastructure has been established in the operation phase, negative impacts to the communities will be limited. What is really expected is opportunities to promote growth and economic and social development in the region and improve living conditions for the inhabitants. To accomplish this, this management plan will serve to promote activities with potential to generate income for local residents, and providing better environmental conditions for the operation of the selected water option.

5.3.4.1 Reduction of pastures and promotion of agro-forestry

The current situation of low ecological risk for the water option to be selected would not be permanent if there are changes in land use in the watershed as a result of imposed limitations by

the physical environment. Because of this and due to the expected intensification of land use as a consequence of the presence of a reservoir, as well as due to the normal growth of the population, it is necessary to direct the increase in land use intensity towards activities that are compatible with the biophysical conditions. In other words, watershed management must follow the general guidelines of sustainable land use showing respect for sustained land use capability, which is defined by the natural environ variables.

This work should be coordinated by the CICH so that technical assistance, successful activities, credit designation and agro-forestry in the Eastern Region of the watershed can be promoted in the Indio River watershed. This would be very convenient to assure that all watershed management pursues prevention of environmental problems in the reservoirs and physical safety of the infrastructure works.

The proposed strategy is that the conversion of pasturelands to forest has to be led by the local population. Nevertheless, it is clear that they will only do it if it is inexpensive for them. This means that proposed forestry and agro-forestry activities will yield a greater income than cattle. Agro-forestry plantations that should be considered include coffee and citric, which are crops adapted to the zone and known by the producers. Forestry plantations should include species of timber-wood trees. The establishment of forestry plantations is a priority in the vicinity of the reservoir with the purpose of obtaining an arboreal plant cover around the lake and restricting cattle grazing in the areas immediately adjacent to it.

5.3.4.1.1 Agro-forestry components.

It is suggested that planting trees in the region should be considered under the **agro-forestry** item and not under reforestation. Given the presence of population that have been living in the region for a long time, agro-forestry provides several advantages that facilitate its implementation, some of which are mentioned below:

- Trees combine with other crops. They do not constitute the only element or the dominant element of the landscape. The combination can be physical and contiguous, such as when trees are combined in the same plot with food products. But the combination can become the way to dedicate some plots within the farm only to trees while in others only annual crops are planted. They are combined in the farm but not necessarily in the same plot.
- The trees in agro-forestry are mainly planted for economical and not ecological purposes. Timber wood trees are planted to be harvested and to sell (or use) the wood

either as wood for fuel or for local constructions. There are ecological advantages, but they constitute a somewhat secondary benefit of activities performed for economical purposes.

- Trees in most efficient agro-forestry systems are of private property and not state owned or community owned. In general the owner of the tree is the owner of the plot.
- Trees in agro-forestry are mainly planted with the intent to harvest them. For this, it is required that the producer planting is the owner of the tree and also has rights to harvest and to sell in the same manner as if he was harvesting plantain or rice.

In the conditions of the Indio River watershed the priority should be timber-wood trees and not fruit trees. In the long term, income generated by the wood would probably be greater than income produced by selling fruit. In general, planting timber-wood trees is economically more advantageous, since the fruit has to be harvested annually in the same moment when the rest of the producers are harvesting too, which lowers the prices. Wood in turn, can be cut when the owner wants. The planted species, would preferably be fast growing species. Ecological conditions in the watersheds – abundant rainfall and modest altitude – are ideal to plant timber-wood trees that would grow very fast.

The main barrier against planting trees is the lack of local experience in terms of wood marketing and commercialization. In our conversations with local dwellers, we heard exceptive comments in terms of the income producing opportunity in planted wood in contrast to cattle raising. Although those perceptions are rational, they are based in the current lack of commercialization mechanisms for the wood. If a project occupies not only the planted wood, but also its eventual transformation and sell, we predict that wood economic potential would surpass that of cattle raising.

In the Indio River watershed and in all the ROCC there exists a cultural and symbolic link to cattle raising that goes beyond the economic aspect. But the cultural link to any activity is a transitory and fragile phenomenon. If income yield capacity form tree planting is demonstrated and if two to three wood planting and harvesting cycles are obtained, trees can reach the symbolic place currently occupied by cattle.

5.3.4.1.2 Agriculture Intensification

Technical assistance to intensify agriculture production in appropriate areas is considered the adequate complement for the agro-forestry activity previously described. If there existed a prosperous wood economy, the owners of trees would not need to plant food. They would buy

food with the income from selling wood. Nevertheless, this situation does not currently exist in the watershed, which is in fact a region with strong tradition for food self-sufficiency.

The transformed agrarian component, in which producers of the zone reach the same independence and self-sufficiency in their food as they have now, but benefiting from an additional element of market access to sell what they produce, would significantly contribute to increase regional incomes. In fact inhabitants of the zone have mentioned in interviews their frustration for not being able to commercialize their agriculture products due to the terrible condition of the roads. For that reason we identify road repair as an important requisite in any effort to develop the watershed.

Under the described scheme, both elements – agriculture and forestry – assume access to the markets, which would be impossible without improvement of the road infrastructure. This is why this component is proposed as a posterior step during the operation phase of the water alternatives when it is expected that the infrastructure will be available.

5.3.4.2 Environmental education campaign

An education campaign to inform about the canal, the reasons for its modernization and expansion, the need for water and the relation between watershed management and water quality of the reservoirs and the use of their fishery resource as a food source provider of protein for the population should be supported as a complement to the substitution program of pasturelands for agro-forestry.

The program's most important duty, and probably most difficult, is to provide environmental education and population awareness regarding the need to use natural resources in a conservative manner to guarantee their sustainable use. The program must indicate that the farmer has a tradition, some customs that induce him to perform certain known practices and that it is not easy to make him change his methods. Efforts must be concentrated in demonstrating that the benefits will be higher for the farmers individually if he adopts the recommendations of the management team.

This will be done through talks, pamphlets and filed demonstrations made both in project areas destined for that purpose as well as in plots of farmers most interested in the project. The talks must be in very basic terms so that everyone can understand, with abundant and appropriate audio-visual aids, but the concepts must be expressed in a clear manner to avoid confusion among the group of producers.

The same concepts of simplicity and clarity must prevail in the illustrated pamphlets and in the field demonstrations. It is very important, in this program, to use schools as centers to diffuse this knowledge because they absorb this knowledge and technology and this is the best guarantee that they will implement it when having the power to decide. Also, collaboration of professors and children in adult education and training is obtained. A directed education program is crucial to consolidate in the population the changes that will be promoted and to make people become active participants, thus ensuring that these changes would be permanent and will be of benefit for local communities and for the canal.

Finally, teaching centers will be implemented so that teachers can learn general concepts about the reservoir installations, including the structure and operation, as well as the importance that they have at a regional and national level. The teacher can transfer this knowledge to their students. In these meetings short environmental management courses will be taught to the teachers and demonstrative lectures will be given about how to interpret and explain posters that will be distributed by the project through them.

5.4 Biophysical and Cultural Conditions Restoration and Protection Plan

The plan to recover and protect biophysical conditions includes prevention, reduction and control actions of socio-environmental impacts and potential risks to environmental goods and services provided by the watershed ecosystems that could be directly and indirectly affected in case that any of the considered water alternatives is implemented. It includes specific activities organized by programs in related topics. Content of each of the programs is similar and starts with a brief justification, its objectives and description of prevention, reduction and control measures. These measures must be applied during the final design, construction, operation and abandonment phases.

Also, for each of the programs, monitoring as well as verification and control activities are included; the contingency plan is described; and finally, costs to implement these measures and monitoring and control activities are detailed. Details associated with prevention, reduction and control measures can be found in the corresponding programs.

Programs formulated to prevent, mitigate and compensate or indemnify for the mentioned socio-environmental impacts, are the following:

A. Air Quality Protection and Noise Control Program;
B. Seismology and Geology Program;

C. Erosion and Silt Transportation Prevention and Control Program;
D Water Quality Program;
E. Biodiversity in Terrestrial Ecosystems Protection and Recovery Program;
F. Aquatic Plants Monitoring and Control Program;
G. Fish Species and Macro-Invertebrates Conservation and Management Program;
H. Archaeological Sites Conservation Program;
J. Other Programs.

Specific programs of the EMP for the Indio River watershed, are described as follows:

5.4.1 Air Quality Protection and Noise Control Program

Potential impacts and risks to air quality and those generated by noise by the different water alternatives were described in the previous chapter. These impacts resulting from the project can be prevented, reduced and controlled and can be completely mitigated.

The objective of this program is to assure, through the proposed measures, that impacts arising as a result of activities associated to the water alternatives, such as the improvement and construction of access roads, the use of heavy duty machinery, excavation, construction of dams and quarry exploitation, among others, are minimized.

This program describes the prevention, reduction and control measures for the impacts on air quality and the increase in the levels of sound pressure associated with the construction, operation and maintenance activities of the water alternatives, in areas of direct and indirect impact.

5.4.1.1 Mitigation measures during the construction phase

The impacts on air quality and sound pressure level for the water alternatives will mainly occur during the project's construction phase and not during its planning, operation or abandonment phases. In the following paragraphs the recommended measures to mitigate identified impacts are presented.

5.4.1.1.1 Prevention and control measures of the direct impacts on air quality

The most important impacts on air quality are mainly related with dust emission from road construction, material extraction from quarries, vehicle increase and barren areas; and due to

truck transportation of materials and/or wastes. There is also a risk of dust particles in suspension at the sites where sand and aggregated materials would be stored. In the impacts chapter the number of villages that could be affected as well as the associated sensitive receptors were identified.

To prevent or minimize impacts on air quality during construction activities, the following measures will be applied:

1. All engines will be appropriately maintained to maximize combustion efficiency and minimize pollutant emission. The Contractor must provide preventive maintenance for the equipment and maintain a record of these activities.

2. A schedule for engine operation will be established to prevent, reduce and control, within possibilities, the operation time of the emission sources.

3. Water sprinkling will be used to prevent, reduce and control dust dispersion, especially in the most sensitive areas, according to what was indicated in socio-environmental impacts and risks section. This includes populated areas along access routes and work areas. It is estimated that water use in itself should be adequate if multiple passes are done in one work day. The Contractor could also consider the use of polymers that aid fixing soil particles, thereby preventing dispersion into the atmosphere.

4. Avoid employee exposure to inhalation, ingestion, and absorption through skin or by contact, of any gas, vapor, smoke, dust or fumes that exceed safety levels.

5. When the dust becomes a nuisance or a health risk, workers will be provided with masks.

6. Concrete and/or asphalt plants should have a filter system to prevent, reduce and control emissions to the atmosphere.

7. Locate concrete and/or asphalt plants including quarry crushers in unpopulated areas.

8. Wet rock material during crushing in the quarry or work areas.

9. Avoid burning residues.

10. Use good quality, oxygen-balanced, explosives.

Activities mentioned associated to dust particle emission are fundamentally important during the dry season and must be performed on a daily basis by the Contractor. Activities destined to reduce emissions by internal combustion engines also will have to be performed by the Contractor on a weekly basis throughout the execution of the construction phase.

5.4.1.1.2 Prevention and control measures of direct impacts on noise

The most important impacts on the levels of sound pressure are mainly related to machinery and heavy equipment transit and operation that could cause direct effects on villages located close to access routes, dam sites, quarries and other components of the works under study. In the impacts chapter the number of potentially affected villages was identified, as well as the sensible receptors to this type of effect.

To prevent, reduce and control impacts due to the increase of sound pressure levels during the construction phase the following activities are proposed:

1. Comply with dispositions established in Decree No. 306, September 4, 2002. This Decree in its Articles 1 and 2 bans the production of noise that due to its nature or untimely presence disturbs health, rest or tranquility of the members of communities or causes material or psychological damage. Thus, the mentioned Decree considers that all work or activity must be performed in such manner that it reduces noise generation by loose or excessively worn machinery; transmission belts and vapor exhausts; and compressed air, as well as unnecessary noise that can be avoided. To diminish noise due to machinery and heavy equipment transit the following measures are recommended:

    a. Not to exceed 60 Km. / hr in internal and access routes to the project;
    b. Not to exceed a daily volume of 500 trucks in a specific point of the access routes;
    c. Slowly reduce speed and not suddenly to avoid unnecessary noise due to compression in populated areas; and
    d. Conduct preventive maintenance of the equipment to avoid noise due to loose or deteriorated or worn parts.

2. Provide advance notice in new work areas that have not been subject to noise from construction activities.
3. If some sensitive receptor such as Churches, Schools and Health Centers will be affected by noise in a sustained manner, traffic speed must be diminished and controlled, flow of vehicles should be diverted or physical barriers that buffer sound pressure should be used.

4. Provide workers exposed to noise of generators, compressors or other heavy duty machinery, with auditory protectors appropriate for the level of noise and period of exposure.

5. When employees are exposed to sound levels that exceed safety levels, feasible administrative or engineering controls must be used. If such controls do not accomplish reduction of noise level to safety standards, personal protective equipment must be used to diminish them to meet those standards.

6. In all cases where noise exceeds safety levels, a continuous and effective hearing protection program must be established.

7. Maintain all rolling stock in good conditions and with appropriate muffler systems.

8. Extraction and crushing areas for rocks and explosion zones should mainly be away from populated places.

9. No demolition or other noisy activity should take place during nighttime.

Activities mentioned here associated to the increase in sound pressure are fundamentally important for areas close to access routes to the project and must be conducted by the Contractor of the works on a daily basis. Activities destined to protect workers to the exposure of high levels of sound pressure will also be responsibility of the Contractor.

5.4.1.1.3 Prevention and control measures for indirect impacts

It is important to point out that although the potential for forest fires should decrease with the implementation of the water alternatives, the increase of human activity in the area could have a contrary effect, which at the same time could contribute to particle emissions. As a part of the Prevention, Reduction and Control Plan, there is a Program to Protect and recover biodiversity in terrestrial ecosystems, that should counteract this situation.

5.4.1.2 Mitigation of direct impacts during the operation phase

Air quality and levels of noise pressure impacts for the water options during the operation phase will be minimal. To prevent or minimize direct impact on air quality during operation activities, it is recommended that the following measures be applied:

1. All motors will be appropriately maintained to maximize the combustion efficiency and prevent, reduce and control pollutant emissions. The operator must keep a record of preventive maintenance of the equipment and have a report on these activities.

2. When access routes are rehabilitated to reach and maintain the different structures built, use the sprinkler systems to prevent, reduce, control and suppress dust, especially in the most sensitive areas such as inhabited areas.

3. Do not burn any wastes.

Also, to prevent or minimize direct impacts due to the increase in the levels of sound pressure during the operation phase, the following activities are proposed:

1. Comply with established dispositions in Decree No. 306, September 4, 2002. The following measures are also recommended to diminish noise due to vehicle movement and of machinery and heavy equipment:

    a. Do not exceed 60 Km. /hr in internal and access routes to the project;
    b. In populated areas, slowly reduce speed and not suddenly to avoid unnecessary noise due to compression; and
    c. Conduct equipment preventing maintenance to avoid noise generated by loose, worn or damaged parts.

2. Provide workers exposed to noise from generators, compressors or other heavy machinery with ear protectors appropriate for the noise level and exposure periods.

5.4.1.3 Mitigation of indirect impacts during the operation phase

Forest fires derived from the change in land use due to induced development generated by the project can occur also during the operation phase. The Terrestrial Ecosystems Biodiversity Protection and Recovery Program, that will start in the construction phase and whose duration will be between three and five years, will contribute to sensitize farmers to avoid fires.

5.4.2 Seismology and Geology Program

Impacts and potential risks of geological and seismic nature for the water options in the Indio River watershed were previously discussed in Chapter 4. These include mass movement

especially landslides of slopes both in cut and natural inclined areas, risks associated with the construction of water transfer tunnels, possible impacts on dam foundations and the risk of seismic activity and its impact on proposed works and in the region in general. These risks can be mitigated or prevented through the appropriated design, construction and maintenance of the proposed works.

The objective of this component of the Environmental Management Plan is to prevent, reduce and control potential impacts and risks of geological, geo-technical and seismic nature that can be associated to the development of surface water resources in the Indio River watershed.

5.4.2.1 Prevention and control measures during the planning and design phase

The execution of a series of exhaustive field and laboratory studies should be the first step in the Environmental Management Plan to mitigate or prevent impact and potential risks of geological, geo-technical and seismic character. Information obtained from these studies will serve as a base for the final design of the different project components. Field research should cover all the sites of the various components of the project including both permanent (dam, tunnels and reservoir, among others) and temporary works (quarries, access roads and material borrow sites). It is expected that both the studies and the final design of the works will be conducted by a consultant selected by ACP. Field work will require a close collaboration among local authorities, ACP and local people from affected communities.

Geological, geo-technical and seismic studies that will be performed as part of planning and design include as a minimum the following components:

- Field reconnaissance of the dam site, the limits of the reservoir and the water transfer tunnel route as well as the infrastructure and construction (roads, places for the quarries, etc.) areas. This initial reconnaissance will allow the establishment of minimum requisites and the scope of the field exploration program.

- Detailed geological mapping of all main structures sites (dam, tunnel portal, etc.) as well as a detailed geological reconnaissance along the tunnel route and the areas to be flooded. Objectives of this study include the identification and evaluation of geo-morphological conditions, stone upwelling, nature of overburden soils, degree of rock weathering, evidence of slope instability, presence of geological faults, joints, cutting zones, etc.

- Geophysical field trials at the dam site. Some options include seismic refraction and seismic downhole or crosshole trials.

- Field geotechnical research including probing (perforations), exploratory borings, trials in situ, etc. The research program should include the different project sites including permanent (dam, tunnel, etc.) and temporary (quarry, access roads, etc.) .

- Laboratory trials program in soil and rock samples and rock obtained from the different sites of the project.

- Develop geological, geo-technical and seismic parameters to be used in the design of the different project components.

The feasibility study conducted by MWH/Tams (April, 2003) for the Río Indio 80-40 option (Option 1) carried out some of these studies at a very preliminary level. The study also presents a description of additional research to be required as part of the final design for this option. Preliminary design conclusions and recommendations presented in this study can be considered as applicable to Option 2 (Indio 45-40), which is based in the same dam site and a similar tunnel route as Option 1. To date no feasibility studies have been conducted for Options 3 and 4 (Upper Indio) or Options 11 and 12 proposed by URS and thus the level of geological and geo-technical information for these options is more limited.

The feasibility study conducted for Option 1 concluded that geological and geo-technical conditions of the proposed dam site do not represent any adverse condition that cannot be prevented and controlled by means of a conventional design and appropriate construction method. The design of geotechnical parameters for the dam site included in the feasibility study are presented in the Table 5-6.

Table No. 5-6
Geotechnical Design Parameters – Río Indio Project (1)

Parameter	Selected Design Criteria
Depth of overburden soil (weathered rock depth)	4 m
Depth of competent rock	8 m
Maximum slope in rock excavation	1H:5V, with benches 3 m wide every 10 m vertical
Maximum slope in soil excavation	
Permanent	2H:1V, with benches 3 m wide every 10 m vertical; benching in the soil-rock contact area
Temporal	1.5H:1V, with benches 3 m wide every 10 m vertical; benching in the soil-rock contact area

(1) Source: Table 3-9, Feasibility Study prepared by MWH/Tams (April 2003) for the Indio 80-40 (Option 1) Project.

Maximum slope recommendations can be applied in other project areas such as access roads and construction camps, in areas with similar geological conditions. In milder slopes excavation in sedimentary rocks of lower quality will be required (for example, shales), or highly weathered rocks or with other unfavorable geological conditions. These design recommendations will provide appropriate safety factors, minimizing the risk of mass movement especially slides of slopes in cutting areas. Risk prevention, reduction and control of unstable slopes in the other water options in the Indio River watershed (Options 2, 4, 11 and 12) will require similar preventive, reduction and control measures. Distribution of rock types as well as soil extension and nature of overburden soils, will vary from one option to the other as described in the chapter regarding socio-environmental impacts and risks.

The chapter on impacts (Chapter 4) also explained that the risk of mass movement, especially slides of natural slopes will depend on the option. The feasibility study done for Option 1 (Indio 80-40) concluded that there are no large problems anticipated regarding mass movement especially collapses and landslides of slopes surrounding the reservoir. Nevertheless, the study clarifies that it will be necessary to research in a more detailed manner the effect of saturation, during the periods of intense rain, on residual and saprolitic soil stability. If necessary, prevention and control measures such as the reduction of slopes in inclined areas and incorporation of benches as well as an extensive program to monitor the slopes would have to be implemented. Identification of critical areas that require such measures will not be possible until the results of the detailed field studies previously described are available.

Studies performed to date for Option 1 indicate that the need of special programs to improve the rocky sandstone bottom that will serve as foundation for Indio River dam is not foreseen. Nevertheless, although the material is considered competent enough and stable, during the final

design, a study of the risk of erosion of the material under the high filtration pressures that are anticipated under the dam will be required. Some treatment measures of the dam foundation proposed on a preliminary basis include: (1) local excavations and filling with concrete in highly weathered rock zones or in other unacceptable areas; (2) injections of cement whitewash in fault or fracture zones exposed during the excavation; (3) a curtain of whitewash to diminish filtrations below the dam through joints and fractures. Besides, the preliminary design considers the incorporation of a drain in the foundation of the dam sink to diminish and control filtration and diminish pore pressure in the rocky mass minimizing the risk of uplifting.

Given that the preliminary design of the rock dam proposed incorporates a concrete filling in the interior face, no filtrations are anticipated through the dam. Nevertheless, similar measures to the ones considered in the previous paragraphs for the dam foundation (for example, injections of whitewash cement) could be necessary in the dam buttress to limit possible filtrations. The need of such prevention, reduction and control measures should be evaluated during the geological and geo-technical studies previously described. In the same manner there is a need to assess rocky anchorages in the buttresses.

Impact and potential risks prevention, reduction and control during transfer tunnel construction will require detailed field studies including a geological reconnaissance of the route as well as an extensive perforation and field trial program. Using results of field research the design and construction of the tunnel should adjust to rock conditions or rocks along the tunnel route, including among other things the selection of drilling equipment and the appropriate type of internal support. As was described in the impact section, it is anticipated that the transfer tunnel of the Río Indio reservoir to Lago Gatún will pass through a diversity of rocks that vary from sedimentary, relatively soft, to volcanic hard rocks. Nevertheless, given the limited studies conducted to date the details for the tunnel design and construction cannot be provided. For the purpose of cost estimation, the feasibility study of Option 1 (Indio 80-40) assumed the following distribution of rock according to their quality along the 8.35 Km. length of the tunnel:

Table No. 5-7
Distribution of the Expected Rock Quality in the Río Indio to Gatún Tunnel

Rock quality	Tunnel length
Excellent	25%
Good to Regular	40%
Regular to Poor	30%
Very Poor	5%

The study also includes preliminary recommendations for the tunnel design, including minimum cover and types of internal support for the tunnel depending on rock quality. Also, the study assumed that the total length of the tunnel will require concrete lining. The main purposes for that lining are preventing erosion and wearing or the material in areas of soft or very fractured rock, and reducing and controlling the loss of water in zones with low cover and fractured rock. In principle, the same preliminary recommendations of design and prevention, reduction and control measures are applicable to the transfer tunnels in the other Indio River watershed options. Nevertheless, the proportion of different types of rock will depend on the option.

The seismic risk prevention, reduction and control measures include the appropriate selection of the dam site and an appropriated design that considers this risk. As was described in the impact section, the studies performed to date indicate that the Indio River project area does not include zones with active faults or potentially active faults, or materials susceptible to liquefying during a seismic episode. Such conclusions should be confirmed during the studies to be conducted during the final design phase. Based on these conclusions, the feasibility study for Indio River recommends that the project be designed for a maximum seismic event (MDE) with a recurrence period of 2,000 years, which corresponds to a redundancy probability of 5 per cent in a period of 100 years. The study also recommends that the seismic event for operation conditions (OBE) corresponds to a redundancy probability of 50 per cent in a period of 100 years, or a recurrence period of 144 years. Parameters of the seismic design corresponding to the Indio River project are the following:

- Maximum Design of Seismic Event (MDE) = 0.21g
- Operation Basic Conditions of Seismic Event (OBE) = 0.14g
  Where "g" is gravity acceleration.

These recommendations are also valid for other development options in the Indio River watershed and will provide an acceptable safety margin against the seismic risk consistent with international practice for seismic design.

Preliminary recommendations and prevention, reduction and control measures described in this section must be confirmed during the final design phase once completed the field research and other required studies.

5.4.2.2 Mitigation of potential impact during the construction phase

Impacts and potential risks during the construction phase can be minimized or prevented through a rigorous implementation of measures placed in the design and construction specifications of the project's different components. For this purpose, the selected contractor must have sufficient experience in similar works so that appropriate construction techniques may be used. Exhaustive field studies during the design phase will also aid in minimizing the risk of finding unexpected conditions that could result in adverse impacts during the construction. Nevertheless, construction plans should be sufficiently flexible as to incorporate required changes resulting from conditions different than what was anticipated.

The main impact of geological or geo-technical nature during the construction phase is the risk of mass movement, especially landslides of slopes in areas with long cuts along access roads that must be built and in extraction areas for construction materials. If possible, these activities of the construction should be performed in the driest period of the year so that risk of mass movement of soil is diminished especially those landslides associated with factors such as saturated soils and high pore pressures. Due to the uncertainty in the rainfall pattern and other climatic factors, construction of works to change the course of the river prior to the dam construction should also be programmed for the least rainy period in the year to minimize the risk of adverse impacts.

Transfer tunnel construction also could result in significant geotechnical impacts as a result of anticipated complex geological conditions. The selected construction technique, including the excavation equipment and the internal support system for the tunnel, as well as the contractor's experience will be critical factors during the tunnel construction. The use of inappropriate equipment or techniques in the construction will increase the risk of accidents, besides producing delays in the construction program and increasing its cost. One of the greatest impacts of tunnel construction is the deposition of excavated material. Although part of the material can be used in road construction and other fillings, it is estimated that most part of the 200,000 m^3 calculated for the tunnel excavation in the Indio River Project (Options 1 and 2) will have to be dumped in refuse areas specifically established for this purpose. A similar volume was estimated for Options 3 and 4 (Upper Indio) and approximately half of that amount was estimated for the tunnel in Options 11 and 12 proposed by URS.

5.4.2.3 Prevention and control of indirect impacts during the construction phase

In chapter 4, it was indicated that based on available information there were no indirect impacts and potential risks anticipated on geological, geotechnical and seismic characteristics during the construction phase.

5.4.2.4 Direct impact mitigation during operation phase

There are no significant impacts of geological, geotechnical or seismic nature anticipated for the operation of the facilities assuming that the necessary studies and the design and construction of the proposed works are executed in the appropriate manner. One of the potential risks that requires special attention, is the possibility of mass movements, especially landslide of slopes around the reservoir and areas with high cut in access roads and other infrastructure works. It is anticipated that the risk of unstable slopes will be greater during periods of strong rainfall. In the case of the reservoir, the arrival of an extensive precipitation period after a long dry period, when the level of the dam will be still much under the maximum operation level, is considered as the highest risk period for landslides. A key element in risk prevention, reduction and control for mass movement, especially slopes landslides is the implementation of a monitoring program following the recommendations presented in the next section.

One of the impacts and potential risks of geotechnical nature in dam projects is the need to periodically dredge the reservoir and dispose appropriately of the dredged material. Nevertheless, preliminary studies conducted to date for the Indio River dam (Option 1) indicate that the deposition rate of sediments in the dam is relatively low resulting in a loss of the reservoir water storage of only 1.9 per cent in a 100-year period. Thus it is not anticipated that the reservoir will have to be dredged during the life of the project. Similar conditions are anticipated for the reservoirs of the other development options in the Indio River watershed. The sediment deposition rate and the need to dredge should be verified during the final design phase of the selected option.

5.4.2.5 Mitigation of indirect impacts during the operation phase

The risk of a large seismic event that could affect any of the water alternatives is relatively small. Besides, the safety factor in the design of the works will consider seismic activity in the area.

5.4.3 Erosion and Sediment Transport Control Program

This program presents the measures to reduce and control erosion and sediment transport in the Indio River watershed. These measures will be implemented with the purpose of preventing, reducing, controlling and monitoring potential socio-environmental impacts and risks that will be caused by the project implementation.

There will be some inevitable impacts as a consequence of the construction and, in a lesser degree, during the operation. A large part of the impacts due to erosion and sediment transport will be localized and temporal, as they were described previously in chapter 4. These impacts resulting from the project can be prevented, reduced and controlled, within possibilities and completely mitigated.

In this program environmental procedures that have to be followed by ACP and/or the Contractors to prevent, reduce and control the socio-environmental impacts during the construction of the project are described. The application of effective environmental measures described in this document are the responsibility of ACP and/or its Building Contractor.

General objectives of this Erosion and Sediment Transport Prevention and Control Program are the following:

- Describe preventive, reduction and control measures for the prevention and control of erosion and sediment transport as a way to avoid, prevent, reduce and control the impacts derived from the conceptualization, design, construction, operation and maintenance of the water option;

- Reduce, control and guarantee the fulfillment of the preventive and corrective measures and allow for the assessment of real impacts so that new measures may be adopted or modified during the implementation and operation phase of the project;

- Implement a socio-environmental monitoring during the conceptualization, design, construction, operation and maintenance of the project to guarantee compliance with the requisites of the program, applicable local laws and regulations, and the guidelines of relevant financial organisms;

- Establish a base line on existing conditions regarding erosion and sediment transport, before the start of construction works;

- Establish a base line to compile information regarding results of implementation of the different measures to prevent, reduce and control socio-environmental impacts caused by the project activities; and

- Evaluate the results of the soil and sampling programs based on pertinent regulatory requirements.

The specific objectives of this program to control erosion and sediment transport are the following:

- Minimize the amount and duration of exposed soil to the elements;

- Protect critical areas during the construction, redirecting and reducing surface water runoff speed;

- Install and provide periodical maintenance to the control of erosion and sedimentation measures during construction;

- Establish vegetation as soon as possible after construction in affected areas, and

- Inspect and provide periodical maintenance to the erosion and sedimentation control measures as required until there is a final stabilization.

5.4.3.1 Direct Impacts Prevention and Control during the construction phase

One of this program's objective is to prevent, reduce and control the erosion and sediment transport potential during the construction as well as to restore and re-vegetate appropriately all other perturbed or affected areas due to construction activities. The measures to control erosion and sediment transport to be used by ACP and/or its Construction Contractors, during the construction should fulfill or exceed the standards presented in this section and it is recommended that these be incorporated into contractual clauses.

Several of the project's components have the potential to generate sediments that if transported through the Indio River watershed would require the implementation of specific prevention, reduction and control measures:

Dam-Reservoir: An important component in the construction works at the dam site and when the reservoir fills, is the prevention and control of erosion and sedimentation outside of the reservoir, during and after the construction. The degradation of water quality that could be produced as a result of these events is an environmental impact that can have important adverse effects at the local level on aquatic life and the functions of the ecosystems adjacent to the project. Along water courses and the reservoir there are several areas where erosion potential varies from intermediate to high as a result of inclined slopes, sandy soils, water currents and the predominance of strong winds.

Adjacent areas to the transfer tunnel, roads, quarries, etc.: The control of sediment generation and transport in the fluvial course should be performed in adjacent areas that have been affected by the construction. ACP and its Construction Contractor will take all necessary measures to reduce, control and limit the erosion and thus, reduce the occurrence of sediments in water courses. Special attention will be given to areas with pronounced inclinations in the fluvial course where it is most probable that erosion and sedimentation is produced as a result of intense rains.

Table 5-8 below presents a summary of sediment generation and transport sources in the project. This section presents the details regarding each prevention, reduction and control measure applicable to the mentioned project components.

5.4.3.1.1 Slope Breakers Water Barriers

Water barriers are standard techniques for erosion control that should be used during the construction to protect water courses and other environmentally sensible areas from degradation.

Water barriers (slope breakers or flow breakers) are small berms built in perpendicular direction to the terrain slope, with the purpose providing short and long term stability. These barriers divert the flow of water to adjacent vegetated zones, thus avoiding the development of the erosion process.

Table 5-8
Potential sources to Generate and Transport Sediments

Works	Prevention, reduction and control measures		
	Water Barriers	**Silt Fences**	**Slopes Stabilizers**
Dam	Use them during construction; the barriers can be left during the dam's filling period.	Use them during the construction; particularly in refuse material dump sites.	Establish them in zones deprived of vegetation in the reservoir walls, during its filling and operation.
Indio-Gatún Tunnel	Does not apply.	Use them during the construction to avoid transport of sediments to Lago Gatún.	Install them during the construction to avoid landslides and sediment generation/transport.
Roads and Quarries	Does not apply	Use them during construction; particularly in refuse material dump sites.	Use them during the construction; particularly in refuse material dump sites.
Fluvial Channels	Use them during the construction; to block the transportation of sediments coming from adjacent areas.	Use during the construction to block transportation of sediments coming from adjacent areas.	Install in the walls of the water course deprived of vegetation and with strong slopes (> 30%).

ACP and/or its Construction Contractor will be responsible for the installation of barriers according to the following guidelines:

- Water barriers will be installed perpendicularly to the slope, and in diagonal manner in all the width of the fluvial course to reduce and control erosion to diminish the runoff surface area.

- Soil will be slightly excavated and compacted to form a temporary channel with a lateral down-slope compacted soil berm.

- The degree of the slope, soil characteristics, runoff area and the appropriate location of the discharge places will determine the amount and form of the required water barriers; nevertheless, the minimal guidelines for spacing these within the fluvial course are the following:

Slope (%)	**Flow breakers spacing**
5 - 10	One every 100 m
11 - 30	One every 65 m
> 30	One every 30 m

- Water barriers will be built in a wide and gradual manner to allow for safe movement and for vehicle and machinery safety.

- Water barriers will be periodically maintained and repaired as needed until they are not required to guarantee stability of the slopes or to prevent erosion. This work will be done during the construction period and mainly after each strong rain.

- Water barriers will divert runoff water to an area with abundant vegetation adjacent to the fluvial course. If there is no such vegetated area, silt fences will be installed with the purpose of filtrating runoff waters in the flow breaker outlet point of the fluvial course.

- In inclined slopes with active erosion processes the terrain should be stabilized with dikes and other drainage works.

5.4.3.1.2 Erosion Control - Silt Fences

To control erosion silt fences, grass pilings or rock rip-rap will be installed. This type of measures will be required for the prevention and control of erosion in the following places:

- In a flow breaker or water breaker discharge when adjacent vegetation is not adequate to prevent and control erosion.

- Around any soil stockpile in areas next to water courses or wetlands.

- Along the base of slopes adjacent to road crossings, where vegetation has been altered.

- In the banks of fluvial courses, within active constructions in wetlands.

ACP and/or its Construction Contractor will be responsible for the installation of silt fences according to the following guidelines:

- The silt fence have an incrustation depth of approximately 10 cm or will be anchored and secured to the soil, as required by site conditions.

- The fence will be installed following specifications of the manufacturer.

- Accumulated sediment will be withdrawn and the fence will be regularly inspected to verify that its base continues appropriately incrusted in the soil.

- An appropriate amount of silt fence will be kept in all construction locations to be used in case of emergencies or for repair purposes.

5.4.3.1.3 Slope Stabilization

Slope stabilization within the fluvial course will be made mainly through the construction of temporary and permanent devices to control erosion and sedimentation (including flow breakers, close to silt fences, jute layers, wooden barriers or sand bags, ripraps, etc.), as well as through the opportune restoration and re-vegetation of affected areas.

Water courses margins that are affected due to construction will also be stabilized through construction of temporary and permanent devices to control erosion and sedimentation as considered necessary by the Socio-environmental Inspector. These margins will also be restored and re-vegetated in an opportune manner and according with the guidelines of this program.

5.4.3.1.4 Erosion Control Structure Maintenance

The structures/barriers to control erosion will be periodically maintained and during the duration of the construction period, and especially after an intense rain. These structures should remain in place until there is proof that re-vegetation measures have been successful.

ACP and/or its Construction Contractor should assign work groups with enough personnel, machinery and equipment, dedicated exclusively to the periodic maintenance and repair of these structures/barriers.

5.4.3.2 Indirect impact prevention and control during the construction phase

Reforestation of certain areas of the watershed and also the coordination of protection actions with the Biological Corridor Program are measures that will contribute to mitigate the impacts of induced development.

5.4.3.3 Prevention and control of direct impact during the operation phase

The same measures described for the construction phase are proposed, when conducting maintenance on the project components access roads.

5.4.3.4 Prevention and control of indirect impact during the operation phase

The maintenance of re-forested areas and the follow up of actions conducted together with the Biological Corridor Program, will continue in effect during the operation phase.

5.4.4 Water Quality Protection Program

The assessment conducted considers the impacts that could occur on water quality during the construction phase and during the operation phase of the reservoirs that were previously described in Chapter 4. Experience indicates that if significant water quality impacts occur, these will mainly be manifested in the operation phase. Therefore, the analysis emphasis, through monitoring activities, will mainly be given to the operation phase.

In the previous impact chapter it was indicated that the information regarding water quality for the different options is minimal. Thus the program will focus on the necessary and sufficient data to determine and improve the water quality both in the final design phase and during the conceptualization, design, construction, operation and maintenance phases.

The program objective will be to prevent and mitigate the damage to water quality during the construction phase of the works and during the operation phase of the reservoir. The confirmation of good water body quality in the watershed during conceptualization, design, construction, operation and maintenance phases will require a periodical and routine sampling campaign that includes taking samples and conducting laboratory analyses. Proposed mitigation actions may also be required when significant water quality changes are identified.

5.4.4.1 Prevention and control measures during the design phase

When final design, including fieldwork, of the works for the selected option are done, there will not be significant negative impacts to water quality. Nevertheless, in this phase, it is proposed that water samples are taken in the sites upstream of the reservoir and downstream of the dam site and the corresponding physical and chemical analyses made. The parameters to be determined and the sampling frequency are indicated later.

5.4.4.2 Direct impact mitigation during the construction phase

Water quality of the main river and its tributaries can be damaged when the dam and associated work are being built, when there is land movement and if no measures to minimize runoff are applied. The damage to water quality is mainly due to the sediment contribution coming from land movement including excavations. In a lesser degree wastewater discharges and hydrocarbons spills to the receptor water bodies will contribute to water quality deterioration.

The experience in dam construction projects has demonstrated that during this phase the main sources of deterioration of water quality, in order of priority, are the following:

i. Construction of temporary and permanent roads constitute a significant source of sediments to water bodies if known preventive and corrective measures are not taken in consideration;

ii. Extraction sites for rock materials can also become sources of sediments for water bodies, especially in river bottoms and quarries, if no opportune measures are taken. Sediment contribution can be significant if rock materials are extracted from river bottoms thus the extraction method must be studied to avoid breaking serious damage to the water course;

iii. Land movement in the dam site, tunnel, temporary deviations and saddle dams, if no preventive and corrective measures are applied, can contribute with large amounts of sediment especially if they are done very close to the main course of the river;

iv. Water extraction from rivers, if strongly suctioned, suspends sediments damaging water quality downstream; and

v. Wastewater from sanitation facilities in the camp and work areas, as well as hydrocarbon spills from maintenance activities can also deteriorate the quality in water bodies.

Impact prevention, reduction and control measures i) to iv) have been described in the Erosion and Sediment Transport Control Program.

Proposed measures for adequate treatment and disposition of wastewater as well as the prevention and recuperation of hydrocarbon spills are of a general character for this type of projects and are included in Other Programs. These measures are known by the contracting firms and are normally included among contracting clauses. Therefore, its cost will be included

in the total cost of the works. Nevertheless, following the prevention, reduction and control measures for wastewater and hydrocarbon spills are briefly described.

5.4.4.2.1 Appropriate treatment and disposition of wastewater

In the camp and in all work fronts, septic tanks and absorption wells or portable latrines, should be used. The volume of the tanks will depend on the number of workers using them. The maintenance of portable latrines will be made by the provider who should show that they appropriately treat and dispose wastewater according to local requirements.

5.4.4.2.2 Hydrocarbons spills prevention and recovery

In vehicle maintenance workshops, areas where diesel or gasoline is dispatched, and in the work fronts, all measures will be taken to prevent hydrocarbon spills. In the machine shops disposing of hydrocarbons (oil) and battery fluid to the soil will be prohibited. These residues will be deposited in metal containers for their recycling or adequate final disposition. The firms that will be in charge of collecting these residues will have to show that they recycle and dispose appropriately of the residues.

Fuel tanks will have to be surrounded by a containment structure whose capacity should be 110% of the stored materials / fuels. In case that a spill accidentally reaches the soil, the contractor should be capablė of rapidly containing and collecting the residues. Spilled liquids should be deposited in an appropriate site.

5.4.4.3 Indirect impact mitigation during the construction phase

The reforestation of certain areas of the watershed as well as the coordination of protection actions with the Biological Corridor Program are measures that will also contribute to mitigate impacts for the induced development and its effect on water quality.

5.4.4.4 Direct impact mitigation during the operation phase

In this phase, activities related with the operation of the dam will not generate major impacts to water quality. Nevertheless, as it will be explained in the monitoring phase, it is recommended that a periodic sampling campaign is done to determine changes in water quality and the risk of eutrophication so that required preventive and corrective measures are taken. In the monitoring program, the sampling campaign will be described in detail.

5.4.4.5 Indirect impact mitigation during the operation phase

No special measure additional to maintaining reforestation areas is proposed.

5.4.5 Terrestrial Ecosystems Biodiversity Recovery Program

There will be some inevitable impacts as a consequence of construction, and in a lesser degree, during the operation. A large part of these impacts on forest cover and habitat will be localized and temporal, as they were previously described in Chapter 4. These resulting project impacts can be prevented, reduced and controlled, within possibilities, and completely mitigated.

The construction of any of the studied alternatives for the Indio River watershed will result inevitably in permanent removal of vegetation in the dam area. The terrestrial ecosystems of the water alternatives in the Indio River watershed, have a relatively low diversity of native plants and animals because they have been degraded by unsustainable agricultural and cattle practices and other human activities. The reduced habitat diversity is mainly due to the poor structure of the vegetation, reduced productivity and the introduction of domestic species. Thus, the isolated patches of remaining forests especially in lower elevations of the watershed, lack many species and functional groups (v.g., large predators) required for the normal functioning of the ecosystem. The ocelot is a key predator in the terrestrial ecosystems in the Indio River watershed. Its demographic density is low, typical of higher predators. Since it is part of the mega fauna of the region it has been suggested that the ocelot could be a flag species for restoration and preservation of native ecosystems and their fauna (Louis Berger International Inc., 2003).

This section describes the prevention, reduction and control measures of negative impacts and risks on terrestrial ecosystems. Also this section describes the opportunities that ACP has to transform the process of prevention, reduction and control in an opportunity to improve the ecological value of the region in the national context and benefit local communities as a result of the execution of the selected option.

The main objective of the ecological diversity recuperation program for terrestrial ecosystems in the Indio River watershed is protecting ecological values of the forested ecosystems of the watershed and sustain those resources values during the conceptualization, design, construction, operation and maintenance of the selected option. Specific objectives are:

- Minimize additional loss of forested areas.

- Promote and conduct restoration of areas upstream of the project with the double purpose of partially replacing displaced forests by the project and protecting middle and upper parts of the watershed against erosion and sedimentation.

- Promote and conduct reforestation and restoration of riverine corridors in the affluents of the reservoirs created by the project.

- Use opportunitites to connect existing fragments of forest through reforestation of intermediate areas to reestablish biological corridors and support the efforts to establish the Mesoamerican Biological Corridor .

- Replace the ecological values lost due to the project.

- Implement appropriate measures to prevent, reduce and control inevitable development and operation impacts of the project.

- Prevent, reduce and control the cut and damage of arbustive vegetation to reduce and control the erosion process and sedimentation and control invasive grasses.

- Mitigate direct impact on the flora and fauna in areas affected by the creation of camps, access routes, work fronts, roads and other activities that produce vegetation loss.

- Mitigate or avoid indirect impact of project development such as the unauthorized establishment along access routes, and in general in terrestrial ecosystems, due to the loss of species and habitat and because of their reduced size and the increase in human use.

- Initiate activities and actions that highlight ecological values and of human use in the ecosystems of the region in a sustainable way with minimal management and that adequately compensate inevitable impacts of project development.

5.4.5.1 Prevention and control during planning and design phase

Activities destined to conserve remnants of natural ecosystems that exist in the Indio River watershed include the protection of ecological habitats, soil retention and prevention of erosion and restoration of degraded areas to lift their ecological and human use values. These measures will diminish not only negative temporary impacts on terrestrial fauna, they will even improve

the efficiency of the project helping to reduce the erosion that could be reducing the reservoir's volume.

Important types of habitat and vegetation are limited to isolated patches of forests, forested areas along rivers and creeks, and to evergreen tropical forests in the higher parts of the Indio River watershed. The plan includes special specific measures to reduce negative impacts in these areas and implement restoration measures in degraded areas within each phase.

Opportunities to minimize the forest area, and associated values to be affected by the reservoir, are subordinated to the needs of its design since these have to satisfy a determined water requirement for Panama Canal operation. Nevertheless, during the final design of auxiliary installation, such as access roads, material borrow sources, and equipment and material stocpile areas, efforts should be made to avoid locating these facilities in forest areas. The plans and final specifications must establish design measures to prevent, reduce and control impact on natural vegetation and must clearly justify the reasons behind impacts that could not be avoided.

Standard construction activities, including leveling terrain and soil movement associated with camps, construction works, extraction of aggregate material, will be adequate to reduce to the minimum potential negative impacts. These procedures will be incorporated in engineering works that will be requested to contractors hired for these activities. Prevention of impacts such as erosion and unnecessary habitat destruction can substantially reduce ecological negative effects of the development of the selected water option.

Detailed measures for prevention, reduction and control will be made for the selected option during the final design. Actions and activities will be performed during the conceptualization design, construction, operation and maintenance phases. These measures will be developed by an ecologist familiarized with the region's ecosystems and with experience in planning prevention, reduction and control of projects in humid tropical zones.

Since the ecosystems include resources such as soils, as well as flora and fauna, the habitat is an appropriate base to estimate and provide prevention, reduction and control for the socio-environmental impacts. This is important in the Indio River watershed where forest habitats, important to conserve biodiversity and as a refuge for rare, endangered and economically important animal and plant species, are very limited.

The **Habitat Equivalence Analysis (HEA)** can be used to determine the size, type and location of areas for prevention, reduction and control. This method combines factors such as severity,

time and area of environmental services lost as a base to determine the types and quantities of restoration required, to attenuate the mentioned impacts. Discount rates used to quantify the loss of ecological services due to the execution of the preferred option, and the type, and quality of the appropriate habitat to attenuate negative impacts. The result of this analysis is an estimation *of the services discounted in a hectare/yr* that can transform in an estimation of the number of hectares required to compensate or appropriately indemnify the negative impacts. This focus is more equitable and comprehensible for the public than traditional focuses that were exclusively based on arbitrary relations.

Restoration areas will be located within the Indio River watershed or adjacent areas. Forest habitat restoration will be centered in elevations higher than the adjacent watershed to the forest fragments that are still exist. Some areas with lower elevations (example, close to reservoirs or communities) can be created to improve forest ecological services to the neighboring villages.

The initial selection of the areas to prevent, reduce and control will be made as part of the final planning for the construction, to optimize in this manner the logistic part and start compensatory prevention, reduction and control concurrent with the disturbances of works development. When integrating these activities to the project schedule, inevitable impacts will be reduced to a minimum and restoration values will be maximized.

5.4.5.2 Direct impact mitigation during the construction phase

Actions and activities designed to reduce negative impacts can be executed during the construction phase. Planning for the areas of prevention, reduction and control related to restoration and protection of evergreen forest will continue especially in the upper part of the Indio River watershed. These efforts should be coordinated with the Mesoamerican Biological Corridor (CBM, acronym in Spanish) to maximize the benefits of the efforts for wildlife in the region.

During this phase, the main measures should be directed to guarantee the minimization of impacts. In particular the following measures should be implemented:

- Approved areas for construction activities should be clearly identified, especially in those areas where the construction zone includes or is immediately adjaccent to natural vegetation areas.

- Once the area is clearly identified, an effort to rescue and transfer fauna species to similar habitat will be conducted for fauna species that cannot escape by themselves from the area to be cleared of brushwood. Example of species that may require salvage include small amphibians and reptiles and eggs or chicks of birds of several species. Areas to be used for their liberation will be previously identified and will require ANAM's approval. Individuals that due to their health status or development stage cannot be immeditaley liberated must be submitted to ANAM.

- Socio-environmental inspectors must monitor construction activities and guarantee that these activities are being performed according to plans and comply with the environmental measures of the project and associated investments.

- Areas affected by cuts and slopes should be stabilized immediately after the impact has occurred. In this manner potential secondary impacts will be avoided and biomass eliminated by the works will be partially restored.

- Access routes, camps and other project installations construction will be located in areas of altered habitat and of secondary growth, whenever possible.

- In the points where the routes cross water courses, erosion prevention and control measures to reduce to a minimum soil loss and sedimentation produced by currents will be implemented.

- The upper soil level, will be stockpiled, which will be carefully spread out as soon as possible (preferable less than three months) to retain feasibility of seeds and avoid or reduce the creation of anaerobic conditions and nutrient leaching.

- Where the construction requires cleaning and leveling, superficial vegetation will be collected and stockpiled along the area's border to reduce erosion and provide convenient conditions for natural re-vegetation. When necessary (example, in slopes) vegetation will be enclosed with fast growing tree shoots that will grow roots and help in stability.

- Instruct construction workers regarding hunting, plant and animal gathering, and the exploitation of ecological resources within the influence area and the consequences of breaking these restrictions, which can include fines and termination.

- The use of access routes will be restricted to the project's personnel and local residents to prevent the illegal use or non authorized use in the project area.

- Vegetation in temporary construction areas will be cut, but land will not be leveled. This will reduce and control erosion reducing impacts on soil ecology and promoting fast re-vegetation.

- Areas cleared by construction activities will be re-vegetated or reforested recreating original terrain conditions and slopes will be stabilized. In most of the situations re-vegetation will require the use of certain materials to conserve humidity and protect soil. All plants employed in re-vegetation will be from the region and preference will be given to an appropriate variety of those used by humans.

- Habitat re-vegetation and restoration will be coordinated with activities of socio-economic improvement and of communities' relocation to strengthen human value use while their ecological values are maintained.

- In agreement with Panamanian legislation, some areas could be developed for forestry purposes, which benefit certain fauna species and provide additional values of these resources to the local communities.

A key aspect in the success of these recovery programs will be fast implementation. The construction contractor will establish plant nurseries in areas close or adjacent to the project to plant and prepare the thousands of trees requiered for reforestation.

The responsibility for these activities rests on the Construction Contractor. It is possible that regulatory national agencies or international financial institutions that finance the project will demand participation of independent inspectors from the Contractor.

5.4.5.3 Mitigation of direct impacts during the operation phase

Potential negative impacts can be greatly reduced by the implementation of preventive actions during the operation phase. Specific actions to reduce negative impacts include the following:

A buffer zone of 30 meters will be maintained along water currents to maintain and protect adjacent vegetation (riverine corridor) and diminish the effect of superficial erosion on rivers and creeks.

- Inform workers of restrictions on hunting, gathering of live plants and animals or of exploiting ecological resources within the area.

- The use of access routes will be restricted for project personnel and local residents

5.4.5.4 Indirect impacts mitigation during the operation phase

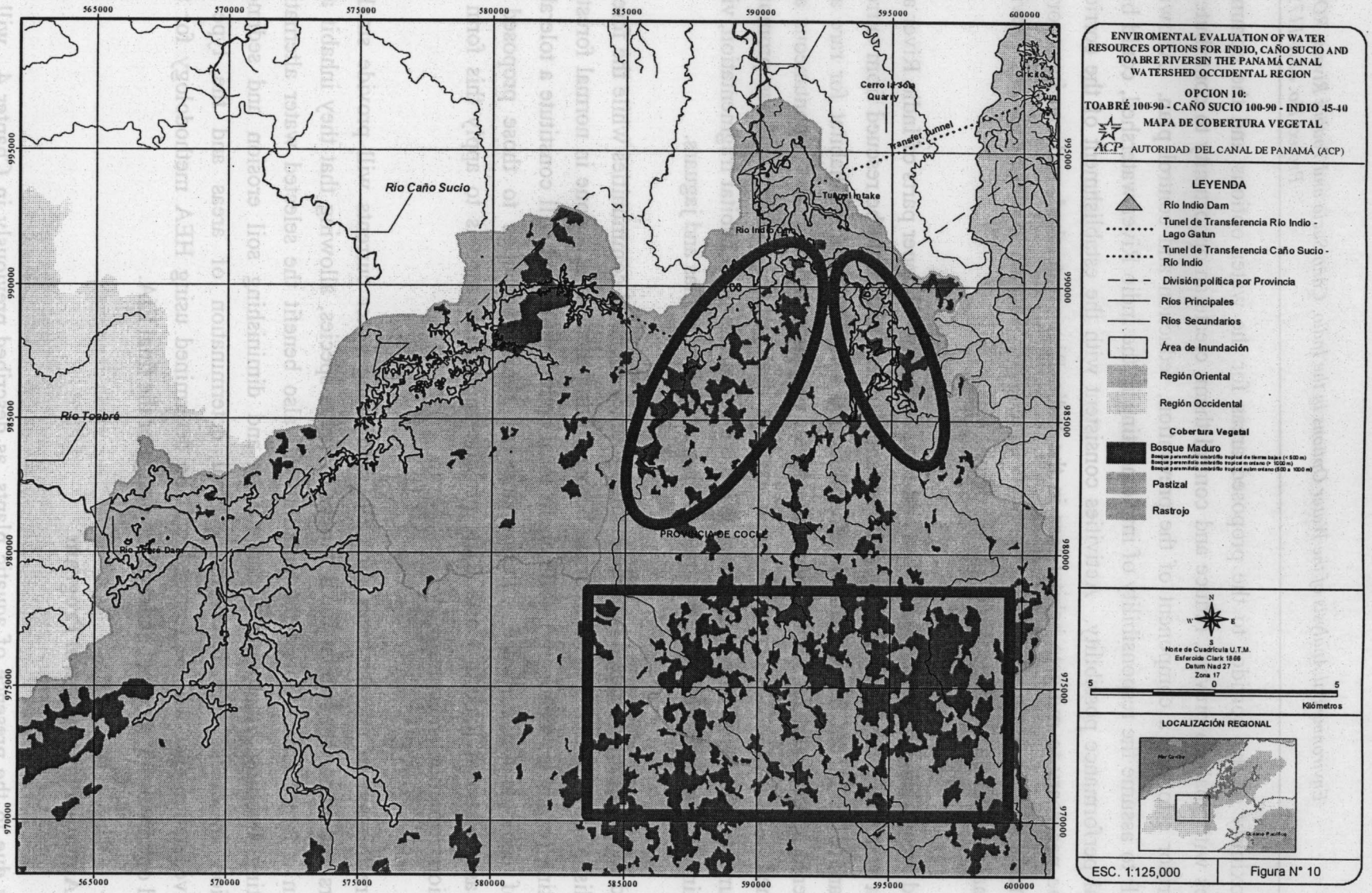
During the operation phase of the reservoirs the efforts must emphasize on reforestaton of the areas upstream of the project; these actions will start in the construction phase and will not have to wait until the operation phase to initiate. In the Indio River watershed there are opportunities to implement an ecosystemic recovery plan centered in existing forest fragments to create contiguous forests along the reservoir (Figure 5.2). In upper areas of the watershed, there are also opportunities to reconnect forest fragments. The reconection of fragments in the upper portions of the watershed provides the additional benefit of promoting the Mesoamerican Biological Corridor in this part of the country.

Coordination with the Mesoamerican Biological Corridor

The importance of maintaining large contiguous areas of forest habitat has been acknowledged for a long time by parties interested in preserving valuable forest ecosystems of Central America. In 1990, Wildlife Conservation Society (WCS), with its partner Caribbean Conservation Corporation (CCC), presented the Paseo Pantera Project with financial support from USAID. The project used a new conceptual focus and proposed the establishment of a Biological Corridor from the Mayan forests of Mexico, Guatemala and Belize, to the Darién in Panamá. In 1998 the World Bank approved $8.4 million to support the part of the Panamanian Atlantic Mesoamerican biological Corridor (CBMAP, acronym in Spanish) included in the Mesoamerican biological Corridor (CBM). CBM has been developed from Paseo Pantera and under the direction of the UNDP, and with technical assistance from WCS.

Since the purpose of the corridor is to facilitate the movement of animals and plants and facilitate the genetic interchange, it is essential for long term survival of many rare and endangered species and the maintenance of forest biodiversity. These values are known as ecologically important and their protection is known and supported by Panama as signatory of international treaties (example, CITES [Convention on International Trade in Endangered Species of Wild Fauna and Flora], and the Convention on Biological Diversity). CBMAP is financed and supported by a variety of institutions and includes areas considered in the Panamanian Atlantic Slope.

Figure 5-2. Opportunities for reforestation activities that will aid in re-connecting forest fragments within the study area



The proximity of the corridor to the proposed areas for the water options and the common purposes with goals to prevent, reduce and control them, create an opportunity to contribute to the corridor effort as a component of the prevention, reduction and control plan. Allowing CBMAP to assume the responsibility of implementing in the Indio River watershed, could be a practical performance possibility. Activities consistent with the establishment of the corridor could be necessary to mitigate habitat loss in the Indio River watershed, and can incorporate components such as forest repopulation projects strategically located to close gaps and provide additional connectivity to the corridor in the region.

Forested areas along the rivers and creeks and forest remnants in upper parts of Indio River and adjacent watersheds represent ecological important elements that could be rescued from current trends and offer in the future valuable environmental services including habitat for rare and endangered species and for high biodiversity levels of plants and animals. Spontaneous and unplanned colonization has occupied the space in a disorganized manner and has promoted environmental and social impoverishment as it has also caused forest habitat fragmentation, vital to sustain viable populations of larger species such as ocelots, pumas and jaguars.

Selected forestry projects could provide income sources for local communities while the forests reestablish, allowing that grasses flourish, before cutting them as it is done in normal forestry. Harvesting (example, mahogany) will benefit local communities and will constitute a tolerable level of ecological disturbance. Performance of similar activities to those proposed in Guanacaste National Park in Costa Rica, provide appropriate models to apply this form of prevention, reduction and control.

Forest restoration in interest areas for CBM and along water currents will provide smaller corridors and important habitat for a variety of fauna species, allowing that they inhabit and move in a larger area. Forest repopulation will also benefit the selected water alternative attenuating flooding, improving water quality and diminishing soil erosion and sediment deposition in creeks and reservoirs. Final determination of areas and the type of habitat/vegetation that will be restored will be determined using HEA methodology for the selected option during the final phase of the design or the final EIA.

5.4.6 Aquatic Plants Control Program

Impacts due to the presence of aquatic plants, as described previously in Chapter 4, will be generated in the operation phase of the water options. Excessive growth of aquatic plants can be managed with physical, chemical and biological controls.

The objective of the program is to maintain the reservoir free of aquatic plants that constitute a problem for the canal operation.

5.4.6.1 Prevention and control measures during the planning phase

The experience of aquatic plant growth in Panamanian reservoirs indicates that these will invade the water bodies that will be built as part of the selected alternatives. Nevertheless, lessons can be obtained from what has occurred in other reservoirs in the country, and one of these is that forest cover of the area to be flooded must be cut since trees when decomposing add nutrients to the water favoring the growth of aquatic plants. Thus, the cutting of trees must be included as a work item during the final design of the water alternatives. But, as is mentioned in the Fish and Macro-invertebrates Conservation and Management Program this component recommends that forest patches are left in strategic places as refuge for fish and macro-invertebrates.

During this phase of the selected option, the aquatic plant species that exist in the area to be flooded must be investigated. With this information, the potential growth projection can be estimated and appropriate monitoring and control measures, and dam operations that can contribute to reduce the magnitude of this potential problem can be identified. In this manner, control measures will start when aquatic plants still do not represent a problem. One aspect to be considered is anticipating the ultimate dissemination of exotic species prior to infestation.

5.4.6.2 Direct Impact Mitigation during the construction phase

Prevention measures during this phase will be: tree and shrub vegetation cutting and appropriately disposing of remains of this activity; and, monitoring the presence of aquatic plants in tributary rivers and during the water filling stage. Among monitoring activities of other programs such as Water Quality, verifying the presence of macrophytes and relating them with the results of water sampling analysis will also be included.

5.4.6.3 Indirect impact mitigation during the construction phase

No specific additional measure than what was indicated is foreseen for the Protection Program and the Protection and recuperation of biodiversity in Terrestrial Ecosystems.

5.4.6.4 Direct Impact prevention and control during operation phase

Measures to prevent, reduce and control impacts during the dam's operation phase will depend on the growth magnitude of aquatic plants. Controls that will be made are physical, chemical and biological. To date, none of the control methods in it can provide a complete solution to the exaggerated growth problem of aquatic vegetation, thus the integrated control combines manual and biological controls.

Aquatic plants physical or mechanical control is the oldest and consist of manual instruments and sophisticated machinery developed for this, which are adaptations of those used in the agriculture industry. Their advantages are that they do not pollute the water and cause very low mortality. Also retaining barriers with log booms are also employed with the mechanical method.

The chemical control methods refers to the use of herbicides. These can be classified in four categories: selective on contact; non selective on contact; selective systemic; and non selective systemic. Herbicides on contact kill tissues in areas close to the application point; and systemic herbicides enter the plant and move through the vascular tissues. For an effective chemical control of aquatic plants, the first step to follow is to define the type (rooted, submerged or floating). Aquatic plants are efficiently controlled with appropriate herbicides if correctly applied. Nevertheless, all herbicides are toxic and thus only those correctly registered and labeled must be used, to avoid risks to the environment and to human health.

The biological control of aquatic plants has been accomplished through the selective use of insects that have an influence on the habitat. Insects can limit aquatic growth in a major or lesser degree, but in most cases they are incapable of completely eliminating problem vegetation in the water body. Also herbivore fish (carps) and manatees have been employed for vegetation control.

A safety plan is required when there is a chemical control program for aquatic vegetation. The directives presented below include the most important elements for such a plan:

- Areas treated with herbicides must be appropriately labeled, in visible places. The labels must have a size of at least 38 x 60 cm. with big letters indicating hazard, herbicide in use, date of application, uses to be given to the water, the period in which the sign is going to be effective, location of the closest office and ACP's telephone numbers. This sign must be of a material that does not deteriorate immediately and should be fixed to the area with wood posts or on trees in the most visible place for the public.

- The population should be informed by other communication means available (radio, television or flyers) over the aquatic weed control operation and the care that has to be given in this regard. In other part, control brigade members should be provided with masks, goggles, gloves and uniforms, and their use should be mandatory. Boats must have a lifesaver per occupant.

- Personnel that are part of the brigades should be instructed in terms of safe management of chemical products used in the program including at least the following recommendations:
  - Avoid contact with eyes, skin and clothes.
  - Avoid breathing vapors for an extended period.
  - Under no circumstance ingest the herbicide.
  - Do not eat, drink or smoke while manipulating the herbicide.
  - Avoid re-entering places treated with herbicide.
  - Herbicides must be kept in ventilated, dry, cool storehouses with restricted access.
  - They will be kept away from children, food, seeds, medicine and livestock forage.
  - Herbicides will not be exposed to high or low temperatures.
  - They should be kept in their original container and should not be kept without their original label.
  - Herbicides will not be transported with people, food or livestock.
  - The mix of herbicides will be done using jars, buckets, canes or paddle, never with the hands.
  - At all times spills must be avoided when transferring liquids.
  - No herbicide or pesticides should be suctioned with a rubber tube; a pump will be used for these purposes.
  - The label instructions will be carefully obeyed.
  - Avoid at all costs that the herbicides are taken by the air into other crops.
  - Observe the label's recommended dosage.
  - Use calibrated containers to conduct measurements.
  - In water bodies with large extensions covered by aquatic weed one third (1/3) to one half (1/2) of the total affected area will be treated.
  - Keep equipment in optimum working condition.
  - Treatment is not recommended during adverse climatic conditions.
  - Weed control equipment must be clean and frequently inspected.
  - The tank as well as all the storeroom used to mix the herbicide should be rinsed out.
  - The clothes used during treatment must be washed and changed.
  - Empty containers will not be used for other purposes and should be eliminated in an authorized place.

5.4.7 Fish and Macro-invertebrates Conservation and Management Program

There will be some unavoidable impacts as a consequence to the construction and others during operation. A large part of the impact on fish and macro-invertebrates will be local and temporal as they were described in the impact section. These impacts resulting from the project could be prevented, reduced and controlled to a certain extent and completely mitigated. Program objectives are the following:

- Provide fluvial alternatives for fish and macro-invertebrate migratory species so that they can overcome the dam barrier.
- To allow vital ecosystem processes water discharge downstream (ecological flow).
- Identify and assess in a preliminary manner fishing activities that can be developed in the associated dams with the selected option.
- Generate basic fishing information required to promote and regulate sport and commercial fishing, in an organized manner once the new reservoirs are established.
- Guarantee feeding and economical security of population occupying the watersheds through a sustainable management of the 'Nile tilapia' fish and eye-spot cichlid.
- Train rural people of neighboring communities to the dams in basic agriculture techniques to conduct fish cultivation and fattening (Nile tilapia) using aquatic enclosures (floating cages and confinement areas) as a production and sustainable use alternative of aquatic resources to be created as part of the development of the water alternative.
- Generate basic information that serves as an alternative model of transferable production to other communities existing in the future reservoir areas.

5.4.7.1 Prevention measures during planning and design phase

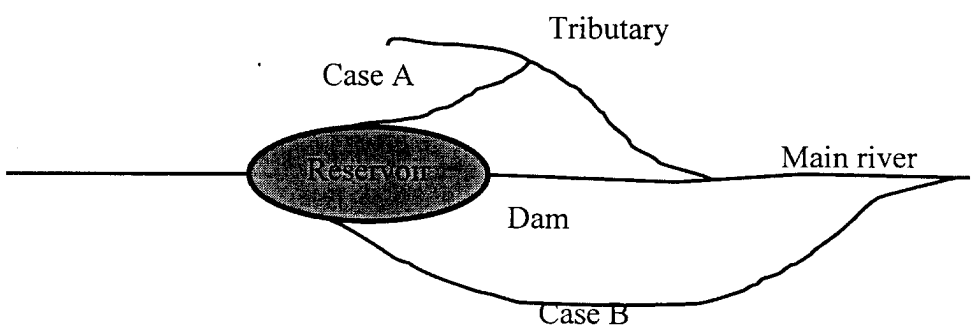
Impacts previously identified and assessed (Chapter 4) establish that at least four fish species and three of crustaceans will disappear upstream of the dam since they will not be able to overcome the physical barrier represented by the dam. Besides, there is not enough information on potential changes to be induced in the salinity gradient within the Indio River estuary, which will determine species distribution in its lower part. Thus, it is recommended that during the final

planning phase of the selected alternative the design of an alternative route for fish and crustaceans identified as a 'ladder' be done and that the ecological flow required downstream is more precisely determined. The following section outlines the considerations that the URS team has made based on available information regarding both topics.

5.4.7.1.1 Fish ladder design

The term 'ladder' for fish refers to structures conceived to facilitate movement of migratory organisms (fish) upstream and downstream of water courses that have been interrupted by the construction of a dam. The objective of this structure is to ensure that organisms that require to move up and down the river during their life cycle can do it so that they do not disappear from the tributaries, upstream of the dam area.

The ladder design must consider several alternatives once the final water option has been selected. In general terms it is conceived as a regulatory structure with low flow that connects the reservoir with the waters below the dam. This connection can be direct or through one of the tributaries that flows into the main river below the dam. The diagram presented below illustrates the possibilities. In both cases one must consider a simple structure as an outlet connected to a discharge channel that allows regulating the flow discharged by itself.



5.4.7.1.1 Determination of the ecologic flow

The flow downstream of the dam must be enough to allow the occurrence of the ecosystem's vital processes and environmental goods and services that they provide. This is in essence the definition of ecologic flow, but in practice the value of this flow is difficult to define. The feasibility study considers that 10% of the monthly flow will be discharged downstream which is the value used generally in this type of projects.

Nevertheless, available information does not seem appropriate to provide a definite recommendation, and thus URS team after studying this recommends that this topic be considered in more detail in the final environmental impact study for the selected option or during the final planning phase and definitive design. To appropriately consider the importance of the topic, it is important to highlight that the proposed value of 10% (~2.6 m^3/seg.) is exceeded in the proposed site for the dam in 96% of the times according to the daily flow series available for the years 1979 – 1997.

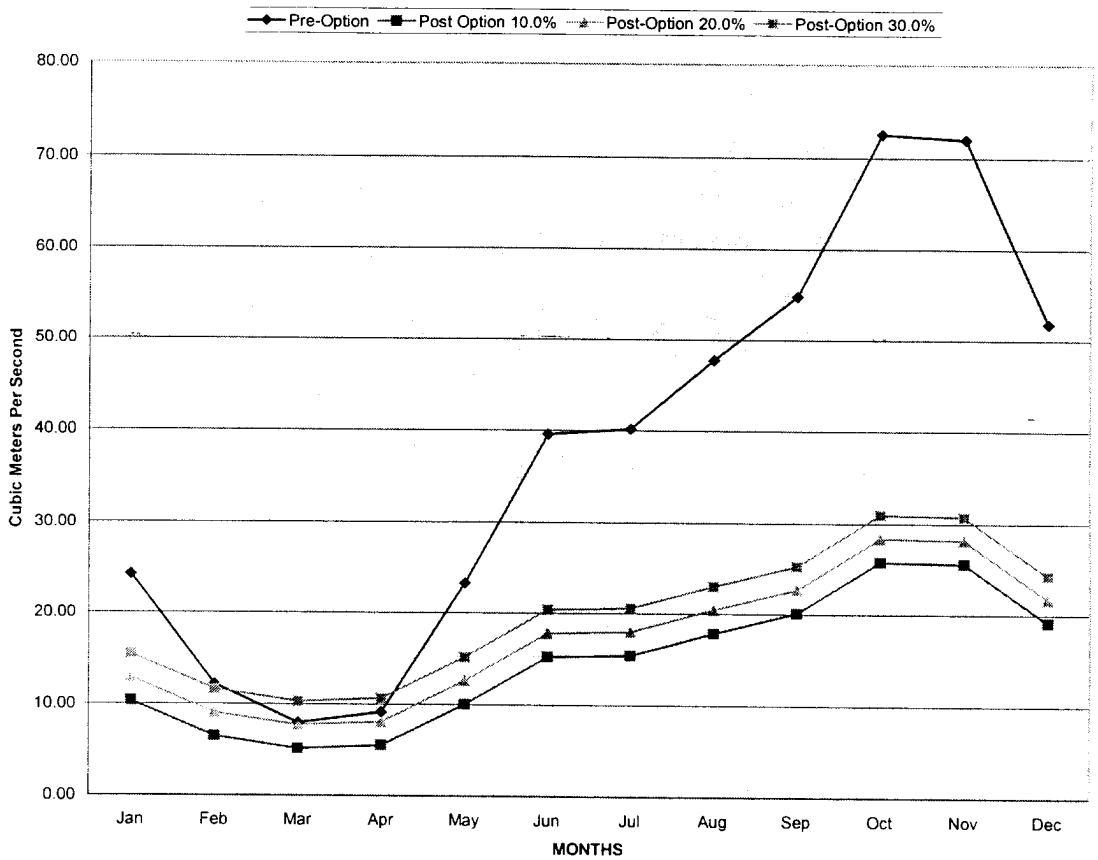
In the analysis for this recommendation it has been considered that one of the important environmental services provided by the river to the communities includes transportation by the water route. The river is navigable precisely to the point where the proposed dam site for Options 1 and 2 is, which are the ones located in the lowest position of the six options considered. This means that during the construction phase there will be no inconvenient since the flow will be maintained to a place very close to the current dock. During the operation phase it is anticipated that fluvial transportation will have slowly evolved into terrestrial transportation due to the effect of induced development that will occur in the area. Thus, the river flow will not be considered as critically important for this function beyond the first years of the construction phase.

In other respect, the importance that the flow can have in fluvial and estuarine community structures has also been considered. Obviously, distribution of estuarine species depend on the salinity gradient in the river section in which the waters they discharge mixes progressively with the sea. With a lower discharge it is expected that the salinity gradient will be displaced inland.

In this sense it can be supposed that the salinity gradient is in dynamic equilibrium and that during the driest season it moves inland while as the flows increase it will be once more pushed towards the sea by the fresh water flow. An analysis of the median flows (Figure 5.3) indicates that the river's minimum discharge occurs typically in the months of March and April. There are two important arguments by which the discharge during the drier period can be the key to prevent a significant change in the salinity gradient in the estuarine portion of the river. In the first place, one can mention the effect of the north frontal systems that causes strong tides during these periods in the north coast of Panama. Obviously the tide pushes the salt water inside the river and its effect is expected to be higher with a decreased discharge. On the other hand, this period is characterized by a higher amplitude of the tides, which could also favor the migration of salt water deep inside the river, under conditions of reduced volume of running water.

It is expected that during the first months of the rainy season this trend would be reverted due to the greater river flow. Nevertheless, this is only a hypothesis that needs to be tested through the observation of the salinity gradient behavior and the distribution of sensitive species along the river at several river discharge levels. In the same Figure 5-3 the effect of three discharge levels on the average year histogram has been included only as a descriptive example.

Figura 5-2: Mean Monthly Flow at Boca de Rio Indio Pre and Post construction of Options 1 and 2 at Various Minimum Discharge Levels



It is important to point out that to modify the low water discharge should not have a significant impact on the Option 1 yield in terms of the lockage that itself can contribute to the functioning of the Canal. This is so because a very important part of the contribution to the system from the 15.5 lockage per day provided by Option 1 depend on the water stored in the useful section of the dam, which is of almost 1300 MMC.

As a result, the water offer from Option 1, is 1300 MMC plus the discharge fraction that is assigned to the Canal system. Considering the proposal to discharge 10% that has been recommended by the feasibility study, the total Option 1 water offer, in an average year is 2032 MMC. Consequently, the 10% of the average volume of running water proposed as discharge downstream represents less than 4% of the water offer of Option 1 in the average year.

On the other hand, it should be considered that on the average year or wettest years, this water will not be really required by the system and in case it is to be transferred to Gatún it will be discharged through a hydroelectric plant. During dry years, when the water will be really required by the system, especially during extreme droughts like the one that happened during the El Niño of 1997-1998, the discharge parameter of the ecological volume of running water could be reviewed because these dramatic events are also important for the natural systems evolution. In other words, a water subsidy should not be given to the natural system when regional general conditions are of extreme drought. Consequently, during extreme drought conditions the water could be available for Canal functioning.

The purpose is to determine which is the better downstream water discharge scheme in order to determine how environmental and economic values of this system are maximized. Information on the salinity gradient evolution in an annual cycle is not available; especially indications that under reduced flow conditions there is a gradient migration toward land and at what point this effect is reverted when the volumes of running water are beginning to increase again. This situation must be considered if the change in itself has a detectable effect on the biological community in the estuarine section of the river.

5.4.7.2 Direct impacts mitigations during the construction phase

During the construction phase, the implementation of the final designs developed during the previous phase to allow fish and crustacean species to continue as dwellers of Indio River waters and its upper tributaries above the proposed dam sites in the considered options should occur.

5.4.7.3 Direct impacts mitigation during the operation phase

During the operation phase of the new reservoir, fish will be under a new regime: from lotic to lentic. When fishery activity starts in the new reservoirs, one of the main risks that it can cause, is the gradual decrease of native and exotic fish in their waters. The manner to prevent, reduce, and control these risks will be through the implementation of fishery management and ordering

measures, like closed seasons, determination of the fishing instruments size, capture amount, regulation efforts, and possible future repopulations.

Since their introduction in the sixties and seventies, the eye-spot cichlid fish (*Cichla monoculus*) and the Nile tilapia (*Oreochromis niloticus*) have been transferred to different reservoirs in the country, among them Gatún, Alhajuela, La Yeguada, Fortuna and Bayano lakes generating with this an important fishery activity for the communities inhabiting their borders.

Once a reservoir is built and these species are incorporated in its waters, fishery will become important among the inhabitants of the watersheds due to the availability of good quality meat and the national and international market prices. In this sense, the development of fisheries of Nile tilapia and eye-spot cichlid in these reservoirs should be studied and promoted because it is crucial to promoting and maintaining any sustainable artesian or commercial fishery exploitation in the area.

This research will generate basic information required to establish a fishery management plan in the future reservoir, an action that will benefit the rural communities, governmental institutions and NGOs that work in the area as well as private enterprises that propose using the Nile tilapia and eye-spot cichlid fish fishing resource for tourism, local commerce or exportation.

Fish cultivation in aquatic enclosures (floating cages and confinement areas) in many places of the world is considered an alternative for food sustainable production. Since the dam construction will imply a radical change in the way of life of rural people, aquaculture emerges as a form to rationally use aquatic resources and at the same time as an employment and protein source for this poor population.

For this reason, there is a need to train rural people in the basic aquaculture techniques in the reservoirs so that they can use resources in a productive manner.

5.4.7.3.1 Preliminary research on fishery resources

In this research project, the potential fishery use in the reservoirs will be evaluated. For this purpose, fishery prospection will focus on the study of species expected to have greater economic importance: Nile tilapia and eye-spot cichlid fish. As part of the fishery investigation, interview with local fishermen in the reservoirs will be carried out as well as surveys on capture in movement (ECM, acronym in Spanish) to obtain data on their yield, daily fishing effort, and other parameters that influence fishing such as fishing tools, frequency and effort, among others.

In this new ecosystem, simultaneous monitoring of Nile tilapia and the eye-spot cichlid biology and the evolution of their populations will be made. For this purpose, different sites will be established within the reservoir, which will be sampled with experimental nets or trammels, to determine relative abundance, structure and composition of populations, growth, condition factor, size at first maturity, reproduction, etc.; essential information for future management of these species in the reservoir.

Besides, twice per year (dry and rainy season) a survey on fish use will be made to measure indirectly the productive use of the reservoir. All information generated with this methodology will be analyzed using statistical packages such as FISAT. Later, the results of these analyses will be conveyed through seminars and trainings to groups of fishermen as well as to governmental or private entities that are related with the integral management or exploitation of the resource. This research will be done at the sites where there is some important fishery activity.

During an initial phase, for a one year period, the evolution of Nile tilapia eye-spot cichlid fisheries will be studied through the evaluation of capture and the fishing effort, in the main areas of the new lake. If it is confirmed that other species also have a significant importance in the captures, these should be included in the study. Simultaneously, in this phase some important biological parameters will be determined for each of the species. For the fishing surveys the methodology known as interview of capture by sampling (ECM, acronym in Spanish) will be used.

These surveys will be made each month traveling in boats to areas of the dam, previously selected at random. Such interviews will be filled applying questions to fishermen found in the trip; form them the data on capture, fishing time, number of fish, species etc., will be obtained. In the same manner organized rural people and other neighboring population to the dam, will be interviewed regarding eating and fishing in two different periods of the year (dry and rainy season).

Biological surveys will be conducted each month using experimental trammel nets (with diverse mesh sizes) that will be located in several previously randomly selected zones of the reservoir. Also, sampling at the reservoir shores will be made using a drift net with the purpose of detecting the presence of reproduction or fingerlings. Of the captured fish, relative abundance, composition and structure of the species, weight, growth data, stomach content and other diverse biological parameters will be taken.

After obtaining these data, their interpretation and analysis will be made to emit recommendations of the information generated by biological and fisheries research to be conveyed (three months), through the training workshops to the groups of fishermen or environmental agencies, private or governmental, involved directly or indirectly with the exploitation of the fishery resource.

5.4.7.3.2 Pilot project to cultivate Nile tilapias in aquatic enclosures

In this pilot project, together with selected farmers groups, two aquaculture techniques to use some zones of the new reservoir will be evaluated as alternative activities of sustainable production for inhabitants of the Indio River watershed. The program should start after the initial period to stabilize the water quality of the reservoir (3-5 years) and after confirming that the eutrophication risk is low.

For this purpose, first with these groups the sites presenting the recommended characteristics to conduct the project will be selected, for example: depth greater tan 10 m, areas with good water circulation, close to villages, etc. Once the site is selected, cultivation or fattening of fish (Nile tilapia) will proceed in floating structures (4 m^3cages) or confinement areas (1,000 m^2) that will be built in the shores of the reservoir. The fish that will be acquired through the Aquaculture National Directorate (Dirección Nacional de Acuicultura), will be fattened with concentrated food or pellets, in the mentioned production enclosures, around more or less 7 months (depending on their growth speed) after which they will be harvested for consumption or local commercialization.

Feeding rates for the fish in the enclosures, will be calibrated per month through samplings. Simultaneously, some parameters or measurements of the fish will be taken (size, weight), to evaluate growth rate in the production system and their adaptation to the new reservoirs. This information will be used to establish a net harvest of nutrients in the reservoir and to calibrate the system in such a way that it has a positive nutrient balance in the water body. All information generated in this experience will be conveyed through a training seminar to the different groups of farmers inhabiting the Indio River watershed.

This project will be conducted in some areas, especially where farmer communities are located. To cultivate fish in floating cages 4 floating cages will be built with PVC with a 4 m^3 capacity, which will be planted with Nile tilapia, at a rate of 200 fish per cubic meter, which will be fed six days per week using concentrate food for fish (25% protein) for a 7 month period, after which they will be harvested and commercialized in the area or neighboring zone. Also, 1 to 3 fish will

be planted per square meter in a confinement area of approximately 1,000 m^2, then fattened with palletized food with 25 % protein during a period of 6 to 7 months. Once fattened, they will be harvested with a drift net, for sale or local consumption. In both instances, monthly measurements of fish growth will be taken to adjust the amount of food to provide.

As with previous activities, all information generated through these experiences will be conveyed to the different groups of farmers or organized groups that live around the constructed reservoirs through seminars of theoretical-practical training.

5.4.7.4 Indirect impacts prevention, reduction and control measures

No other additional measure is foreseen to the ones indicated for the direct impacts, for promoting commercial fishing combined with sport fishing, as an alternative to sustainable production.

5.3.8 Archaeological Sites Conservation and Recovery Program

There will be some unavoidable impacts as a result of the construction and, to a lesser degree, during the project operation. A large part of the impacts on the cultural heritage will be localized and temporal, as previously described in chapter 4. These impacts, which are the result of the project, may be prevented, reduced and controlled, whenever possible, and completely mitigated.

The current archaeological inventory of the Río Indio river basin indicates there is a total of 20 known archaeological sites of varying importance within the combined potential impact areas of Options 1-4, 11 and 12. This indicates the need for mitigation measures associated with various phases of the project. Options 1 and 11 would entail substantially more impacts; the impacts of Options 3 and 4 would be relatively limited. In all cases, however, the proposed options would impact archaeological resources. Valuable scientific and cultural information would be lost if measures for the prevention, reduction and control of these impacts are not enforced or implemented on time.

Potential impacts and risks may severely disturb site stratigraphic contexts and damage artifacts via direct action of construction activities, through erosion and water damage, and by rendering the sites inaccessible to archaeological research for an extended period of time while they remain flooded. Sites not yet identified by the ACP inventory could suffer similar impacts if they are located within areas of direct impact. The current best practices of cultural resources management offer a series of options to address these potential impacts and risks. In order of

preference, the measures proposed are: prevention; minimization; and mitigation of impacts. The discussion below on impacts reduction follows international guidelines for cultural resource management and may be developed in consultation with, and following the archaeological guidelines of the Republic of Panama's National Institute of Culture.

The objective of the program is to identify a specific series of prevention, reduction and control measures that may be required for each of the six water alternatives in the Río Indio watershed, and a detail is given of those measures that would be required for all of the options as well as specific measures for individual options. The measures not specifically identified as applicable to a particular option are applicable to all options.

5.4.8.1 Prevention and Control Measures during the Planning Phase

An intensive archaeological inventory should be conducted in the direct impact areas and surrounding area for the selected option. The inventory conducted to date has been sufficient to locate and describe what appears to be a representative sample of archaeological resources that lie within the areas of the six options, and the largest and most important archaeological sites have been located. It is likely, however, that there may be additional archeological sites within each zone. A detailed inventory within the zone of the selected option would allow the identification of additional archaeological sites possibly requiring investigation for the recovery and interpretation of data.

The additional inventory should also be conducted in access roads, quarry sites, yards and other temporary and permanent support facilities that should be designed and sited so as to avoid and lessen impacts. If possible, other significant sites that may be additionally identified by the detailed inventory should be avoided by introducing design and siting changes, if feasible. Significant sites that cannot be avoided through project design change should be subject to salvage work and data and artifacts recovery as described below.

The prevention, reduction and control of unavoidable archaeological impacts will be accomplished by salvage operations in significant archaeological sites (sites of moderate to high importance) that would be impacted by the selected option. The salvage works would be carried out through intensive excavation, analysis and reporting of significant sites prior to be beginning of construction. The studies should follow a research design established for each site that is tailored to recovery and preservation of the key cultural and scientific values present at each site. Resulting artifacts should be prepared for conservation in coordination with the National Institute of Culture. Only sites that are deemed significant by preliminary studies and which lie within

the direct impact should be included in the salvage effort. Public participation programs should be undertaken to share recovered information. This could include publications and museum exhibitions, school programs, and other means of public communication.

Changing project design may also limit impacts, just as in the case of highways or "cut and cover" pipelines, both of which involve substantial ground disturbing activities. The most significant potential impacts of the water alternatives (reservoir) cannot, however, be prevented by design changes. This is due to the fact that topographic requirements of water impoundments require that a reservoir be located in the areas where pre-Hispanic archaeological sites are common. The existing archaeological site inventory indicates a pattern of pre-Hispanic sites located near major watercourses, which were typically used as transportation routes just as they are today.

Certain design features of each option, other than the reservoir system itself, are more flexible in terms of possible location and may be designed to avoid known archaeological sites. These include such necessary project components as temporary construction camps, access roads, borrow pits and construction materials storage areas. If there are archaeological resources in these areas, their relocation to a less sensitive archeological site would help to prevent the total project impacts. Thus, some, but not all, of the project's impacts may be avoided.

5.4.8.2 Mitigation of Direct Impacts During the Construction Phase

During the construction phase, an archeological site conservation program should be formulated. This program, that would be defined during the EIA for the selected alternative, or during the detailed inventory described above, would provide guidelines for the range of relevant archeological issues that would include a detailed discussion of the impact mitigation, and the reduction measures indicated above. Said program should also include the following components:

- Revised inventory for the area of the selected alternative, including detailed maps;
- Specific site assessment and guidelines for data recovery;
- Operation guidelines related to specific construction, maintenance and operation procedures which may cause an impact on the archeological sites:

- Guidelines for best construction and maintenance practices so that archeological resources are not threatened; and

- Protocols for late findings, describing actions and procedures to report fortuitous archeological findings by field personnel during the construction, operation and abandonment phase of the project.

This document should be prepared with adequate technical rigor but in a language and format accessible and useful for the ACP management personnel and their contractors.

The prevention, reduction and control measures for each of the alternatives under consideration are described below:

Option 1

- Investigation and recovery at archaeological sites Pn-50 y Cp-37;

- Brief confirmation visits to the 14 low significance archaeological sites that lie within the project direct impact area; and

- Investigation and recovery in additional sites, identified through intensive inventory of the selected alternative, considered of high or moderate significance that cannot be avoided through project design.

Option 2

- Investigation and recovery at archaeological sites Pn-50 y Cp-37;

- Brief confirmation visits to the 5 low significance archaeological sites that lie within the project direct impact area; and

- Investigation and recovery in additional sites, identified through intensive inventory of the selected alternative, considered of high or moderate significance that cannot be avoided through project design.

Option 3

- Investigation and recovery at archaeological sites Pn-50 y Cp-37;

- Brief confirmation visits to the 3 low significance archaeological sites that lie within the project direct impact area; and

- Investigation and recovery in additional sites, identified through intensive inventory of the selected alternative, considered of high or moderate significance that cannot be avoided through project design.

Option 4

- Investigation and recovery at archaeological sites Pn-50 y Cp-37;

- Brief confirmation visits to the 3 low significance archaeological sites that lie within the project direct impact area; and

- Investigation and recovery in additional sites, identified through intensive inventory of the selected alternative, considered of high or moderate significance that cannot be avoided through project design.

Option 11

- Investigation and recovery at archaeological sites C-35, Cp-43, Cp-44;

- Brief confirmation visits to the 15 low significance archaeological sites that lie within the project direct impact area; and

- Investigation and recovery in additional sites, identified through intensive inventory of the selected alternative, considered of high or moderate significance that cannot be avoided through project design.

Option 12

- Investigation and recovery at archaeological sites Cp-35, Cp-43, Cp-44;

- Brief confirmation visits to the 3 low significance archaeological sites that lie within the project direct impact area; and

- Investigation and recovery in additional sites, identified through intensive inventory of the selected alternative, considered of high or moderate significance that cannot be avoided through project design.

5.4.8.3 Mitigation of Indirect Impacts During the Construction Phase

No further measures other than those indicated for direct impacts are anticipated. The development impact of the project on the archaeological sites will be partially mitigated through the investigation and recovery measures indicated for direct impacts.

5.4.8.4 Mitigation of Direct Impacts During the Operation Phase

No impact on the archaeological sites is anticipated at this stage. However, no worker should be allowed to remove any archaeological remains. Besides, if during the maintenance and rehabilitation works for roads and works any remains were found, they should be reported to Panama's Institute of Culture.

5.4.8.5 Mitigation of Indirect Impacts During the Operation Phase

The development impact of the project on the archaeological sites during the operation phase will be partially mitigated by the disclosure of the results of the archaeological information of the area.

5.4.9 Other Programs

This section will provide a list of those programs for the prevention, reduction and control of socio-environmental impacts and potential risks that should be undertaken specially during the construction phase and that all projects with this scope should have. Therefore, these programs are applicable to any of the water alternatives. Additionally, when the best option is selected, it will be necessary to clearly specify the activities and actions to be followed. It specifically refers to the following programs:

- Waste Management:
- Health and Safety:
- Environmental Training of Workers:
- Decommissioning of Facilities at the Work Fronts and Camps; and
- Relations with the Community.

There should also be a Contingency Plan including preventive measures for accidents, which will be described under section 5.6.

Table 5-9: Summary of Environmental Impacts and Potential Risks, and Prevention, Reduction and Control Measures for the Water Alternatives in the Indio River Watershed

Socio-Environmental Impacts and Potential Risks	Prevention, Reduction and Control Measures
A. Impacts on the Physical Environment 1. Geology and Seismology The geological and geotechnical features of the watershed do not have any adverse condition that cannot be prevented, reduced and controlled through appropriate conventional design and construction methods. Besides, at the dam site for options 1 and 2, no active faults are detected nor any material susceptible to liquefaction during an earthquake. -During the construction phase, the risks will be due to: ▪ Mass movements, specially collapse and slope slides: i) roads (greater risk with options 11 and 12 since the area has steeper slopes); and ii) in the other works. ▪ Tunnel construction with concrete finish to avoid water seepage and presence of hazardous gases. ▪ Inadequate disposal of waste material (larger volume with the largest option: 1, 12, 2, 11, 3 and 4, respectively). -During the operation phase, the risks will be due to: ▪ Mass movements, specially collapse and slope slides: i) roads; and ii) reservoir (greater risk where there will be greater level fluctuation: option 1, 12, 11 and the rest): ▪ Earthquake: the possibility for an earthquake affecting the project is relatively small. ▪ Water seepage through, under or around the dam: i) seepage is considered to be minimum; ii) if there were a failure, the greatest damage (downstream) would be caused by options 11 and 12 since they are in the upper watershed.	**A. Measures on Physical Environment** 1. Geology and Seismology • Performance of detailed geological and geotechnical studies of the option selected an incorporate them to the design. • Use of appropriate design and construction methods. • Maximum slopes, depending on type of rock. • Monitoring and control of seepage and hazardous gases. • Adequate disposal of waste material. • Road maintenance (adequate collection and disposal of material). • Earthquake monitoring network • Consider the incorporation of drainage to the dam foundation; instruments to detect seepage.
2. Soils The largest percentage of soils in the watershed have little agricultural and livestock vocation and capacity (classes VI and VII). -The larger the Project (reservoir) the greater the impact on the soil (1, 12, 2, 11, 3 and 4). -Development as a result of the Project may cause deforestation and more agricultural and cattle raising activities.	2. Soil Conservation • Zoning of land use; • Control of induced settlements.

Table 5-9: Summary of Environmental Impacts and Potential Risks, and Prevention, Reduction and Control Measures for the Water Alternatives in the Indio River Watershed

Socio-Environmental Impacts and Potential Risks	Prevention, Reduction and Control Measures
3. Water Resources The water resources in the watershed are of good quality, but may deteriorate during the construction if no measures are implemented to reduce and control runoff and overflow and to treat wastewater. During the operation, the water quality of the reservoir will be monitored to detect changes and risk of eutrophication, so that the necessary preventive and corrective measures are taken. A. Water level and flow, downstream from the dam: -During operation, the maximum resulting flows downstream will be significantly attenuated (around 85 to 90%; HEC-5), therefore there will be flood reduction (negative effects on terrestrial and aquatic ecosystems but less damage on assets and loss of human life). -During operation, there will be attenuation of the river bed downstream. The river bed consists of coarse material (median = 16.5 mm). The bed degradation will be insignificant (no stabilization works will be required). ▪ The flow reduction in the fluvial channel will be evidenced by the degradation of the tributaries mouths; ▪ The reduction in the sediment load transported will be evidenced with an increase of the river channel erosion; ▪ The reduction of the river capacity to transport sediments will be evidenced with the accumulation of sediments in the tributaries mouths. ▪ Navigation may be affected due to flow reduction and material deposition. B. Erosion and Sediment Transport: -During the construction, there will be deterioration of the water quality due to the sediments resulting from earthworks. -During the operation, the reservoir sedimentation will not be a problem, therefore, dredging will not be required; the reservoir capacity will be affected by no more than 1 to 2% at 50 and 100 years, respectively (1.4 mm/year; 1.04 ton/m3). C. Water quality and eutrophication risk: -During the construction, deterioration of the water quality due to contribution of sediments (erosion), wastewater and hydrocarbon spillage. -During the operation, the concentrations of dissolved oxygen will be: i) downstream from the dam sites: lower concentrations in the layers close to the bottom, specially when the reservoir is filled, affecting the ecosystems and water quality. This situation may be relieved by varying the depths of the water outlets; and ii) Gatún: the lake water quality will not be affected by the water transfer from any of the Río Indio alternatives. A variation of the intake depth will not be required. -During operation, the temperature or thermal stratiphication will be more or less stable, will be influenced by the presence of winds, specially during the dry season: Options 3 and 4 and in the dam at the Cabecera (headwaters) of the Indio river, the water will circulate with certain frequency due in part to its comparatively low mean depth. The thermocline will be between 10 to 15 meters in depth. The light penetration will reach up to 15 meters in depth. -During the operation, the eutrophication risk is low. The phosphorous and chlorophyll concentration in the water alternatives increase as follows: 12, 11, 1, 2, 3 and 4.	3. Water Resources • Monitoring of erosion and sedimentation processes and delivery of sediments to reservoir • Set up of a system of incentives and fines for those improving or deteriorating the water quality, directly or indirectly. • Set up of minimum ecological flow to maintain the current vital functions of ecosystems • Measures such as water barriers, silt fences and slope stabilization • Maintenance of structures for erosion prevention and control. Monitoring of sediments and changes in land use • Prevention and control measures for erosion, and wastewater and spills. • Arrange water outlets at different depths. Monitoring of oxygen concentration in water column. • Monitoring of temperature in all the water column. • Trees and vegetation to be flooded should be cut. Monitoring.

Table 5-9: Summary of Environmental Impacts and Potential Risks, and Prevention, Reduction and Control Measures for the Water Alternatives in the Indio River Watershed

Socio-Environmental Impacts and Potential Risks	Prevention, Reduction and Control Measures
4. Air Quality The most significant impacts on air quality are mainly related to dust emission for road construction, extraction of material from quarries, increase on vehicle traffic and areas deprived of vegetation and due to transit of trucks transporting material on the terrace roads. -During the construction more than during operation, options 1 and 2 would affect the air quality of a slightly larger number of communities, but options 11 and 12 would affect the largest number of sensitive receptors (schools, churches, health centers), more than other alternatives. -During the construction, workers will be exposed to dust and eventually other substances. -During operation, incidence of forest fires. The reservoir area will no longer be susceptible to fires (positive impact). But a better access to the area may intensify the alteration of the vegetative cover and contribute to more areas with fires.	4. Air Quality • Prevention, reduction and control measures such as watering of roads and periodical and systematic maintenance of vehicles and, of systems for noise and pollutants control. • Provide workers with equipment for protection against dust. • Program for control of induced settlements and fire prevention and control programs.
5. Noise The most significant noise impacts are mainly related to the construction activities and transit of trucks transporting material. -During the construction, rather than during operation, options 1 and 2 would affect a slightly larger number of communities, but options 11 and 12 would affect the largest number of sensitive receptors (schools, churches, health centers), more than other alternatives. -During construction, workers will be exposed to noise exceeding safety levels.	5. Noise • Control of schedule for vehicle transit and of vehicle speed, and periodic and systematic maintenance of vehicles and equipment. • Provide workers with noise protection equipment.
B. Impacts and potential risks on biological diversity 6. Terrestrial communities As a result of the existing high human intervention degree, biological diversity has a relatively low value in the Indio River watershed, the construction of any option will unavoidably result in the permanent removal of vegetation. The larger the reservoir, the larger the loss of vegetation. None of the impacts and potential risks are significant enough to prevent project execution. -During the construction phase, between 110 (option 4) and 460 hectares (option 12) of mature forest will be cut to build roads, other works and the reservoir. -During the construction phase, most species of terrestrial fauna would be negatively affected due to loss of habitat, specially in the slightly intervened forest. -During the operation stage, additional habitat would be provided for aquatic birds.	**B. Measures on biological diversity** 6. Terrestrial communities • Set up a system of payment for environmental services for the protection of biodiversity, specially of the watershed forest, specially upstream from the reservoir • Revegetate 30 meters along the streams and protect adjacent vegetation • Restrictions on workers against hunting, and plant and animal collection. • Incorporate the ROCC and specially the Indio River watershed as part of the Central American Biological Corridor.

Table 5-9: Summary of Environmental Impacts and Potential Risks, and Prevention, Reduction and Control Measures for the Water Alternatives in the Indio River Watershed

Socio-Environmental Impacts and Potential Risks	Prevention, Reduction and Control Measures
7. Aquatic Communities The experience on growth of water weeds in Panamanian reservoirs indicate they will invade any proposed reservoirs. -During construction, even by cutting most of the tree vegetation, water weeds will proliferate. -During operation, there is experience in the country in water weed control. -During reservoir operation, the fish will be subject to a new regime: from lotic to lentic. The experience in the country's reservoirs indicate that the introduction of the sergeant and tilapia fish species, generates significant fishing activity for riparian communities. - During operation, fish and macro-invertebrate have the following characteristics: ▪ 23 fish species will remain in the lacustrine area and effluents; ▪ 4 species will disappear upstream; ▪ alteration of populations will not be so drastic downstream from the dam: ▪ rapid fluctuation of the reservoir level affects the fish that use the shores to place their eggs (trunks and weeds), since they would be exposed; ▪ the 2 most significant species are associated to small rivers upstream, and will remain in the reservoir; ▪ the introduction of the sergeant and tilapia fish species will generate significant fishing activity for the communities relocated around the reservoir.	7. Aquatic Communities • Monitoring • Integrated control, if necessary. • Design of fish ladder to provide a fluvial alternative to migratory species. • Development of sports fishing and natural tourism in the reservoir • Study of fishing resources. • Train population close to reservoir in aquiculture techniques to breed fish in water tanks. • Contribute to food and economic safety of the communities through sustainable management of tilapia and sergeant.
C. Potential risks and impacts on socio-economic and cultural aspects 8. Socioeconomy: The Río Indio watershed, similarly to all the ROCC region has families and small communities living mostly in extreme poverty. -During the construction, the following potential risks and impacts will arise which are proportional to the size of each option: ▪ Between 286 (option 4) to 1,568 people (option 1) will have to be displaced; ▪ There will be an impact on community cohesion, since once displaced, it will be difficult to reconstruct it, even more when settlements are larger; ▪ There will be strong reduction of commercial activities of populations located on the river shore; ▪ There will be loss of infrastructure; ▪ There will be loss of agricultural and livestock production representing 42% of family consumption. ▪ There will be local employment and income as long as population is trained. -Given the poverty of the region and population dispersion, the direct costs for replacement of the social and economic infrastructure are relatively small. The higher costs are associated with compensation costs for displaced families and mechanisms to ameliorate impact on family and community cohesion.	**C. Socio-economic prevention, reduction and control measures** 8. Socioeconomy • Set up of a resettlement and human development plan for communities, families and people affected by the selected option(s), to compensate and remedy and specially improve existing conditions. • Assess which options comply with minimum volume and reliability requirements to ameliorate unnecessary impact on population. • Program for socio-economic improvement of the communities of concern • Prevention, reduction and control of direct displacement impact due to flooding; • Prevention, reduction and control of loss of production for self-consumption and trade; • Prevention, reduction and control due to loss of social infrastructure and social cohesion; • Prevention, reduction and control of loss of economic infrastructure.

Table 5-9: Summary of Environmental Impacts and Potential Risks, and Prevention, Reduction and Control Measures for the Water Alternatives in the Indio River Watershed

Socio-Environmental Impacts and Potential Risks	Prevention, Reduction and Control Measures
9. Cultural Resources The current archaeological inventory in the ROCC indicates there are 20 known archaeological sites with different significance. Valuable scientific and cultural information will be lost due to the flood. -The archaeological sites that would be affected have been classified as of high, moderate and low significance. Only options 1 and 2 report 1 site of high significance, options 11 and 12 report 3 sites of moderate significance, the rest of the options report only 1. The low significance sites reported are 14 for option 1, 15 for option 11 and 17 for option 12.	9. Cultural Resources Program of investigation and salvage or recovery of archaeological sites with moderate to high significance.
10. Landscape and Scenic Resources -The water alternatives in the upper Indio River watershed tend to affect less populated areas reporting resources of interest for their communities.	Develop a community program for the development of natural and adventure tourism, using landscapes and scenery goods and services

At all times, the ACP legal requirements, and international and national legislation for the conservation of the natural and cultural heritage will be applied and followed. Also international conventions to which Panama is signatory related to these aspects will also be applied and followed

5.5 Monitoring Plan

The objective of the Socio-Environmental Monitoring Plan is to document the degree in which the prevention, reduction and control and compensation measures described in the EMP attain their objectives during the design, construction and operation of the water alternatives. In order to show and document if the goals are attained, it is necessary to collect and report the key information showing how the environmental variables have behaved when the measures and investments considered are executed to assess their degree of effectiveness in the prevention, mitigation, and compensation or remediation of the socio-environmental impacts.

5.5.1 Execution

Preferably, the monitoring plan should be executed independently from the ACP and/or the Contractor, i.e., the ACP and/or Contractor should directly contract the company that shall perform the socio-environmental monitoring. The contracted environmental company will work directly with the contractor's Socio-Environmental Coordinator to provide guidelines and execute specific activities.

Among the specific functions of the company contracted for the socio-environmental monitoring are:

1. Development of a Work plan for the implementation of a Socio-Environmental Monitoring Plan. The Work Plan should establish personnel identification, their responsibilities, the field logistics, schedules, training, monitoring requirements, forms for monitoring reports and communications and mode of exchange of information with the contractor, sub-contractor and the country's regulatory agencies, especially ANAM; and

2. Follow-up the socio-environmental measures indicated in each one of the Programs included in the EMP.

The company contracted for the monitoring program shall have access to all the contractor's information on the Works and subcontractors, who should also provide the contact information with the corresponding engineering and inspection teams to ensure that all work activities comply with the EMP requirements. In order to fulfill their functions, the personnel of the company contracted for the socio-environmental monitoring, shall meet with the socio-environmental coordinator of the contractor, who shall supply the required information. The

company contracted for the socio-environmental monitoring plan will have the following responsibilities:

i) Perform periodical monitoring activities to supplement the information collected daily and weekly by the Project Socio-Environmental Coordinator;

ii) Establish overall priorities for the monitoring plan;

iii) Keep a Project data base related to permits or compliance issues;

iv) Prepare the monitoring reports;

v) Follow up compliance actions;

vi) Gather, together with the Socio-Environmental Coordinator, the field data;

vii) Prepare monthly reports of the environmental status of the area of influence of the project and EMP execution; and

viii) Inform about any lack of compliance to the Contractor within 24 hours of documentation of said failure to comply.

The responsibilities to be carried out jointly by the personnel of the company contracted for the socio-environmental monitoring with the contractor's Socio-Environmental Coordinator should cover, but should not be limited to, a follow-up of the measures for erosion prevention and control, protection of water resources, wildlife and vegetation and social aspects. Besides, due to the nature of the Project area of influence, there shall be a follow-up of environmental noise levels and measures to maintain them within tolerable ranges for the society, air quality protection measures, effects on infrastructure and services, and speed for their restoration if interrupted. There should also be a follow-up on the contractor's relations with the members of the community to prevent, reduce and control complaints due to service interruption, and when they are affected.

Among others, environmental monitors should observe and record all activities related to:

- Areas which require special stabilization and protection measures;

- Structures for erosion and sedimentation control, setup, maintenance and efficacy;
- Measures to restore altered areas;
- Geographical space where construction activities are performed and authorization for their use;
- The requirements established by the Contingency Plan and degree of compliance;
- Waste collection and disposal practices;
- Document, with photographs, the condition of sensitive areas and work spaces before, during, and after the construction;
- Document, with photographs and videos, if feasible, the construction activities;
- Identify potential problems and recommend to the contractor appropriate measures for the problems that may arise;
- Inform and train the contractor on the Project specific environmental issues and topics.
- Suggest to the contractor restrictions on the activities in areas adjacent to fragile areas, where the weather conditions (such as rainfall) may be adverse; and
- Environmental noise and air emission levels as a result of the construction. To that end, equipment specialized in the measurement, control and analysis of samples should be available or arrangements should be made with local specialists, institutions and laboratories that may perform them.

The personnel of the company contracted for the monitoring plan should use its best criteria in the field at all times to ensure that the documentation on violations, audits, and other events related to the environment are transmitted to personnel relevant to the Project. Also, it shall inform about all issues to the contractor's Socio-Environmental Coordinator.

The specialist responsible for the Socio-Environmental Monitoring should prepare monthly reports, and also, extraordinary reports in case there is an unforeseen event or when a goal established in the Work Program is attained. These results should be sent to the Project Manager

and the contractor's Socio-Environmental Coordinator within five working days after the month in which the report is made. Copies shall be sent to the ACP. This report shall include information collected in the different work fronts, with emphasis on the environmental management measures executed, attainments and difficulties encountered.

Unforeseen events, such as accidents causing spills of toxic or hazardous products or special and extraordinary programs for traffic and industrial accidents, will always require special reports to document the impact size and effectiveness of the response.

Within two months after the conclusion of the Project construction, the draft version of the *Summary Report on Socio-Environmental Monitoring During Construction* should be submitted. It shall describe the work performed by the Contractor in relation to each one of the environmental issues. This draft shall be reviewed and commented by the Contractor's personnel, and by the ACP. The final version of that document shall contain all comments made and shall be delivered one month after receipt of comments.

As evidenced by the above, the greater effort of the monitoring activities will take place during the construction phase; however, there are other actions requiring monitoring after the water alternative begins its operation (e.g., sampling of water quality).

The Socio-Environmental Monitoring Program shall include resources to perform at least two independent and autonomous environmental assessments (audits) to assess all the EMP, following the ISO 190011 criteria and requirements. The product of these environmental assessments must be open to the public, especially those involved in the EMP. Their recommendations and conclusions in legal, financial and technical matters must be compulsory enforced. Below is a description of the monitoring activities of each of the EMP components.

5.5.2 Monitoring of Resettlement and Human Development Plan

The opposition shown by some groups to the water alternatives (e.g., communities, church) clearly indicate the need to establish a reliable socio-environmental monitoring system so that the displacement, compensation and resettlement process is highly transparent, and so that it may proceed without setbacks for the construction of the water option selected. A transparent monitoring system will contribute to an environment of trust necessary to execute the water alternative selected without mishaps. The monitoring system should be designed as soon as possible and shall include:

(i). The constitution of a technical committee with 3 members that shall take into account the concerns of each of the stated actors, and that shall develop a set of performance indicators that will allow the follow-up of compliance with the agreements with the families and communities displaced. Possibly, if the Canal expansion is financed through international development banks (e.g., World Bank, IADB), these set of indications may be used as conditioning mechanism for the regular disbursement required for the project.

(ii). Preparation of baseline indicators and dates of review of the performance level. In each one of these dates, the technical committee will submit to interested stakeholders, the results of the socio-environmental monitoring.

The socio-environmental monitoring activities must start the moment a water alternative is chosen to make the necessary institutional arrangements, establish the baseline data and participate as observer of the negotiation phase with the families affected. The socio-environmental monitoring activities to be performed by the contracted organization would conclude when the construction phase is over, allowing one year of overlap to transfer their management to entities responsible for the indicators substantive aspects. For example, the responsibility for the education and health indicators would be assigned to the ministries of education and health, respectively.

The monitoring costs are: cost of a technical committee for 3 members: B/.150,000 per year for 7 years, operative costs at B/.150,000 per year, for a total of B/.2 million.

5.5.3 Monitoring of the Plan for the Recovery and Protection of Biophysical Conditions

The monitoring activities for each one of the programs described below follow the order indicated above.

5.5.3.1 Monitoring of Air Quality and Noise Level

The air quality monitoring activities shall focus on the following:

- Supervising adequate watering of the existing roads and roads to be built, as well as any work front generating dust.
- Verifying if the vehicle and equipment exhaust system is in good conditions.
- Verifying if the explosive used in blasting is of good quality and oxygen balance.
- Ensuring waste and vegetation are not incinerated.
- Ensuring adequate provision of equipment to workers (masks, etc.)

- Ensuring all rock material is watered prior to its crushing.

The noise monitoring activities will focus on:

- Ensuring all equipment and machinery have adequate mufflers and in good conditions.
- Supervising that the areas chosen for extraction and grinding of aggregate materials are located in adequate sites far from populated areas.
- Ensuring the contractor uses physical barriers to minimize noise when necessary.

5.5.3.2 Monitoring of Geological Risk

The geological and geotechnical monitoring activities may be grouped under two main categories. First, a system should be implemented to monitor slopes in critical areas susceptible to slides, both in natural slopes around the reservoir as well as in areas cut along the access roads. The second component of the monitoring program is the dam instrumentation to assess the risk of excessive seepage through the foundations and its possible impact on dam stability. The monitoring activities will make it possible to timely identify any sign of potential problems (e.g., excessive slope movement, high pore pressure on the dam foundation, etc.) so that the necessary corrective actions may be taken.

The monitoring of both slopes as well as of the dam may include piezometers used to measure pore pressure, inclinometers to assess lateral movement of slopes, and survey bench marks to monitor critical points movement. Specific details of each type, location, number, depth, etc, of the monitoring instruments should be established during the studies and final design once the critical areas that pose a potential risk are identified in the slope as well as in the dam foundation. The planning of the monitoring system for geological risk should be considered an integral part of the project design process.

The monitoring activities should start during the construction period (e.g., to monitor the foundation stability during the dam construction) and continue during the reservoir filling and during the facilities operation phase. Monitoring should be periodical with a frequency which shall depend on the project stage, e.g. during the dam filling, the dam instrumentation should be monitored weekly, or every time the reservoir water level rises 1-2 meters. During the operation phase, monitoring may be performed quarterly or more frequently during critical periods such as seasons with heavy rainfall and/or when the reservoir storage level is low.

The geotechnical monitoring plan involves the set-up of instruments before and during the construction, and its review during the conceptualization, design, construction, operation and

maintenance phases. Depending on the conditions existing in the area to be monitored and the potential risks to be assessed (to be determined during the studies and final design phases), the geotechnical instrumentation may be classified in the following groups:

- Instruments to assess groundwater levels and pore pressures (e.g., in the rockfill dam body and in talus with risk of slides).
- Instruments to measure ground movement (e.g. at the foot of potentially unstable slopes).
- Instruments to measure land pressures (e.g., at the level of the dam foundation).

Although in many cases, the use of seismic instrumentation is recommended for dams built in earthquake prone areas, in our option, the risk for seismic activity in all the ROCC, including the Indio River watershed is relatively low, and, therefore, the set up of seismographs or other instruments used to measure the structures seismic response is not justified. However, this should be finally decided by the project designer during the studies and final design phases. Most of the instruments that the geotechnical monitoring plan is anticipated to require for the water alternatives include instruments in the categories (1) and (2) described above. The specific details in relation to location, number, and type of instruments cannot be established at the moment on the basis of the information available.

The instruments used to measure ground movements range between simple survey bench marks to instruments used to measure horizontal and/or vertical movements of the ground at set points or continuously throughout its depth. URS anticipates that the instruments to measure ground movements will include survey bench marks and electronic inclinometers used to measure horizontal movement with depth. The survey bench marks are easy to install and monitor by a land surveyor. On the other hand, the pipes and casing used for the insertion of inclinometers, as well as the inclinometer itself and the electronic equipment and software used for data monitoring and interpretation, are highly specialized equipment manufactured and distributed by few companies. The set up of the pipes for inclinometers must be performed by a geotechnical company with drilling equipment and experience in the setup of those instruments.

The instruments used to measure groundwater levels and pore pressures on the ground consist mainly of piezometers. There are several types of piezometers in the market, which include small open well, pneumatic equipment and electronic equipment of several types and brands. The appropriate piezometer will depend on the place and depth at which it will be installed, type of soil, purpose of installation, etc. One of the critical factors for the selection of an adequate equipment for this project must be its durability, since the instruments selected must reliably operate for many years. Under URS' criterion, the electronic piezometers may be the most

appropriate for the conditions anticipated in the areas to be monitored. The electronic piezometer, as well as the electronic equipment used to read them, are highly specialized equipment. As with inclinometers, the piezometers should be installed by a geotechnical company with boring equipment and experience in this type of work. The reading both of piezometers and of inclinometers and the interpretation of the data obtained in combination with the surface movement data obtained by the land surveyor, must be performed by an experienced geotechnical engineer specialized in this type of techniques and their implications in the behavior of the geotechnical structures being monitored. Said personnel shall expeditiously inform any indication of any possible problem to the organization in charge of taking corrective actions, if necessary, or other actions both during the project construction as well as during its operation.

5.5.3.3 Monitoring of Erosion and Sediment Transport

This part of the program presents the requirements and specifications for the socio-environmental monitoring related to erosion and sediment transport during the Project construction. The Socio-Environmental Inspectors shall verify the preparation and implementation by the Construction Contractor of the *Program for Erosion and Sedimentation Control* in order to guarantee that erosion and subsequent transport of sediments will not affect, severely or permanently, the drainage patterns of the natural surface runoff in the Project area. The following are the general monitoring activities:

- Ensuring the contractor does not unnecessarily remove soils and vegetation.
- Ensuring the contractor adequately disposes the removed soils and vegetative material.
- Ensuring there is no accumulation in the river shores and ravines of removed soils and vegetative matter.
- Ensuring the constructor builds all drainage structures necessary to prevent, reduce and control erosion.

The specific monitoring activities for the water alternatives considered are the following:

<u>Monitoring of River Bed</u>

The Construction Contractor shall perform the final cleanup of the river bed once the construction activities are over. The river bed shall be cleaned until it is in conditions similar to the original ones. After this operation, the river bed and all other areas affected by the different construction activities will be restored and revegetated. The Inspector shall verify the restoration and revegetation works. The technical compliance of the measures to restore the soil shall be randomly verified at three points per linear kilometer of the river bed within one week of the date

planed for its conclusion. The percentage of vegetative cover shall be monthly monitored at three random sited within every linear kilometer of the river bed from the date of conclusion of each restored and/or revegetated stretch. A minimum 70% cover will be considered as adequate at the beginning of the rainy season for the works constructed during the dry season or within four weeks from the conclusion of the works performed during the rainy season. The vegetative cover monitoring will be performed until the end of the first rainy season once restoration and revegetation is concluded.

Monitoring of Concentrations of Solids in Suspension

The Socio-Environmental Monitoring Contractor shall establish a water quality baseline for the surface water bodies within the Project. This work will be performed by obtaining representative samples of each one of the water bodies.

The Socio-Environmental Monitoring Contractor shall establish a regular program for in-situ monitoring of water quality to determine its content and sediment load. This program shall include the taking of representative samples of water from the water bodies in order to monitor in-situ the sediment concentrations, and consequently the estimated sediment load in the watercourse during Project construction. The Socio-environmental Monitoring contractor shall review and verify the implementation of the *Erosion and Sedimentation Control Program* in order to guarantee that erosion and subsequent transport of sediments will not affect, severely or permanently, the drainage patterns of the natural surface runoff in the Project area.

The collection of baseline water samples will be performed by a professional with ample experience in the execution of this activity, and in compliance with an adequate Chain of Custody procedure from the moment the samples are collected until the laboratory becomes responsible for them. At least the parameters indicated below shall be analyzed for each sample by an approved laboratory:

- Total Suspended Solids
- pH
- Temperature
- Turbidity. This parameter shall measure the concentration of solids in suspension in the water body using a portable turbidity meter (Lamotti Turbidity Meter Model No. 2020 or equivalent).

5.5.3.4 Monitoring of Water Quality

The water quality monitoring activities will involve the following:

- Ensuring that in the work fronts and camp no solid or liquid waste is discharged in rivers, ravines, and sloped areas where there may be water runoff.
- Ensuring waste material is deposited in adequate places.
- Ensuring containment structures are built in sites used for refueling.
- Ensuring the population in the area of direct influence decrease the pollutant loads, and to that end that the necessary training is provided.

From the beginning of the reservoir construction, a water quality sampling campaign should be implemented for the tributaries and downstream of the dam site. Monitoring sites should be established in a way that would also enable flow measurement. The objective of this program is to know the behavior of the reservoir water quality so that the necessary corrective measures are timely taken and problems that may hinder the operation may be prevented.

The objective of the monitoring activities are:

- To verify the effectiveness and efficiency of the activities and actions involved in the EMP components, which among its purposes involve the improvement of the reservoir water quality and maintenance of its regime, i.e., to obtain information on the concentration and load trends for the reservoir:
- To provide relevant information for the reservoir operation; and
- To assess the water quality of the reservoir and its tributaries through periodic sampling to determine compliance with the standards established according to its uses. These standards will probably be developed in the future.

<u>Sampling Stations</u>

The objective of the station network is to transfer the monitoring objectives into a guideline, which may indicate where, what, and when to make measurements. The network design implies locating the stations, the sampling frequency and selection of physical, chemical, biochemical, bacteriological and biological parameters. In order to obtain the necessary information, the following types of monitoring stations are required:

- **Baseline Stations**: The data and information on water quality of tributaries of the water alternatives so as to have baseline information to characterize them. The monitoring program shall enable the determination of the baseline data. The water quality of the tributaries of the reservoir and from the reservoir should be monitored where there is little

effect from point and non-point contamination sources, and to provide information on the natural or almost natural conditions, their effects and trends.

- **Impact Station**: Also, the water quality and pollutants transport shall be monitored. These stations will be located downstream from the current and future sources of pollutants.
- **Source Monitoring Stations**: Their purpose is to monitor the water quality of the reservoir and to estimate the pollutants load. These stations must be located in the main point sources and in sub-basins receiving the influence mainly of non-point sources.

Additionally, a requirement to select the location of the stations is for them to be close or in the site where there is a hydrometric station or where the flows could be easily computed. This is due to the fact that the interpretation of the water quality is not possible unless there are hydrometric data; all field and sampling information must be associated to hydrological measurements. Other requirements for the selection of stations include accessibility, ease of sampling, operator safety and time to take the samples to the laboratory.

The monitoring frequency must reflect the variability, as well as size; large sources should be monitored more frequently than small sources. If it is not possible to measure some point sources, they may be calculated with information existing on similar sources and in the case of non-point sources, an export coefficient must be used.

The stations must be monitored once a month, during the year. During the rainy season, the field reports must indicate if it has rained prior to the sampling and how much. Once the year is over, a statistical analysis of the data will be performed to determine the frequency, as well as the parameters and sites.

Methodology

Once the objectives have been established, it is necessary to identify the information necessary to achieve it. In the diagnosis of the water quality to be performed, as part of the Study, the main priority problems shall be identified, therefore, it is necessary to indicate appropriate parameters to determine changes in the sources causing the deterioration. Then a sampling network should be established to assess spatial distribution and temporal trends.

The monitoring aspects to be specified are: a) physical, chemical, biochemical, bacteriological and biological parameters; and ii) sampling frequency. The loop is closed with the management and control actions by the decision makers. Monitoring must begin by identifying the specific data and information needs.

Information Organization and Flow

The objective of the information system is to provide information on the water quality and contamination load. The main type of data to be processed by an information system are: i) on the reservoir itself (area, volume, water residence time, mean depth, water quality); ii) sources of contamination of the reservoir (solid and liquid waste from the population, soil, and agrochemicals from agricultural and livestock activities, eroded soil from roads); and iii) physical environment (geology, climate and hydrology of the microbasins and sub-basins).

The different activities are organized at three levels: the first tier is responsible for generating data through monitoring, as well as validating and storing them. It is necessary to control the data quality since the information generated at this level will influence the results. The second tier corresponds to information management, through computers. The computers convert the data in information, i.e., use the data and produce the required information. The tools are plotters, statistical packages and prediction models. The third tier is made up of users and decision-makers. At this level, the information is used to verify and correct management policies and procedures. However, this level is responsible for conveying the information to the public and interested sectors, therefore, they must have the tools to integrate the information on water quality with that of other sectors.

Data Collection and Management

Data collection refers to the generation and storage of monitoring data. The data must be stored to ensure its precision and allow easy access for handling them. A computer, with electronic worksheets, statistical packages and plotter is adequate and easy to operate. To manage large volumes of data, a data base system provides better management capacity.

Data management requires statistical packages, models and plotters to analyze and interpret data. The data analysis presented in graphic form is probably the most convenient way to do it. The graph analysis is easy to make, the graphs are easy to construct, and the value of the information is high when the graphs are adequately presented.

The statistical analysis is the most frequent data handling tool for making decisions on the basis of quantitative information, for example, if the water quality has improved or worsened with time, or whether there is compliance of the water quality standards. The statistics help to summarize the water quality data in a simple form, typically understood as mean and variation coefficient. Statistical methods, such as variance analysis, have been applied to the data of the reservoir in the Study, and are very useful. These statistical methods exist as statistical packages for computers (SAS and SPSS).

The water quality models may be valuable tools since they may simulate the potential reservoir response to changes, such as increase or decrease of nutrients or pollutants. In the case of the water options under study, where measures for the sustainable development of environmental assets or renewable natural resources will be implemented, it is a valuable tool to monitor the upgrade of the water quality in the reservoir. In the case of the reservoir tributaries, the water quality indexes or classes may be used.

The data used for pollution control, such as water quality, flows, sources of contamination, land use, application of fertilizers, geology, is measured in different units and different spatial and temporal scales; a Geographical Information System such as that existing at the ACP, is a valuable tool to present, analyze and interpret data. For example, it may provide information on: i) location, spatial distribution and area affected by point and non-point sources; ii) correlations between land use and topography with environmental variables such as runoff and sub-basin size, and iii) presentation of modeling and monitoring results at a cartographic scale.

Use and Disclosure of Information

The preparation of reports and disclosure of information is another significant aspect of the information system. The reports must respond to the users needs, at the desired frequency, with the required detail level; etc. The reports present the results of routine analysis of data collected for the monitoring program and present the development of water quality and pollutants load carried forward from the previous period, and must be prepared in the same format. Some reports present the information using GIS.

Parameters

The following table indicates the sampling parameters and frequency, depending on the monitoring level. It should start at an intermediate level.

Table 5-10
Water Quality Parameters

Level	Frequency per Year	Biophysical Parameters in Water	Biophysical Parameters in Sediments	Biological Parameters	Required Resources
Simple	6	T, pH, O_2, TSS, ions, transparency			Small sampling group and general chemical laboratory
Intermediate	6-12	Besides, Total Phosphorous, Total Nitrogen, PO_4, NH_4, NO_2, H_2S	Total Phosphorous, Total Nitrogen, Organic Matter	Chlorophyll "a" count and algae identification	Specialized chemical laboratory and specialists group
Advance	>12	Besides, pesticides, metals, colliforms	Besides, metals	Besides primary productivity	Central Laboratory and Research Institute

Source: Taken from the proposal for Bayano (2000)

The physical, chemical, and biological parameters to be determined at the sampling sites are indicated below.

i. **Physical:** In-situ, temperature, dissolved oxygen, conductivity, pH and redox potential should be measured with a portable equipment, such as hydrolab. In the rivers, the water samples must be superficial and in the reservoir they must be taken every meter until the bottom is reached. Also, in the reservoir, transparency shall be measured with a Secchi disk. The objective on determining these parameters in the reservoir is to identify thermal stratification, oxygen distribution, light penetration, the influence of tributaries and eutrophication status.

ii. **Chemical:** The emphasis must be on nutrients: Total phosphorous and orthophosphates, total nitrogen, ammonium, nitrate, and nitrite. In the rivers, samples must be taken on the surface and in the reservoir every meter until the bottom is reached, through a Van Dorn bottle or similar device. These data allow the determination of the eutrophication degree. At the dam site, the concentration of hydrogen sulfide should also be determined. The water samples must be transported on the same day to the laboratory.

iii. **Biological:** "A" chlorophyll count and algae identification must be measured in the reservoir stations; there should also be additional sampling when there is a special conditions evidencing a greater eutrophication degree, for example, when there is algae proliferation or fish mortality.

iv. **Pesticides:** Although the volume of pesticides currently used in the Indio River watershed is comparatively low, it is necessary to determine their concentration before implementing the management plan components. The pesticides used in the watershed may be determined in the rivers, when it has rained heavily on the days prior to the sampling. Attention should be paid to organochlorinated pesticides, relatively insoluble in water, but that are absorbed by the organic matter, and easily transported by the runoff and rivers. Some pesticides, like Dieldrin, remain active for several years.

v. **Sediments:** The concentration of phosphorous, nitrogen and organic matter in the reservoir sediments is information valuable to determine the availability of these nutrients and their contribution to the water-sediments interface in anoxic conditions. Eckman dredges or similar dredges should be used for the sample taking.

5.5.3.5 Monitoring of Terrestrial Biodiversity

The monitoring methods used to determine performance of the prevention, reduction and control measures shall be standardized, transparent, and focused on the decisions. The monitoring program shall include the specific criteria that provide the basis to determine and improve the quality of the conditions as a result of the execution of the prevention, reduction and control

measures. The decision criteria shall include general ecological considerations and specific requirements in relation to habitat protection, conservation of biodiversity and protection of significant species (for example, rare, threatened or endangered). Every monitoring action shall produce data that may be used to decide on:

- Satisfactory environmental health conditions or conditions that have changed the way they affect the prevention, reduction and control areas due to external influences (for example: floods and fires); and
- Environmental health conditions that have changed or not followed the anticipated modifications. In this case, adjustments or structural changes to the proposed measures may be required.

The use of criteria based on decisions for the monitored data ensure an appropriate and timely action. The use of reference sites will be created within the watersheds affected to provide a basis for the assessment of the prevention, reduction, and control measures and their restoration.

Specific measures to prevent impacts shall be incorporated in the construction plans and shall be executed by those in charge and responsible contractors. A monthly review will be performed during the construction by a qualified ecologist to determine conformity with the prevention, reduction and control measures and their capacity to reduce or avoid negative impacts.

Conformity with the prevention, reduction and control measures, and preventive measures

The measures proposed to mitigate unavoidable impacts during the construction phase will provide specific criteria in relation to the size, location and type of action to be taken. They shall be incorporated into a regular monitoring program and in the monthly and semester reports. The post-construction monitoring of these efforts will be performed by an ecologist familiarized with regional ecosystems. The success of the prevention, reduction and control measures will be based on specific criteria and goals within a decision making framework.

The field monitoring methods shall include observations focused on documenting the presence of species, their occurrence and population conditions, apart from the standard methods to document vegetative cover, diversity and structure of the ecosystem. The transects methods (lines and strips), measurement of height of upper cover, and quadrant methods are included for the diversity of minor species. The methods will vary, depending on the habitat. The equipment required shall include plant presses, binoculars, metric tapes, inclinometers, hand-held GPS and quadrants. The main monitoring activities shall include, among others:

- Ensuring that the cut and clear activities are within the established limits.
- Ensuring the disposal of stumps and bushes in adequate sites.
- Supervising that the wood cut is used specifically for the agreed uses.
- Ensuring that the revegetation and forest conservation management methodological processes are performed as set forth in the Program.
- Ensuring the application of the maintenance measures suggested for the success of the reforestation.
- Verifying the survival levels of planted trees. These activities shall be performed every quarter during the first year, and every six months from the second to the fifth year, and annually between the fifth and tenth year.
- Analyzing aerial photographs or satellite images to estimate vegetative cover in the areas under study, and also performing a large scale follow-up of plant succession.

During the first year, the replanting of trees shall be necessary in areas where mortality exceeds 15% of planted trees. The activities for the conservation of the tree cover must be coordinated with other programs of the plan, for example:

- The vegetation is closely related to the erosion potential.
- The recovery of forest areas will have positive effects on the wild life and fauna distribution.
- The selection of areas for reforestation must take into account the possibility of displacement of human settlements and potential effects on agricultural and cattle raising activities.

Monitoring of Environmental Conditions

The environmental condition must be monitored in areas directly or indirectly affected by the development of the selected option and in areas where the prevention, reduction, and control measures were executed. Monitoring will be performed every quarter during the construction phase and the first year of operation. If no significant problem is found, monitoring will then take place every two years, during the rainy season and the dry season. Monitoring of compliance and efficacy of prevention, reduction and control will be performed by a qualified ecologist familiarized with the habitat and region conditions.

The environmental health will be established by the condition of the values identified for each ecosystem. At the biological community level, the plant and animal biodiversity, the transport and recycling processes (for example, decomposition, primary productivity), and the patterns of organization will be assessed under the criteria specified. Monitoring will assess the existing

conditions and trends as a means to determine the efficacy of the recommended prevention, reduction and control measures. The deviation from that expected will be observed and, it will be decided if more data are necessary, if any influence foreign to the project has created a change, or if the prevention, reduction and control plan needs changes to adequately mitigate the socio-environmental impacts and project risks.

5.5.3.6 Monitoring of Aquatic Plants

The management plan during the operation must include monitoring and control activities of aquatic plants. The cutting of the vegetation of the reservoir must be verified so that it timely takes place. By observing the negative experiences in other parts of the world and in Panama, like Lake Bayano and Gatún, it is necessary to create an integrated management and control plan for the aquatic weeds of these reservoirs.

A monitoring program is recommended and if an exagerated growth is detected, an erradication program should be developed for every aquatic weed representing a potential hazard for the new reservoirs. Mainly, it is important to avoid the entry of foreign weeds, such as *Pistia stratiotes, Eichornia crassipes* and *Hydrilla verticillata,* to these areas since they may be transported by boats, people or animals from the canal reservoirs or other points downstream, where they are abundant.

During the initial reservoir stabilization phase and during the project life, the areas covered by potentially invasive aquatic plants should be established. Specifically, at the beginning this determination should be performed monthly to accurately determine the risk of significant impact. Then, the determination must be performed at the end of the dry and rainy seasons.

The monitoring activities for aquatic plants must be coordinated with those performed for water quality sampling and for fish and macro-invertebrates.

5.5.3.7 Monitoring of Macro-Invertebrate and Fish Population

Although several reservoirs have been constructed in Panama since the beginning of last century, little is known about their impact on the aquatic fauna that existed prior to the impoundment of rivers. The most outstanding post-impoundment assessments are those performed in Bayano, Fortuna and Alhajuela, which served to predict the impacts and potential risks on the aquatic fauna for the water options considered. However, those assessments lack some significant data, and do not provide a completely clear idea of what actually happens at the moment the reservoir

is created. That is why this study will serve as a framework or reference to better understand these changes and find, if possible, alternatives to prevent, reduce and control the negative effect on the aquatic fauna, at the time of the construction of future reservoirs as part of the Canal Modernization Program.

The monitoring objective of this component is to assess the effect of the reservoir construction on the indigenous fish fauna and macro-invertebrates present in the continental water bodies, during and after the impoundment. Once the results are obtained, strategies for the conservation of indigenous species in these reservoirs will be formulated.

This monitoring will take 12 months and the behavior of the indigenous fish populations present in the new reservoirs and tributaries as well as downstream from the dam site will be studied, during the stage prior and subsequent to the filling. The monitoring of existing species will be performed using different fishing techniques, such as electrofishing, drag nets, experimental tangle nets, in some areas which will be randomly selected, with emphasis on those tributaries located in the lower, mid and upper sector of the future reservoir.

With the help of the drag nets, electrofishing and experimental tangle nets, biological samples of the species existing in these zones will be taken to determine their reproduction, population, and feeding behavior, during the creation of these new ecosystems. Simultaneously, during the study, notes will be taken of the most relevant environmental characteristics. With these field data, quarterly reports will be drafted to inform about the evolution of native species under the new environmental conditions.

Simultaneously to the capture of fish and macro-invertebrates, some environmental parameters shall be measured, for example, water temperature, oxygen concentration, description of the area, etc. All specimens caught will be preserved with a 5% formalin solution in the field, and stored in plastic bags labeled with the corresponding field label for laboratory analysis. In the laboratory, their taxonomic category will be determined. With the fish caught, their relative abundance, composition and structure of species, weight, size, growth data, stomach content, and other biological parameters will be determined.
Then, all the information obtained during this time will be compared to the information generated by the baseline studies of each area, and thus the changes that have occurred will be determined.

The results will be monitored through the submittal of bimonthly reports, and upon the project conclusion, the final report will be presented. This study will generate the necessary basic

information to know and understand the changes in the native species at the time of creation of tropical reservoirs. This will be for the benefit of state institutions such as the ANAM and ACP.

The macro-invertebrate and fish monitoring activities must be coordinated with those performed in the sampling and analysis of water quality and aquatic plants.

5.5.4 Monitoring of Archaeological Sites

The activities for the archaeological monitoring during the construction phase will be led by a professional in archaeology. Protocols will be established in relation to appropriate response to different types of late findings. The solutions may include short periods during which work is stopped to perform quick assessments and potential quick salvage excavations. The ACP contractors for the archaeological part shall consult appropriate representatives of the Institute of Culture in relation to the way the late archeological findings will be arranged. At all times, national and international legislation and international conventions on this matter shall be applied and followed for the conservation of the cultural-archaeological heritage.

5.5.5 Socio-environmental Monitoring of Other Programs

The activities for the monitoring of the programs for health and safety, environmental training of workers and relations with the communities are described below:

A. Health and Safety

- Ensuring compliance of health programs.
- Inspecting the execution of environmental sanitation programs and programs for disposal of waste and organic waste.
- Monitoring the health conditions existing in the project facilities.
- Verifying the quality of water for human consumption.

B. Socio-Environmental Training of Workers

- Recording the workers' behavior and attitude at the works in relation to the environment.
- Establishing training programs to improve productivity and achieve attitude and behavior changes that may benefit the EMP.

- Establishing the means of communication between workers and the population to prevent and reduce social conflicts through training guided towards mutual respect and solidarity.

C. Relationship with the Community

- Recording, through exchange of information with the members of the community, their concern in relation to their participation in the Project development as well as the degree of compliance of the Contractor's obligations.
- Ensuring communication with the communities through signs, notices, leaflets and/or radio announcements.
- Ensuring the contractor employs sufficient qualified and trained personnel, preferably among the population in the project area.

SOCIO-ENVIRONMENTAL MONITORING PLAN
Water Options in the Indio River Watershed

PROGRAMS	ACTIONS TO BE MONITORED	FREQUENCY				
		D	S	Q	M	RU
Resettlement and Human Development	• Verifying the compensation and resettlement process.				x	
Air Quality	• Supervising adequate watering of the existing roads and roads to be built, as well as any work front generating dust.	x				
	• Verifying if the vehicle and equipment exhaust system is in good conditions.		x			
	• Verifying if the explosive used in blasting is of good quality and balanced with oxygen.					
	• Ensuring waste and vegetation is not incinerated.		x			
	• Ensuring adequate provision of equipment to workers (masks, etc.)					x
	• Ensuring all rock material is watered prior to its crushing.	x	x			
Noise	• Ensuring all equipment and machinery have adequate mufflers and that are in good conditions.					
	• Supervising that the areas chosen for extraction and grinding of aggregate materials are located in adequate sites far from populated areas.		x			x
	• Ensuring the contractor uses physical barriers to minimize noise when necessary.					x
Geological Risk	• Verifying the stability of slopes around the reservoirs and roads.		x			
	• Overseeing any risk of excessive seepage at the dam base.		x			
Erosion and Sedimentation	• Ensuring the contractor does not unnecessarily remove soils and vegetation.					
	• Ensuring the contractor adequately disposes the removed soils and vegetative material.			x		

SOCIO-ENVIRONMENTAL MONITORING PLAN
Water Options in the Indio River Watershed

PROGRAMS	ACTIONS TO BE MONITORED	FREQUENCY				
		D	S	Q	M	RU
	• Ensuring there is no accumulation in the river shores and ravines of removed soils and vegetative matter.		x			
	• Ensuring the contractor builds all drainage structures necessary to prevent, reduce and control erosion.			x		
	• Verifying the vegetative cover in the river channel.					
	• Verifying that the river channel is cleaned until left in conditions similar to the original ones.			x	x	x
Water Quality	• Ensuring that in the work fronts and camp no solid or liquid waste is discharged in rivers, ravines, and sloped areas where there may be water runoff.					
	• Ensuring waste material is deposited in adequate places.					
	• Ensuring containment barriers are built in sites used for refueling.		x			
	• Performing physical, chemical and bacteriological analysis of water (dissolved solids, solids in suspension, and total solids, COD, BOD, dissolved oxygen, temperature, turbidity, conductivity, pH, greases and oils) and flow rate determination .			x	x	x
Terrestrial Biodiversity	• Ensuring that the cut and clear activities are within the established limits.		x			
	• Ensuring the disposal of stumps and bushes in adequate sites.		x			
	• Supervising that the wood cut is used specifically for the agreed uses.		x			
	• Ensuring the application of the maintenance measures suggested for the success of the reforestation.		x			
	• Ensuring that the recommended compensation measure is implemented, following the same methodology for revegetation proposed in the Program.					x
	• Verifying that all areas affected are restored and revegetated.			x		
	• Analyzing aerial photographs or satellite images to estimate vegetative cover.		x			x
	• Ensuring that the habitat of significance for the fauna is maintained, and ensure the restoration of the lost habitat (revegetation) is fulfilled.		x			x
	• Supervising that no hunting of wild animals by workers takes place.					
Aquatic Plants	• Verifying the vegetation is timely cut in the floodable area.					
	• Verifying the quantity of aquatic plants.					x
Fish and Macro-invertebrates	• Verifying the effect of the dam construction and filling on fish and macro-invertebrates.				x	
Archaeological Sites	• Verifying the investigation and recovery activities.				x	
Other Programs:	**A. Health and Safety** • Ensuring compliance of health programs.					

SOCIO-ENVIRONMENTAL MONITORING PLAN
Water Options in the Indio River Watershed

PROGRAMS	ACTIONS TO BE MONITORED	FREQUENCY				
		D	S	Q	M	RU
	• Inspecting the execution of environmental sanitation programs and programs for disposal of waste and organic waste.		x		x	
	• Monitoring the health conditions existing in the project facilities.	x				
	• Verifying the quality of water for human consumption.				x	
	B. Environmental Training of Workers					
	• Recording the workers' behavior and attitude at the works in relation to the environment.			x		
	C. Relationship with the Community					
	• Recording, through exchange of information with the members of the community, their concern in relation to their participation in the Project development as well as the degree of compliance of the Contractor's obligations.		x	x		
	• Ensuring communication with the communities through signs, notices, leaflets and/or radio announcements.					
	• Ensuring the contractor employs sufficient qualified and trained personnel, preferably among the population in the project area.			x		

Notes: D = Daily; S = Weekly; Q = Fortnightly; M = Monthly; RU = Single Review.

5.6 Verification and Control Program

The main objective of the Socio-Environmental Verification and Control Program is to ensure that the actions identified in the EMP for the prevention, reduction, mitigation and compensation or remediation of socio-environmental impacts are actually and timely implemented, and to verify and control the application of all the ACP legal requirements as well as the requirements and obligations derived from the applicable national and international legislation on the conservation of the cultural and natural heritage and the international conventions signed by Panama and related to the EMP of the water options involved. This is a task, which by definition involves the country's public agencies; legal requirement under the provisions of the General Environmental Law (Law 419 and Decree No. 59 dated March 2000 (Art. 25). However, since the ROCC is under the jurisdiction of the ACP, it is subject to specific legislation.

On the other hand, it should be pointed out that on March 15, 2000, the Inter-Institutional Committee of the Canal Watershed (*Comisión Interinstitucional de la cuenca hidrográfica del Canal* or CICH) was created under the ACP Charter (Law 19, dated June 11, 1997, articles 6, 120 and 121). The CICH's main objective is to integrate the efforts, initiatives and resources of government agencies and NGO's for the conservation and management of the canal watershed and the promotion of sustainable development for the benefit of the communities therein established and of the country. The main duties of this organization is to establish the

coordination mechanisms necessary to ensure that the canal watershed capacity is not exceeded, as well as to provide a coordination forum for a long-term orderly and sustainable development for the population settled in these areas. Therefore, the CICH is responsible for guaranteeing that the water resources of the watershed are protected, and to that end, it will develop adequate programs to oversee and preserve the watershed resources, through the integration and involvement of the residents in the area as well as the applicable authorities. Any program must be coordinate with the ACP who has the hydric resource responsibility.

The CICH is integrated by representatives of the Ministry of the Interior and Justice, Ministry of Housing, Ministry of Agricultural and Livestock Development, National Environmental Authority, the Inter-Oceanic Region Authority and Caritas Arquidiocesana, Natura Foundation and the Panama Canal Authority, that presides this committee. The objective of ANAM is to verify that the socio-environmental prevention, reduction and control measures proposed in the environmental impact assessments (EIA) are adequately and timely implemented in the conceptualization, design, construction, operation and maintenance phase of the projects. Therefore, ANAM will be the agency within the CICH that will have a significant role in the EMP verification and control.

Taking into account the prior paragraphs, a recommendation is made so that the ANAM is the authority in charge of the Program for the Verification and Control of the Environmental Management Plan for the selected water option. It should be pointed out that one of the most significant follow-up tasks will be performed by the socio-environmental monitoring contractor to be retained by the ACP. For the purposes of this program, the socio-environmental monitoring firm to be retained is the one considered to be in charge of following up on the issues contained in the EMP, and the one acting on behalf of the ACP. The organization necessary to execute the EMP for the water alternatives under study is presented below. The indicated reports are the ones considered necessary to facilitate the verification and control by ANAM.

5.6.1 Regular Reports

The **Socio-environmental Monitoring Contractor** shall prepare two types of socio-environmental monitoring reports: Daily Reports and Weekly Reports. Copies of these reports, both in hard copy as well as electronic copy, will be maintained in the project files of the Socio-Environmental Monitoring Contractor central office as well as in the work front offices.

Daily Reports

Every Socio-Environmental **Inspector** shall be responsible for a Daily Report at the end of each working day, which shall mainly include the following information:

- General information on the Project (parties responsible for environmental issues, names of Socio-Environmental Inspectors, sites where work is being carried out, etc.)
- A summary of the most significant events during the socio-environmental monitoring activities of a given day.
- Steps for the resolution of the environmental deficiencies pending to that date, which were recorded in prior daily reports.
- List of the socio-environmental deficiencies observed during the inspection of a given day. The list must be presented in order of priority, placing first high priority items (e.g., lack of compliance of regulations) and those with less priority towards the end (remarks/ warning, etc.)
- Notes or remarks about the socio-environmental monitoring on that day in particular.

As part of the daily monitoring activities, the Socio-environmental Inspectors shall also be responsible for taking digital photographs to document environmental practices of the Construction Contractor and its subcontractors during the construction works. The basic purpose of these photographs is to provide additional support to the remarks made in the daily report. Copies of these reports, in hard copy, will be submitted daily to the Construction Contractor.

Weekly Reports

The Environmental **Supervisor** of the Socio-Environmental Monitoring Contractor shall be responsible for the preparation of a Weekly Report once the work week is over, which shall mainly include the following information:

- A summary of state of environmental compliance of the construction activities during the period covered by the report.
- Description of progress made in the resolution of the main environmental issues pending to that date.
- List of most significant environmental deficiencies identified during the period covered by the report, and suggestions and recommendations for their prevention and/or solution.
- Description of progress of the prevention, reduction and control measures proposed in each one of the EMP programs, during the construction.
- Results of significant meetings, discussions or communications between the Socio-Environmental Monitoring Contractor personnel and other project personnel, representatives of the ACP.

- Selected digital photographs to illustrate the information presented in that report.

Copies of these reports, in hard and electronic copy, will be distributed weekly to the ACP, to the Construction Contractor and its subcontractors. At the same time, the ACP shall provide copies of these reports to the CICH. To facilitate quick and efficient communication among the parties. The weekly report shall be delivered, one day before the weekly meeting on the construction progress, at the latest.

Weekly Meetings

The Socio-Environmental Inspectors shall participate in the weekly meetings on the construction progress and on social and environmental issues of the Construction Contractor and its subcontractors to be held at the work camps. In each one of these weekly meetings, a progress report related to environmental issues pending to that date, the most significant deficiencies identified during the period covered by the meeting, and suggestions and recommendations for their prevention and/or solution, among others, will be presented.

5.6.2 Required Personnel

The ACP shall be responsible for ensuring to the local authorities and the ANAM the adequate execution of the project. As such, it shall appoint an **Environmental Management Plan Coordinator** responsible for verifying the execution of the construction activities related to the project in compliance with the applicable local regulations and the requirements and guidelines of the Plan as well as for the supervision of the environmental inspection performance during the construction. Additionally, the ACP will retain the services of a company to implement the Socio-Environmental Monitoring Program described above, during the project construction. This company referred to as **Socio-Environmental Monitoring Contractor** shall be duly qualified and authorized to operate in Panama and with ample experience in the execution of similar projects.

A Socio-Environmental Inspector will be permanently appointed to each one of the work fronts, and their base shall be the work camps. The Socio-Environmental Monitoring Contractor shall have sufficient substitute inspectors to ensure the permanent presence of an inspector in each work front during the construction activities. Each Socio-Environmental Inspector shall be responsible for the socio-environmental monitoring of the construction activities carried out by the Construction Contractor and its subcontractors in all work areas (river beds, camps, storage areas, borrow sources, access roads, etc.) within each corresponding front, so as to guarantee the

prevention, control, and reduction of potential socio-environmental impacts and strict compliance of the Plan requirements and conditions.

The Socio-Environmental Inspectors may request the temporary suspension of the construction activities at any moment they deem it necessary due to any of the following causes:

- Failure of the Construction Contractor or its subcontractors to comply with the Plan requirements and conditions, or with applicable local regulations and laws.
- Presence of adverse socio-environmental impacts, which require the immediate implementation of a corrective measure or action.
- Presence of potentially hazardous or unsafe situations or conditions.
- Lack of compliance of the ACP legal requirements, or of the obligations derived from applicable national or international legislation for the conservation of the natural and cultural heritage or of international conventions signed by Panama and related to the EMP of the selected water option.

When a Socio-Environmental Inspector requests the temporary suspension of the construction activities due to any of these reasons, immediate notice shall be given to the Plan Coordinator and Environmental Manager of the Construction Contractor.

Plan Coordinator

The specific responsibilities of the Plan Coordinator shall be as follows:

- Ensure compliance of the environmental requirements established in the plans and procedures and licensing and permitting conditions imposed to the project by Panamanian regulatory agencies.
- Verify that the environmental agreements, the prevention, reduction and control programs and the Plan are adequately implemented and monitored.
- Supervise the activities of the Socio-Environmental Monitoring Contractor responsible for monitoring and supervising Plan compliance.
- Establish the main inspection priorities; prepare and update the data base on compliance/lack of compliance of the Plan requirements and regulatory requirements; periodic follow-up of issues in lack of compliance.
- Review the reports prepared by the Socio-Environmental Monitoring contractor.
- Prepare and present compliance reports to the applicable regulatory agencies.
- Periodically inspect the construction areas to verify compliance of the Plan requirements.

- Coordinate with the Environmental Supervisor and Socio-Environmental Inspectors of the Socio-Environmental Monitoring Contractor and Environmental Manager of the Construction Contractor, as deemed necessary, to promote and ensure environmental compliance.
- Remain in the project once the construction activities are over, until the environmental provisions of the phase prior to the operation are implemented.
- Deliver to the Socio-Environmental Monitoring Contractor copies of all documents related to the construction and documents/correspondence of the license issued by the applicable environmental authority for the project construction.

Environmental Supervisor

The responsibilities of the Environmental Supervisor of the Socio-Environmental Monitoring Contractor shall be as follows:

- Report to the ACP all technical aspects related to the work executed by the Socio-Environmental Monitoring Contractor.
- Review specific environmental plans and documents that must be prepared by the Construction Contractor.
- Supervise compliance of the technical environmental specifications established in the Plan, which shall cover the procedures for the construction, setup and operation of camps, Code of Conduct for the project, quality of the environmental work by the Construction Contractor and its subcontractors, etc.
- Supervise the Socio-Environmental Inspectors activities during the construction.
- Coordinate with the Socio-Environmental Inspectors the submittal of the status of environmental and social compliance in the weekly meetings on progress of the construction. The presentation shall include: progress in the resolution of environmental aspects pending to that date, most significant deficiencies identified during the period covered by the meeting, and suggestions and recommendations for their prevention and/or solution, etc.
- Assist the ACP in the preparation of responses to concerns or observations made by applicable regulatory agencies.
- Review the Daily Socio-Environmental Monitoring Reports of the Socio-Environmental Inspectors to be delivered to the ACP and the Construction Contractor.
- Prepare Weekly Socio-Environmental Monitoring Reports to be delivered to the ACP and the Construction Contractor.

Socio-Environmental Inspectors

The Socio-Environmental Inspectors shall verify compliance by the Construction Contractor and its subcontractors of the following aspects in all work areas:

- Setup, periodic maintenance and repair of the necessary prevention, reduction and control measures described in the EMP program.
- Execution of the construction activities within the working areas authorized, in particular in the watercourse, and that only the previously approved access roads are used.
- Protection of the surface drainage systems during the construction.
- Restriction of construction activities in agricultural or livestock areas or wetlands, when the weather conditions make it advisable.
- Use of imported soils as backfill and/or additional cover material in sensitive areas (such as agricultural or residential areas, and wetlands).
- Implementation of restoration and revegetation activities of the areas affected by the construction, in particular watercourses, crossings of water bodies and wetlands, agricultural and residential areas, borrow areas, areas with steep slopes, camp and storage areas, etc.

The Socio-Environmental Inspectors shall also assess the success of the restoration and revegetation measures and those for the stabilization of the river channel and of the work areas affected by the construction activities. Any deficiency in the establishment of the temporary vegetative cover will be reported to the Construction Contractor who will be obliged to effectively repair the work.

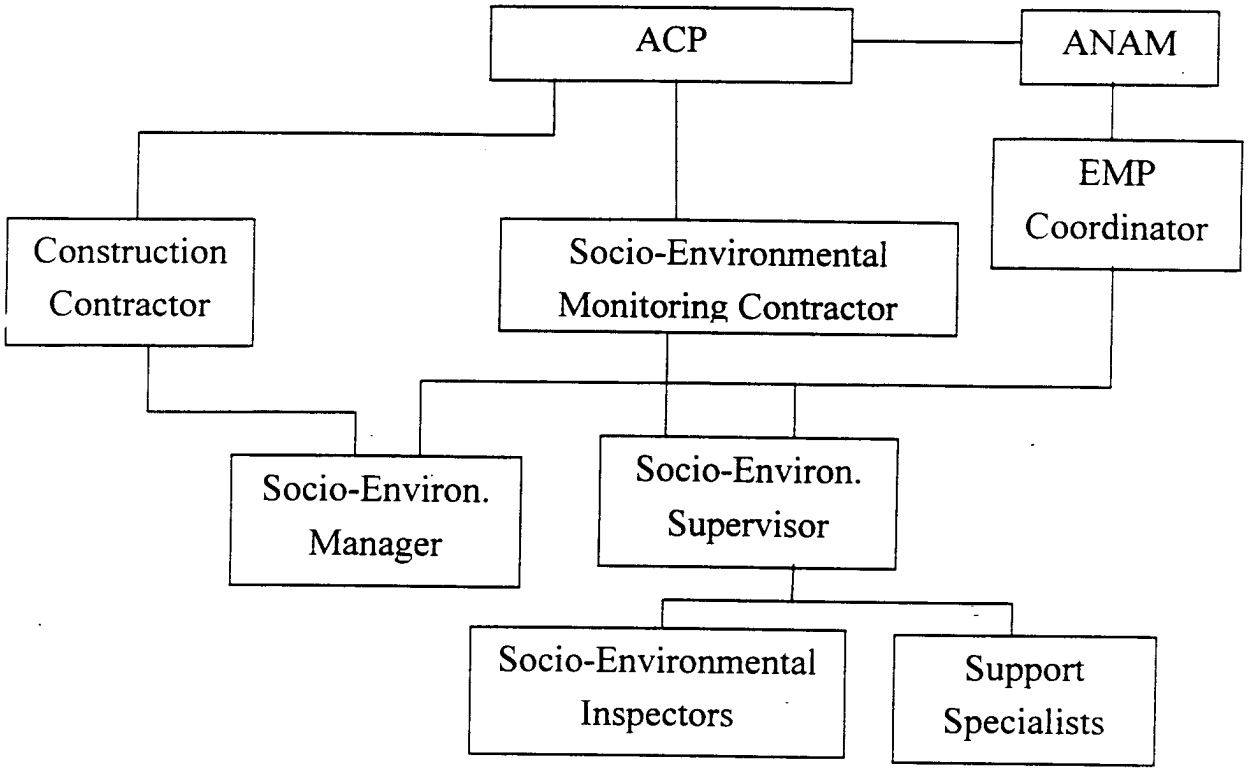
Material and Infrastructure Requirements

The inspectors shall have the equipment and materials necessary for the monitoring works, which shall at least include the following:

- An appropriate 4x4- wheel drive vehicle equipped with radio communication, first aid kit, etc. with visible identification of the company to which it belongs.
- Laptop or desktop computer and digital camera.
- Equipment and instruments for the execution of the sampling program.
- Personal protection equipment.

Organizational Chart for the EMP execution

The organization anticipated for the execution of the Environmental Management Plan, under the functions indicated above is shown in the following organizational chart.



5.6.3 Verification and Control of Specific Programs

This section briefly describes the organizations involved in the socio-environmental verification and control at the level of each of the programs proposed, indicating their corresponding function.

Air Quality and Noise Control Program

The ANAM shall be responsible for the verification and control activities of this program.

Seismology and Geology Program

The verification and control activities of this program will be under the responsibility of ANAM, which will request technical support from the Department of Geology of the University of Panamá.

Erosion and Sediment Transport Prevention and Control Program

The ANAM shall be responsible for the verification and control activities of this program.

Water Quality Program

The ANAM shall be responsible for the verification and control activities of this program; however, an independent specialized professional or company should also be retained during the operation of the reservoir (at 5 years), to review the water quality results and submit recommendations.

Biodiversity of Terrestrial Ecosystems Protection and Recovery Program

The regulatory agency in charge of regulating the prevention, reduction and control activities and actions shall be the ANAM and the government agencies appointed with responsibility for managing forest, biological diversity, and enforcing compliance of the protection of endangered species. The international or regional financing institutions will also impose additional controls to ensure the prevention, reduction and control, and also adequate conformity of the project with the international standards and conventions and government regulations (e.g., CITES). ANAM shall be responsible for the verification and control activities of this program.

Aquatic Plants Monitoring and Control Program

ANAM shall be responsible for the verification and control activities of this program.

Fish and Macro-Invertebrates Conservation and Management Program

The verification and control activities of this program shall be the responsibility of the MIDA, through the National Department of Aquiculture (*Dirección Nacional de Acuicultura*), and regional offices R-4 (Coclé), R-6 (Colón) and R-5 (Capira), which have agencies in the project areas. The University of Panama, through its Limnology and Ocean Sciences Center (*Centro de Limnología y Ciencias del Mar)* and the ANAM should be involved.

Archaeological Sites Conservation Program

The ANAM and the National Institute of Culture shall be responsible for the verification and control activities of this program.

During the planning phase, the cooperation of the National Institute of Culture will be requested in the form of a specialist for the management of cultural resources, who will perform two field visits. The technical reports generated as a result of the data survey shall be subject to external review by a specialist in archaeological resources.

During the conceptualization, design, construction, operation and maintenance phases, the verification and control program shall be subject to a semi-annual external review by a specialist in the management of archaeological resources.

Resettlement and Human Development Plan

The verification of the prevention, reduction and control actions of this program, specially relocation will be the responsibility of ANAM, which will perform monthly visits, before, during and after its execution.

The control should be performed through the mechanisms established by the requirements of the ***involved*** organizations. The better the prevention, reduction and control program is performed, the less delay there will be in the execution of the works, and the less the total financial cost. It should be pointed out that the prevention, reduction and control cost is a small fraction of the total cost, therefore, a delay in the works as a result of inadequate prevention and control will have disproportionate financial implications.

The operative costs for the verification are estimated at B/. 200,000 to cover regular meetings with the interested stakeholders.

5.7 Contingency Plan

The purpose of this plan is to provide practical measures applicable to the construction activities in the water alternatives so as to contribute to the prevention, reduction and control and/or to provide a response to emergencies.

The objective of this program is to reduce any possible harm or damage to the population and their property or to the environment as a result of hydrocarbon or other toxic or hazardous material spills from the works. Among the specific objectives of the program are:

- To prevent or minimize the contamination of water and/or the soil as a result of a fuel, lubricant and any other hydrocarbon byproduct or toxic material spill within the facilities of the operation centers or in the work fronts; and
- Avoid any possibility of fire or explosion as a result of fuels, lubricants or any other hydrocarbon byproduct or toxic material spill, within the facilities of the operation centers or in the work fronts.

In order to attain these objectives, the Contractor must include in the plan several critical elements, such as procedures to prevent spills and containment measures in case of spills, to prevent the contamination of soils and water, and if there is a spill, to have the necessary measures to clean it up and mitigate it. In terms of procedures, there are routine visual inspections and planned maintenance that will help reduce the potential of discharge of oil and other material into the soil and water. In terms of control measures, the work areas should have facilities for the prevention and control of spills, such as perimeter containment structures around the area for the storage of hazardous material. In terms of application of preventive measures, an emergency response procedure, appropriately planned and executed, will reduce the potential environmental damage.

5.7.1 Action Priorities

Since the substances that have the potential to be spilled affect people, properties and the environment in general, it is necessary to establish an order of priority when there are multiple risks. The program actions takes into account the following order of priorities:

1. Protection of human lives;
2. Protection of human settlements;
3. Protection against contamination of water bodies (aqueducts, rivers, ravines, etc.)
4. Protection against contamination of crops; and
5. Protection against contamination of wild life

The Contractor shall follow appropriate operational procedures, develop control measures and preventive measures to indicate the actions to be followed in case of a spill. The appropriate development and implementation of the program will help the contractor to reach these objectives. It shall also include an educational component to train the contractor's personnel in the response to spills. The Contractor shall keep the Ministry of Health and ANAM regional representative informed about any change or event affecting the established procedures. The program shall at least include the following components:

- Measures for prevention and containment of spills;
- Measures for preparation and prevention;
- Measures for emergency response;
- Procedures for spill response;
- Safety previsions; and
- Training program for workers.

In order to efficiently plan the protection, preparation, containment, emergency response, clean-up and training measures, the location of the water body closest to the facilities where fuel may be stored and the water table must be taken into account.

5.7.2 Measures for Prevention and Containment of Spills

The following paragraphs describe the program for the management of spills during the execution of the works:

1. **Fuel Management during Construction**: The fuel management during the construction should be under the responsibility of one of the fuel suppliers in the country. The selected company must provide a detailed contingency plan specific for operations in the area.

2. **Inventory of Materials**: There shall be a Materials Safety Data Sheet (MSDS) and/or chemical analysis available for each of the materials stored, both in the administrative office as well as in the storage area. Their purpose is to provide information on the chemical risks of the product and adequate treatment in case of accidents.

   The Contractor shall prepare a table specifying all hazardous materials stored in quantities over domestic levels and their corresponding location. Also the Above Ground Storage Tanks (AST) and 55 gallon (208 l.) drums and their content in each of the facilities related to the project shall be listed:

3. **Storage Areas and Tanks**: The Contractor shall, at least, comply with the following operation specifications and standards, when storing hazardous material in a facility:
   - Identification of Drainage Pattern. The Contractor shall identify general drainage patterns for each facility. The general drainage patterns shall be exhibited in a site plan. The drainage of the storage areas with containment structures, shall be retained through valves or other adequate means to prevent a spill or other excessive leak of oil to the drainage system. The valves used for the drainage of areas with containment structures shall be manual with an open/close design. The drainage systems shall be adequately designed to ensure the spilled product does not reach the soil or water bodies, in case of failure of the equipment or human error.
   - Bulk Storage Tanks: No tank shall be used for the storage of hazardous products unless their material and construction are compatible with the type of material and storage conditions (e.g., pressure and temperature). All facilities with bulk storage tanks shall be built so that there is a secondary containment structure for the content of the largest

tank, as well as sufficient clearance space for precipitation. The areas with dikes shall be impervious enough to contain the spilled oils or other fluids.

- Drainage of Containment Area: There will be no drainages in the containment area unless those drains lead to a containment area or container where the spills may be recovered.
- Storage of Fuels and Lubricant Oils: There is always danger of large spills in areas where fuels, lubricating oils and hydraulic fluids are stored. The Contractor shall take the necessary measures in areas for refueling or fuel transfer from tankers transporting fuels and where oil drums are loaded. Special measures shall be implemented to prevent spills in those areas. The containment equipment shall be close to the tanks and drums to minimize the spill response time and it shall include absorbent pads or mats. The amount and capacity of the mats shall be sufficient to contain the maximum anticipated spill.
- Secondary Containment Structures: To prevent the discharge of oils or hazardous waste into the environment, the Contractor shall equip all above ground tanks with secondary containment structures. These structures shall be designed to collect discharges and accumulated liquids until the material is removed. The spills, leaks or any excess precipitation shall be drained in the most adequate possible way to prevent any damage to human health or the environment. The dirt embankments with a base full of gravel will provide secondary containment for lubricant oils and used oil tanks. Fifty-five gallon (208 liter) drums will be used for clean-up and collection of spills and leaks until the arrangements are made for adequate disposal outside the site. Drainage of stormwater will be accepted when:
  - The drainage valve is normally sealed (closed);
  - Inspection of stormwater shows it will not produce a hazardous discharge and ensures compliance of water quality standards; and
  - The drainage valve is opened and sealed again after drainage, under the supervision of those responsible for this.

The diesel drums and tanks stored in work areas and storage yards shall be located in covered areas in which there are dirt embankments with low permeability and soils used for secondary containment. The spills shall be contained, cleaned up and collected as soon as possible in 55-gallon (208 l) tanks that shall be disposed of outside the site.

4. **Refueling Operations**: The Contractor shall ensure all refueling and lubricating activities are performed within the right of way, and at a distance of about 15 meters or more from the water bodies, when it cannot be performed in the sites previously assigned. Besides, the

Contractor shall verify that all refueling activities are performed under the following conditions:

- The equipment and prevention, reduction and control measures shall be sufficient to prevent the spilled fluids from leaving the right of way or reaching the water bodies, and should be easily available for use. The following elements may be combined; dikes, berms or containment walls sufficiently permeable to contain the spilled oil or product;
- Absorbent material and barriers, in the amount determined by the Contractor to be sufficient to capture the greatest reasonably predicted spill;
- Sufficient disposable containers to contain and transport contaminated material;
- The contractor shall prepare a list of the type, quantity and area of storage of the containment and cleanup equipment to be used during the construction. This list shall include the impact minimization procedures and measures to be followed in case there is a spill.
- The Contractor shall prepare a written inventory of all lubricants, fuel and other material that may be accidentally discharged during construction.
- All spills shall be immediately cleaned. The containment equipment cannot be used under any circumstance for storage of contaminated material.

5.7.3 Preparedness and Prevention Measures

Preparedness and prevention are the preferred alternatives to reduce and control the common small spills that often occur when oil is changed in the oil pan of the crankshaft, hydraulic lines are repaired and coolant is added to the equipment. The absorbent pads and mats must be placed on the floor, under the equipment, before maintenance. The maintenance personnel must take the absorbent material for each equipment piece. The equipment kept in the refueling area and in routine maintenance area must have small absorbent equipment (or its functional equivalent). Every facility and work area must be adequately equipped to satisfy the preparedness and prevention objectives established in this plan. There should be routine inspection (i.e., daily) of storage tanks and fuel transfer areas. The contractor shall keep records of those inspections.

Among the main preparedness measures, the following may be mentioned:

1. **Design and Operation of Work Areas:** The work areas must be designed, built, maintained and operated so as to minimize the possibilities of fire, explosion, or accidental, sudden or non-sudden leak of petroleum byproducts, hazardous waste or hazardous waste elements into the air, soil, or surface water which may endanger human life or the environment.

2. **Fire-Fighting Equipment.** Every facility must have the means to immediately respond to an emergency, when the personnel is in the facilities, using the equipment described below:
   - Fire-extinguishing and fire control systems must be available in every facility; and
   - The facilities and structures (e.g. trailers and storage areas) shall have fire detection systems.

3. **Fuel Transfer and Loading and Unloading Facilities.** The loading and unloading areas of each facility will only be used for fuel transfer and loading and unloading lubricant oils or used oil. Secondary containers shall be available in the these areas. All areas shall use drip pans under the hose connections while liquid is being transferred. The Contractor personnel shall be present during all fuel transfer operations. All outlet valves of the tank trucks shall be inspected before leaving the fuel transfer area, to prevent possible leaks while in movement. As a precautionary measure, all valves should be inspected in the transfer connection, before leaving the area after transferring the material. If there is a spill or leak, then the refueling or transfer operation should be stopped, the spill should be contained, cleaned and collected before continuing with the operation. The Contractor shall have a diagram of the fuel transfer areas.

4. **Aboveground Storage Tanks Inspections.** The aboveground tanks for the storage of diesel and gasoline shall be daily inspected by the Contractor's personnel to look for signs of deterioration or leaks that may cause a spill or accumulation of the product in the environment.

5. **Spill Control Equipment.** Every facility where fuel, oils or other hazardous products are stored shall have a convenient supply of equipment for spill control which shall includes equipment for earthworks, such as backhoes, and absorbent material, shovels, rakes, pumps, empty drums and absorbent barriers. The absorbent material shall be used to recover the material spilled on the soil or in the surface water. The spill collecting equipment shall be placed in the storage areas. Shovels, rakes and pumps may be used to collect any residue of the material spilled on the soil or in the surface waters. Also, the construction of terraces, dikes or embankments may be used to stop the flow of spilled material.

6. **Communications and Alert Systems.** The internal and external communications equipment shall consist at least of a radio transmitter and loudspeakers. These radios may be used as part of the internal and external communications systems in the work areas. There shall also be radios for communications in all trucks.

7. **Miscellaneous Equipment.** Each work area shall also have first aid kits. These kits must be placed in each work front and in all trucks.

8. **Test and Maintenance of Equipment.** The personnel in each work area shall routinely inspect, test and maintain the emergency equipment to ensure its correct operation. The intercommunication radios, telephone systems, loudspeakers and any communications systems to be used, shall be daily tested. All fire-extinguishing equipment shall be monthly inspected.

9. **Access to Communications or Alarm System.** Every time oils or hazardous material is handles, the plant personnel involved in the operation shall have immediate access to radios and telephones, whether directly, or through visual or verbal contact with other employees.

10. **Space Requirements.** Every facility shall have adequate transit spaces to allow for transit of personnel, fire protection equipment, spill control equipment and decontamination equipment without any obstructions between structures, when necessary.

11. **Arrangements with Local Authorities.** The contractor shall try to make all necessary arrangements with the Police, Fire Departments and Emergency Response Teams. The property of the materials of the hazardous waste handled in the facilities or types of injuries or diseases caused by fires or explosions shall be reported to the closest hospitals and clinics. The local authorities shall be invited to inspect the facilities. If they refuse to do it, the Contractor shall document the refusal in the Records for the Management of Hazardous Materials.

12. **Emergency Equipment.** The Contractor shall prepare a list of the type, quantity and location of the equipment for the storage, containment, and cleanup to be used in the work areas or construction sites. This list shall include the procedures and measures to minimize the impacts that shall be followed in during response to a spill. The choice of prevention, reduction and control equipment by the Contractor shall be in accordance with the characteristics of the terrain affected as well as the type and quantity of material that may be spilled. The contractor shall provide, at least, the following equipment for spill containment and cleanup:

    - Absorbents such as pillows, cloths, and cotton waste to contain and collect the spilled liquid;

- Commercial equipment for spills (or its functional equivalent) which comes already pre-packed with a great variety of absorbents for large or small spills.
- Excavators and backhoes for the excavation of contaminated material; and
- Containers, drums and temporary storage bags for cleaning and transporting the contaminated material.

13. **Inspection and Maintenance of Equipment.** The Socio-Environmental Coordinator shall inspect and require maintenance of the equipment for the supply of fuel or lubricant under a strict program. The Contractor shall submit written documentation on the methods employed and the work done. All containers, valves, piping and hoses shall be regularly inspected to assess their general conditions. During that test, any sign of deterioration which may cause a spill, such as leak signals (e.g. accumulated fluids) shall be identified. Leaks shall be corrected or repaired as soon as possible.

14. **Equipment Failure.** Spills may be the result of unpredictable events, such as breakup of fuel tanks, radiators and hydraulic lines. Devices with an absorption capacity of up to 20 liters may be placed under the operator's seat in the construction and earthworks equipment.

    The Contractor shall train the construction personnel in the operation and maintenance of the equipment to prevent accidental fuel, oil or lubricant discharge or spills. The personnel shall also know the laws, regulations and provisions for environmental contamination control applicable to their work. Talks on the prevention of spills will be scheduled and held with the workers, frequently enough to guarantee the learning of the spill prevention measures. These talks shall especially focus on the following aspects:

    - Preventive measures to avoid spills;
    - Spill sources, such as failure or malfunctioning equipment;
    - Standard procedures for operation in case of spills;
    - Equipment, materials and supplies available for the cleanup of a spill;
    - A list of known cases of spills;
    - Emergency equipment;
    - Alarm and communication system; and
    - Agreements with local authorities.

5.7.4 Emergency Response Measures

The Contractor shall prepare Emergency Response Measures for Spills in order to minimize the dangers which may affect the construction personnel and the environment in case of an unplanned or sudden discharge of hazardous material in the air, ground or water. For the purposes of this plan, an emergency is defined as "the release of hazardous material which may threaten or cause harm or damages to the health of human beings or to the environment". The plan provisions must be fulfilled whenever there is an emergency, and it shall include, at least the following components:

1. **Containment.** Containment is the immediate priority in case of a spill. If possible, the spill must be retained at the site of occurrence.

2. **Cleanup.** The cleanup procedures will start immediately after the spill is retained. Under no circumstance, the containment equipment shall be used to store contaminated material. A list of the equipment to be used for cleaning, prevention, reduction and control of damage to the environment must be available.

3. **Notice.** In case of a spill, the emergency response team, the Socio-Environmental Coordinator and the personnel for socio-environmental monitoring shall be notified.

4. **Excavation and Disposal.** The excavation and cleanup of the spilled material, the absorbent and of the contaminated soil will be performed immediately and they shall be deposited in the disposal sites used by the Contractor.

5. **Duties of the Emergency Coordinators.** The emergency coordinators on duty shall remain permanently in the facilities or in contact (e.g., available to respond to an emergency and reach the facility or work area in a short time) with the responsibility of coordinating all emergency response measures. These employees shall know the details of all aspects of the Contractor's Contingency Plan, including all the operations and activities in the facilities, location and characteristics of the waste managed, location of records and distribution scheme in the facilities. Likewise, they shall have the authority to use the necessary resources to comply with the contingency measures and if necessary, proceed with the evacuation of the personnel in the spill site to a safe area if the case is serious enough.

5.7.5 Spill Incident Response Procedures

The containment group in the site of origin has to reduce and control the spill at the point where it originated. It is also in charge of preparing containment barriers to prevent the spilled product from contaminating the soil and waters or generating a higher risk of explosion or fire, and is also in charge of reducing and controlling any fire which may arise as a result of the spill. This group is made up of the people who are usually at those points, such as the operators of gas stations, mechanics and their assistants. The brigade follows different action plans to contain spills depending on the area where they take place:

1. Action Plan for Containment in Fuel and Lubricants Storage Areas

In the areas where gasoline, diesel, asphaltic oil and other tanks are, there shall be secondary containment with sufficient capacity to contain the spill. In case of a spill, the brigade shall follow the steps indicated below:

- Act in accordance with the instructions of the Brigade Coordinator.
- Avoid a large fire within the facilities; and
- Be prepared to extinguish any fire which may begin. If there is a fire:
  - the fire alarm shall be activated;
  - firemen shall be informed; and
  - the area shall be kept clear so that the firemen may extinguish the fire.

2. Action Plan for Containment of Spills in the Refueling or Fuel Transfer Area

In the areas for fuel transfer from tankers, if there is a spill, the brigade shall follow the steps indicated below:

- Act in accordance with the instructions of the Brigade Coordinator.
- Avoid a large fire within the facilities; and
- If there is a fire:
  - firemen shall be informed; and
  - the area shall be kept clear so that the firemen may extinguish the fire.
- The group for containment of spills at origin will contain the product following the steps indicated below:
  - Close the bottom and discharge valves of the tanker, place containment cloths to stop and absorb the material so that it does not exceed the containment dike; and
  - Take measures so that the material does not reach the stormwater drains.

- The group for the contention of the spill in the surrounding area, shall place retainers in the ground slopes so that the material does not run off.

3. Action Plan for the Containment of Spills in the Refueling Area

In these areas, the action plan is slightly different, depending on the amount spilled:

- Spills of less than 20 gallons:
  - Give warning to the brigade coordinator so that containment and collection of spill is organized;
  - Absorbent material will be placed to contain the spill and to absorb the spilled material; and
  - Absorbent material will be placed in the ground slopes so that the spilled material does not run off.

- Spills larger than 20 gallons: Act in accordance with the instructions of the Brigade Coordinator;

- Avoid fires;
  - Absorbent material will be placed to contain the spill and to absorb the spilled material;
  - Absorbent material will be placed in the ground slopes so that the spilled material does not run off; and
  - The fire fighting group shall be organized to reduce and control any fire.

4. Action Plan for the Containment of Spills in Lubricants Storage Areas

If there is a spill in this area, the following actions will be followed:

- Act in accordance with the instructions of the Brigade Coordinator; and
- Avoid fires, to that end:
  - Absorbent material will be placed to contain the spill and to absorb the spilled material;
  - Absorbent material will be placed in the ground slopes so that the spilled material does not run off; and
  - A fire fighting group will be organized to reduce and control any fire.

5. Action Plan for the Containment of Spills in Work Fronts

The procedure below corresponds to spills due to accidents involving fuel transport vehicles:

- Give warning to the Project Manager or Emergency Coordinator on duty. They will decide whether to call the firemen to support the tasks for the containment and cleanup of the area. These calls will depend on the size of the spill and geographical position of the vehicle:
- Make a report of the spill indicating:
  - Exact place of the accident;
  - Products involved;
  - Approximate quantity;
  - Proximity to houses, schools or health care centers:
  - Possibility of fire/explosions, danger to human lives, damage to ecosystems; and
  - If there are surface water sources nearby.
- Prepare the spill containment team to get close to the area to support the containment and cleanup of the area; and
- The vehicle driver will assist the containment initiative at the site of the accident.

6. **Training.** All the spill containment team and drivers of tankers shall attend at least one spill containment drill every three months and a training course in spill containments every six months.

7. **Materials Available at the Center of Operations for Spills Containment.** A monthly inventory shall be made of the materials listed below. The amounts recommended to have in stock are:

Square shovels	2	Straw brushes	2
Machetes	2	Absorbent booms, 20 feet	2
Picks	2	Absorbent booms, 10 feet	2
Lanterns	2	Containment cloths , 2" x 2"	100
Rubber Gloves	6	Large plastic bags	5
Leather Gloves	6	Protecting glasses	5
Absorbent Rolls	1		

5.7.6 Procedures to Report Spills

The Contractor shall have an appropriate system to keep the Reports of Spill Incidents describing the date, time, and their detail, as well as the corrective actions used in the response. This report

shall be drafted by the Socio-Environmental Coordinator with the support of the Emergency Coordinator with information relevant to that case. Copies of those reports must be kept in the files located in the operations center and sent to the ACP and ANAM.

The paragraphs below describe the type of notice and procedures to draft the reports on oil spills, fires, explosions or discharge of hazardous material to be followed by the Contractor:

1. **Report Contents and Initial Notification.** If there is an accidental discharge of a hazardous substance in a quantity or concentration which may cause damage to the soil, water, or any natural resource or which may endanger the health or public wealth, then the Emergency Coordinator shall give notice by phone to the ANAM and local organizations, providing the following data:

- Name of the person reporting the incident;
- Type of substance involved;
- Estimated quantity of discharge;
- Location of the discharge;
- Actions proposed to stop, clean and/or remove the substance, if necessary;
- Any other information related to the discharge, requested at the time notice is given;
- Circumstances leading to the spill;
- Dimensions of affected area;
- Estimated depth that the material has reached in the water or soil;
- Determination of the possibility that the spill may leave the area and/or the operation centers area;
- Degree of control of spill; and
- Person notified and time of notification.

2. **Written Report to the ANAM.** Within seven days of the initial verbal notice, an official report shall be sent to the ANAM and corresponding local organization. The written report shall at least contain the following elements:

- Description of discharge incident;
- Source of discharge;
- Description of measures taken to clean and remove the discharge;
- Measures planned or implemented to prevent the repetition of the incident:
- Description of immediate actions taken and estimate of quantity and disposal of material recovered as a result of the incident;

- Schedule of implementation of measures suggested by the company to eliminate the problem; and
- Report the environmental assets or renewable natural resources affected.

3. **Arrangements with the Police, Fire Department and Health Care Centers.** The Contractor shall make the necessary arrangement to familiarize the Police, Fire Department and Health Care Centers with the floor plan of the facilities, properties of the material handled and associated risks, places where the personnel of the facilities usually work, access roads and exit roads for the facilities and possible evacuation roads. During a crisis, the cooperation and team work between employees and the emergency response personnel shall be essential to prevent, reduce and control the damage.

4. **Safety Previsions.** The Contractor shall develop and implement safety measures to avoid free access of visitors to workshops, refueling area and discharge yard, etc. All facilities shall be fully fenced with wiring. All accesses to the facilities shall be reduced and controlled. All visitors shall sign a registry at the main door. There shall be a floor plan indicating position of the fences and entries. All facilities shall have adequate lighting to provide good visibility. There shall also be warning signals in the fences. These signals shall read "Private Property - Do not Enter". The sign shall be legible from a distance of at least 10 meters.

5. **Worker Training Program.** The personnel of the work teams and operation center shall be trained in the management of hazardous waste to efficiently respond to emergencies by knowing about the procedures, the equipment and communications system in case of emergencies. The personnel handling, collecting samples or in direct contact with petroleum byproducts or hazardous material shall receive training courses with emphasis on environmental control. The procedures for control and prevention of spills shall be widely explained during the training sessions. Other aspects to be discussed during the training sessions are the procedures for the identification of hazardous waste, "in-situ" generation, management of hazardous waste and other toxic substances, appropriate storage, transport and disposal of hazardous waste and procedures for sample collection.

   All employees shall receive training during the first work week or before that time at the project site. Every facility shall have records of employee training, which shall be filed from the moment the employee starts working.

6. **Procedure Distribution Checklist.** The Contractor shall provide copies of the procedures for the prevention, control and containment of spills to all relevant organizations. The contractor shall verify that the copies of the procedures and the revisions are:

- Kept in the work fronts and in the storage facilities;
- Sent to the local police and fire departments, and health centers to which the emergency services will be requested; and
- Distributed to the socio-environmental monitoring personnel, responsible for ensuring the precision of the plan execution and that all interested parties receive the corresponding changes.

5.8 Environmental Management Plan Costs

All costs associated to the EMP range between B/.9.6 and 24.8 Million Balboas. The main items of the EMP clearly respond to the relocation and socioeconomic improvement program for the communities. This is followed, to a lesser extent, by the program for the prevention and control of erosion and sediment transport.

Table 5-11
Overall EMP Budget for the Río Indio Water Basins

	OPTIONS					
	1	2	3	4	11	12
Duration of Construction Stage (years)	5	3	3	3	5	5
A. Mitigation, Monitoring and Verification and Control						
Resettlement and Human Development	17.032.174	9.759.817	5.375.428	5.172.907	13.531.131	13.750.287
Air Quality and Noise	S/C	S/C	S/C	S/C	S/C	S/C
Seismology and Geology	S/C	S/C	S/C	S/C	S/C	S/C
Erosion and Sediment Transport	4.750.000	2.850.000	2.850.000	2.850.000	4.750.000	4.750.000
Water Quality	450.000	290.000	290.000	290.000	450.000	450.000
Recovery of Terrestrial Biodiversity	996.960	370.800	272.640	261.120	1.013.520	412.560
Aquatic Plants	115.372	88.748	88.748	88.748	115.372	115.372
Fish Macro-Invertebrates	149.740	115.185	115.185	115.185	149.740	149.740
Archaeological Sites	1.300.000	780.000	780.000	780.000	1.300.000	1.300.000
Other Programs	S/C	S/C	S/C	S/C	S/C	S/C
SUB - TOTAL	24.794.246	14.254.550	9.772.001	9.557.960	21.309.763	20.927.959
B. Compensation for Land Use Change						
Forest	5.740.035	2.708.385	1.759.135	1.684.785	1.124.685	1.183.085
Grassland	969.230	509.730	269.130	254.080	91.840	103.700
Shrubland	1.642.300	868.300	507.100	488.300	747.180	785.070
SUB - TOTAL	8.351.565,0	4.086.415,0	2.535.365,0	2.427.165,0	1.963.705,0	2.071.855,0
GRAND TOTAL	33.145.811	18.340.965	12.307.366	11.985.125	23.273.468	22.999.814

S/C = No cost, included in the works contract.

It is important to point out that the monitoring costs presented herein, refer specially to the construction stage. The costs during operation shall be reviewed once the work is finished. The estimated costs have been quantified according to the existing quality and amount of information for the water options, and should be considered only as an indicator of actual costs. When the final EIA is prepared for the selected alternative and once more information is obtained, the costs must be estimated with an error margin no greater than 10% as well as contingent expenses. Below is a brief description of the considerations made to calculate the overall costs, this margin of error is considered to be acceptable by the international institutions of credit as the World Bank and the BID.

5.8.1 Resettlement and Human Development Plan

The costs presented in the table below are approximate. First of all, only direct costs for the ACP are considered and they do not include internal costs for the ACP nor financial costs. This is to avoid counting those costs twice since the administrative and financial costs are part of the total ACP package. Secondly, the costs approximate the average value the families would accept as compensation for displacement. This is still to be determined, but the amount indicated is only a first approximation. Third, the costs do not take into account potential increases due to speculation or corruption, which cannot be estimated *a priori*. The total direct cost of the alternatives range between B./9.0 and B./18.9 million depending on the option. To this cost, the cost of additional infrastructure for the families located around the reservoirs to be able to communicate again must be added. These costs are estimate at B./500,000 per reservoir[16].

5.8.2 Biophysical Conditions Recovery and Protection Plan

Air Quality and Noise Control Program

No cost is allocated to this program since they are included in the Contractor's contractual terms and conditions.

Seismology and Geology Program

No costs are allocated to this program due to the following reasons:

- The activities of prevention, reduction and control associated to the studies and design of the project are costs included in the project design cost.

[16] This estimate would be used to rectify the cost for buying motor boats, building quays, for training on traditional fishing and the cost for improving access to public services (education, health) for those who choose to remain while, on the other hand, the health care centers or schools they used to attend have been flooded.

Table 5-12
Total Costs of the Resettlement and Human Development Plan

Río Indio River Basin	Río Indio 80-40	Río Indio 45-40	Upper Indio 50-40	Upper Indio 45-40	Teriá Sub-Basin	Teriá Sub-Basin+Indio Cabecera
Family Displacement	5,165,000	3,128,000	1,108,000	1,023,000	4,257,000	4,492,000
Loss of Production	696,267	416,961	140,319	126,998	615,451	670,957
Replacement Lands	7,474,587	3,380,196	1,391,539	1,260,619	1,584.54	1,695.38
Infrastructure and Social Cohesion	1,495,120	508,460	152,170	152,170	730,680	669,330
Economic Infrastructure	683,600	286,600	111,800	94,600	28,000	18,000
Additional Infrastructure	500,000	500,000	500,000	500,000	500,000	500,000
Help Desk	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Monitoring	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000
Verification and control	200,000	200,000	200,000	200,000	200,000	200,000
Total	18,414,574	10,620,217	14,399,986	9,053,914	18,985,118	15,631,523

- The cost of prevention, reduction and control activities associated to the construction works is included in the project construction cost.

- Monitoring activities: Since there is limited information available up to this date, it is not possible to determine the scope of the geotechnical monitoring program. The planning of the monitoring plan is an integral part of the process for the design of the dam and other project components. The geotechnical instruments to be used in the monitoring plan shall be setup during the construction by the selected contractor and, therefore, its cost is typically included in the construction costs.

Erosion and Sediment Transport Prevention and Control Program

A preliminary estimate of the costs of the Program for the Prevention and Control of Erosion and Sediment Transport may be summarized as follows:

Table 5-13
Erosion and Sediment Control Program Costs

Concept	Construction[1]	Operation[2]
Personnel	150.000	100.000
Materials	200.000	
Infrastructure	600.000	
TOTAL	950.000	100.000

[1] Annual Cost in Balboas.
[2] Annual Cost in Balboas

The costs of this program will vary according to the duration of the construction stage.

Water Quality Protection Program

The estimated costs of the Water Quality Program are shown below:

Table 5-14
Water Quality Protection Program Costs

Phase / Line	Total Cost (balboas)
Final Design / a) Equipment Acquisition	50,000
/ b) Personnel for the sampling of water quality	80,000 /1
Construction / Measures to prevent contamination	No cost, included in contract
Operation / a) Sampling of water quality per year	100,000 /1
/ b) Verification and control	30,000 /2

/1 This is annual value
/2 This value is every 5 years.

In order to differentiate between options, the duration of the construction stage (B/.80,000 per year) plus equipment (B/.50,000) have been used.

Terrestrial Biodiversity Protection and Recovery Program

In the final design of the option selected, the number of hectares to be planted will be determined, and the nurseries must be implemented in time to satisfy this demand. Typically, trees will be planted with a spacing of 3 to 5 meters, depending on the species and size anticipated for the adult tree. Therefore, for each hectare of forest to be planted, approximatley 400 to 1,100 trees will be needed. At an average cost of B/.2 per tree planted, the cost per planted hectare could range between B/.800 and B/.2,200, approximately.

Chapter 4 describes the impacts and shows the forest hectares to be affected by each water alternative in the Indio river basin. Therefore, the hectares to be reforested to compensate or remedy those flooded or affected by the project shall be multiplied by 1.2. Besides, resolution No. AG-0235-2003 establishes the rate to be paid as ecological compensation, for the issuance of permits for clear cutting and elimination of undergrowth or grass formations. The rate for cutting primary, intervened or secondary mature natural forests is of B/. 5,000/hectare, B/. 1,000/hectare for shrubland (young secondary forests) and B/.500/hectare for grasslands. The number of hectares of forest, as well as of grasslands and shrublands to be affected by the reservoirs in the different alternatives are indicated in the chapter related to impacts. The tables below indicate partial and total costs.

Table 5-15
Reforestation Cost per Option

Options	Affected Forest (ha)	Forest to be Replaced (ha)	Total Cost B./
1	1148,0	1377,6	2.755.217
2	541,7	650,0	1.300.025
3	351,8	422,2	844.385
4	337,0	404,3	808.697
11	224,9	269,9	539.849
12	236,6	283,9	567.881

1 The cost per planted hectare is estimated at B/.2,000.

Aquatic Plants Monitoring and Control Program

The estimated costs for monitoring and detection of growth of aquatic plants are as follows.

Table 5-16
Cost of the Aquatic Plants Monitoring and Control Program

Description	Total Cost
Personnel	21,600
Materials and equipment	26,080
Office supplies	3,000
Administrative costs	4,000
Transport (gasoline, oil, maintenance, diesel)	26,000
Subtotal	80,680
Contingent expenses (10%)	8,068
Total	**88,748**

The reservoir surveillance will be carried out in any of the options selected and does not represent a significant variation in the costs between options. Therefore, a 30% increase is assumed for larger reservoirs (options 1, 11 and 12: the latter because it involves two reservoirs).

The chemicals most often used for monitoring and control of aquatic plants are: Glyphosphate, Copper Sulfate and 2-4D. The estimated cost for chemical control is of B/.250/ha.

Fish and Macro-Invertebrates Conservation and Management Program
The costs for the study of tilapia and sergeant are detailed below:

Table 5-17
Study on Tilapia and Sergeant

Description	Total Cost (B/.)
Personnel	30,000
Materials and equipment	14,000
Office supplies	3,000
Administrative Costs	4,000
Transport (gasoline, oil, maintenance, diesel)	12,000
Final report	3,000
Subtotal	66,000
Contingent expenses	6,600
Total	**72,600**

The estimated costs to execute the pilot project for breeding fish in aquatic tanks is described below. The first table lists the materials to be used and the second the personnel and equipment costs.

Table 5-18
Costs of Pilot Project for Fish Farming in Tanks

Materials	Quantity	Unit Price	Total Cost (B/.)
Infrastructure (cages)	4	250	1,000
Nets for cages	4	60	240
Nets for tanks	1	1,800	1,800
Cage Construction	4	100	400
Tank Construction	1	200	200
Feeder Construction	4	5	20
Floaters, 5 gallons	40	2	80
Rope for anchors and tanks (roll)	1	55	55
Cage anchors	4	50	200
Hand net	1	20	20
Plastic Tanks, 5 gallons	4	2	8
Fish measuring table	1	10	10
Portable Scale, 1000 gallons	1	205	205
Scale, 20 pounds	1	60	60
Pelletized food, 25 % protein	60	30	1,800
Young fish	2,500	0.10	250
Technical assistance (12 months)	12	1,100	13,200
Transport and maintenance	12	1,000	12,000
Training seminars	2	500	1,000
		Subtotal	32,548
Contingent expenses 10%			3,254.80
		Total	35,802.80

The estimated costs to assess the post-reservoir impact on the fish fauna and macro-invertebrates is indicated below:

Table 5-19
Cost of Assessment of Fish and Macro-Invertebrates

Description	Total Cost (B/.)
Personnel	20,400
Materials and equipment	8,748
Office supplies	2,000
Administrative costs	4,000
Transport (gasoline, oil, maintenance, diesel)	7,200
Final Report	2,000
Subtotal	42,348
Contingent expenses	4,234.8
Total	46,582.80

Materials: 4x4 diesel pick-up truck, outboard engine 25 hp, 18-foot aluminum boat, trailer, gasoline and oil for outboard engine, diesel, life jacket, computer, binoculars, digital counters, drag net, experimental tangle net, fishmeters, scale, stereoscopes, formalin, paperwork, salaries, traveling expenses (per-diem).

The total cost of the three projects amounts to 115,185.60 balboas per year. These projects will be performed for the options selected and do not represent a significant variation between one or another option. A 30% increase is assumed in larger reservoirs (options 1, 11 and 12; the latter because it involves two reservoirs).

5.8.3 Archaeological Sites Conservation Program

The costs, especially those which depend on an archaeological survey and site excavation are difficult to accurately estimate due to the unpredictable nature of archaeological studies.

Final Planning Phase

- Archaeological inventory of the option selected: B/.100,000.
- Preparation of the Cultural Heritage Conservation Program for the option selected: B/.75,000.
- Elaboration of Public Participation Program: B/.100,000.

Additional costs per option would be the following:

- Option 1. Studies and recovery: B/.100,000.
- Option 2. Studies and recovery: B/.100,000.

- Option 3. Studies and recovery: B/.25,000.
- Option 4. Studies and recovery: B/.25,000.
- Option 11. Studies and recovery: B/.75,000.
- Option 12. Studies and recovery: B/.75,000.

Construction Phase:

- Public Participation Program: B/.100,000.
- Archaeological Monitoring: B/.50,000 per year.
- Response to Late Findings: B/.100,000.
- Monitoring Program: B/.10,000 per year.

The Total costs during the construction vary depending on each option. The estimated annual cost is of B/.260,000.

Operation Phase

- Public Participation Program: B/.100,000.
- Archaeological Monitoring: B/.10,000 per year.
- Response to Late Findings: B/.50,000.
- Monitoring Program: B/.5,000 per year.

5.8.4 Other Programs

The estimated costs of these programs will be calculated for the option selected, therefore they are not included in this assessment.

6.0 ALTERNATIVE COMPARISON AND ANALYSIS

This chapter presents the procedures and results obtained from the comparison process of identified water option alternatives at the Rio Indio basin. The differences between feasible alternatives and those considered non-feasible are significant; therefore, the results obtained from the comparison process are quite consistent. The preferred option is, without a doubt, Option 1: Rio Indio 80-40. In the event that this option, due to technical reasons, could not be implemented, Option 11 which involves the Rio Teria sub-basin, and Option 12 which includes, in addition to the previous sub-basin, a diversion from the upper portion of Rio Indio, are feasible, but produce less water than Option 1, at a higher cost.

This chapter is organized in three sections. The first section discusses the general aspects of the procedure and the criteria used for the comparison process. The second section presents a discussion on the results obtained from this process, for the evaluated water options at the Rio Indio Basin. Finally, the third and last section is a brief conclusion on the performed comparisons.

6.1 Methodological Aspects

The selection of one or more feasible water options to support the Canal Modernization and Expansion Program is carried out based on two fundamental criteria:

(i) The option, or options, considered feasible must significantly contribute to the future Canal operation, with a 99.6% water reliability level;

(ii) Among all feasible options, the preferred option must minimize both economical and financial costs as well as those considered social and environmental.

These two criteria complement each other perfectly. The first criterion indicates that the preferred option must contribute enough water flow, to maintain the reliability of the Canal's water level under a higher demand scenario. Whereas the second criterion imposes certain limits on the feasibility of some options because they could be too expensive, affect many people, or cause unacceptable environmental impacts.

The process of impact identification and evaluation performed on the water options considered in this study clearly determined that the issues with greater relevance are those associated to social costs. Therefore, in order to evaluate and select one or more water options a Linear

Programming Model[1] is used, which minimizes the social cost of the selected water option, subject to additional constraints as described below:

a. The selected option, or options, must provide the required water to maintain a reliability level or 99.6%.
b. The water contribution obtained for the future operation of the Canal must be of 15 lockages per day or more.
c. The social - environmental management cost must be reasonable.
d. The direct construction costs must not be too high.

The number of potentially displaced families, for each alternative, has been selected as the prime indicator for assessing the social cost of implementing any of the water options. Even though this does not represent the total social cost, it is without doubt the most significant aspect, and all other costs are directly related to it.

6.1.1 Methodological Justification

For this particular case, it is considered that the use of a Linear Programming Model, as a selection instrument, is more appropriate than the use of weighted indexes. The use of weighted indexes is adequate when there is only one variable that will be evaluated among the different water options. However, if every water option has more than one variable that could be at an advantage or disadvantage relative to each other, the use of weighted indexes is not adequate, since this would imply the creation of many comparison tables for which only one comparison criterion would vary in each. For example, if there are three comparison criteria: number of displaced families, water volume stored, and total costs, the methodology of weighted indexes would create nine (9) comparison tables. However, a lineal programming model considers all variables simultaneously, thus reducing the time and cost required for analysis.

Also, the use of linear programming modeling eliminates the need to assign subjective weighted indexes. For example, it is quite common to assign more weight to environmental or social variables in order for them not be dominated by the magnitude of physical variables (i.e. water volume, square kilometers, total surface area, etc). In linear programming, a critical variable of small magnitude could be the most important factor in the selection process, depending on its

[1] Linear Programming Models are originated in the military, where it was widely used for route optimization and logistical problems. They are currently used in transportation, food production, and manufacturing, in order to optimize a large number of inputs and variables that interact in a very complex way. References about Linear Programming are vast, but the most considerable is Gass, Saul. I., 1985. *Linear Programming: Methods and Applications*. 5th Edition. New York: International Thomson Publishing.

relative importance within the coefficient matrix. The alternatives evaluation matrix is based on the concepts set forth in the Project's Scope of Work, and the interpretation made by URS in its Technical Proposal. The structure of the matrix used for this process is simple, and allows the evaluation of alternatives using real values for each of the water options being considered.

The platform used throughout the process has enough flexibility to incorporate all options in one matrix, or even add options derived from other areas or technological savings. From this stand point, the platform could provide an additional tool to the integral analysis that the ACP will probably be carrying out in the future.

6.1.2 Model Structure

The goal of the linear programming model is to minimize the objective function:

$$\phi(\mathbf{x}) = c\mathbf{x}$$

Subjected to the following conditions:

$$\mathbf{Ax} >\leq \mathbf{b}$$

$$\mathbf{x} \geq 0$$

Where **x** is a vector for variables x1,..., x6 that represents the six water options to be evaluated; **A** is the most relevant coefficient matrix for the final evaluation; **c** is the vector for displaced families in each option **x;** and **b** are the limiting vectors. Matrix A is not square, which indicates that it has a different number of columns and rows, so the relation **Ax** = **b** provides an array of values for **x** that could minimize the objective function, **cx**.

In the case of the water options within the Rio Indio Basin, **x** is binary, in other words, each **xi** (i= 1,..., 6) takes a value of 1 or 0 depending if the option is chosen or not. This forces the model to chose each option fully, or reject it entirely within the final solution. Also, given that the options are considered exclusive; a restriction has been introduced in the model that will not allow for combinations. In other words, it reflects the fact that the combination of various civil works (dams, channels, tunnels, etc) has been considered in the definition of each analyzed option.

6.1.2.1 Objective Function

Following the theoretical criteria for the model, and consistent with the results obtained in the impact analysis, the goal is to minimize the number of displaced families. This is the objective function **cx,** defined in the above paragraphs. As mentioned previously, this is the most relevant social cost and is used as a performance indicator for each option regarding the social aspects.

6.1.2.2 Restrictions Vector

The relation $\mathbf{Ax} \succ\preceq \mathbf{b}$ shows the restrictions imposed by the cost and physical limitations vector on the selection of options. This means that each matrix component has a limitation that is taken into account when a solution is generated. Sometimes this limitation has a minimum value, and other times a maximum value. Vector **b** must include the environmental management costs required to assure that: potential negative impacts are mitigated in an appropriate way by means of preventive measures or compensation activities, and the physical restrictions related to the sustainable management of natural resources and biodiversity. These environmental management costs should include all compensation costs to be paid to the population in the affected zone, including the amount to indemnify the affected families (displaced or not) by each option and the total mitigation costs of the program used to gain support for the implementation of the selected water option (before, during, and after construction), which includes efforts to provide better public services in the region. Naturally, the vector that defines restrictions depends on the information considered as relevant by the technical team. For the model's practical purposes, the relation $\mathbf{Ax} \succ\preceq \mathbf{b}$ is comprised by the following equations:

a. Total water production

$$\sum_{i=1}^{6} p_i x_i \geq P$$

For all options i = 1, …, 6

Where **p** is the water flow, in lockages per day, produced for each option and **P** is the water flow needed, also expressed in lockages per day that ACP foresees for the next fifty (50) years. Currently, 15 lockages per day are considered adequate. This model could be modified by changing **P** in order to evaluate the system's sensitivity to the total water demand. This is an interesting subject since it is currently estimated that, by the time the Canal's third set of locks is inaugurated, the required amount of water is equivalent to 50

lockages per day, but a more precise demand forecast for the next 50 years is not clearly defined at this time.

b. Direct construction cost

$$\sum_{i=1}^{6} g_i x_i \leq G$$

Where g_i (i=1, ..., 6) is the construction costs vector for the 6 options, and the sum of all total construction costs for the selected option, or options, cannot exceed a total cost of G. The initial model run uses a $600 million limit, as a first approximation. As a matter of fact, several model runs are performed with different total values in order to give ACP an idea of the array of resulting solutions by using different limits in the total amount of available financing.

c. Population displacement

$$\sum_{i=1}^{6} c_i x_i \leq C$$

This equation was previously defined as the objective function, where c_i (i=1, ..., 6) is the vector for the number of families to be displaced for the 6 options. However, in addition to looking for the solution that minimizes the number of families to be displaced, the model puts an additional restriction on the number of families affected directly by the reservoirs, which must be maintained under a critical value of **C**. As an initial value, **C** is equal to 450 families; varying up or down to analyze the impact caused by the inclusion or exclusion of the options in the solution.

d. Social - Environmental management cost

$$\sum_{i=1}^{6} s_i x_i \leq S$$

Where s_i (i=1, ..., 6) is the vector for the social – environmental management costs for the 6 options, and the sum of compensations and costs related to the proper management of all social and environmental aspects, as described in the environmental management plan, must

be kept below a number (S) considered as acceptable. The initial value is B/. 40 millions, but varies up or down to analyze the sensitivity of the solution produced by changes in this variable.

e. Recovery time

$$\sum_{i=1}^{6} t_i x_i \leq T$$

Where t_i (i=1, ..., 6) is the recovery time vector for the 6 options, and the total number of years **T**, needed to fill the reservoir or reservoirs that are part of each considered option, must not exceed a target value. A two year period was chosen as the initial value.

f. Proportion of forests in the affected area

$$\sum_{i=1}^{6} h_i x_i \leq H$$

Where h_i (i=1, ..., 6) is the vector for the proportion of forests in the affected area for the 6 options, and the proportion of total forest habitat in the affected area for the selected option, or options, **H** must not exceed a target value. A proportion of 30% was chosen as the initial value.

g. Proportion of affected area in the total basin area

$$\sum_{i=1}^{6} e_i x_i \leq E$$

Where e_i (i=1, ..., 6) is the vector for the proportion of the affected area in the total basin area for the 12 options, and the relation between the total area submerged by water and the total available area in the drainage basin for the selected option, or options, **E,** must not exceed a target value. A proportion of 15% was chosen as the initial value.

h. Proportion of displaced population of the total basin population

$$\sum_{i=1}^{6} f_i x_i \leq F$$

Where f_i (i=1, …, 6) is the vector for the proportion of displaced population of the total basin population for the 12 options, and the total proportion between the number of families to be displaced by the selected option, or options, **F** must not exceed a certain percentage target of the total amount of families in the basin area. This parameter, in relative terms, is considered as an indicator for the impact of displacement. A proportion of 20% was chosen as initial value.

i. Water Body Eutrophication risk

$$\sum_{i=1}^{6} u_i x_i \leq U$$

Where u_i (i=1, …, 6) is the vector for the water body eutrophication risk for the 6 options, and the total estimated eutrophication risk estimated as the estimated phosphorus concentration in the basin's water, **U**, must not exceed a target level value established for mesotrophic lakes. A concentration of 30μg/lt was chosen as the initial value.

6.2 Water option Comparison at the Rio Indio Basin

In comparing the alternatives it must be taken into account that Option 1 has been studied in greater detail. Some costs and implications of other alternatives have been inferred from collected information and analyses carried out for Option 1. The most relevant aspects for the six options, from the model application's perspective, are described in the following sections.

6.2.1 Relevant Aspects for the Options

Option 1, previously mentioned, considers the creation of a reservoir at the Rio Indio with a maximum operational level of 80 masl and a minimum level of 40 masl. In addition to the dam, a discharge point to maintain a minimum water flow down stream, a spillway to regulate the reservoir level during maximum flows, and an 8 km tunnel to transfer water to Gatun Lake, are included. This alternative implies flooding an area of 45.6 Km^2, relocating 327 families, and contributes with the equivalent of 15.5 lockages per day for the Canal operation.

Option 2 is a variant of Option 1; the main structural difference being the dam height, which defines a maximum operating level of only 45 masl. This modification reduces somewhat the total investment, and the total flooding area is also reduced to 20.9 Km^2, as well as the total number of displaced families to 199. Nevertheless, these modifications significantly reduce the reservoir's usable volume, which practically becomes a water diversion structure from the Rio Indio basin to the Gatun Lake. However, given that during the dry season, when water is low in Gatun Lake the water needs for canal operation are higher, the water flow at Rio Indio and other surrounding rivers is also reduced. Thus, the water contribution for the operation of the Canal is reduced to the equivalent of only 1.4 lockages per day.

Options 3 and 4 are somewhat similar to Option 2, with the main difference being the location of the dam which is moved upstream of Rio Indio. With this modification, the flooding area is reduced even more, 8.5 and 7.8 Km^2, respectively – since the reservoir created by the Rio Uracillo branch is eliminated. Family displacement is also substantially reduced to a total of only 72 and 67 families, respectively. Nevertheless, reductions in terms of water production for the canal operation is even greater, and according to the analysis carried out with the ***HEC 5*** model, they only contribute water for an equivalent of 0.7 and 0.3 lockages per day, respectively.

Options 11 and 12, on the other hand, consider an even more limited geographical area, but where the unit surface runoff is greater. This area is the Rio Teria Sub-basin, which is the Rio Indio tributary located adjacent to the Lake Gatun basin, specifically to Rio Ciri Grande. Option 11 includes two reservoirs at Rio Teria and a 4 km transfer tunnel towards the Gatun basin. Due to costs, in Option 12 a reduction in the elevation of the reservoir at the lower part of Rio Teria and a derivation reservoir at the higher area of the Rio Indio basin are proposed to increase the available water flow for this alternative. The total flooded area increases to 15.8 and 16.9 Km^2 for options 11 and 12, respectively. Regarding the amount of displaced families, totals reach 174 and 181, respectively. Water production for canal operation reaches 5.1 and 5.3 lockages per day.

6.2.2 Simulation Results

Table 6-1 summarizes the key coefficients used as inputs for the linear programming model (LP). Without running the model, some comparative advantages can be identified that indicate that Rio Indio 80-40 is a viable option. For example, compared to Rio Teria Sub-basin (Option 11), Rio Indio 80-40 supplies 203% more lockages per day at 66% of the total cost. However, the number of families to be displaced by Rio Indio 80-40 option is 327, which is 91% higher

than the Rio Teria option. Clearly, to carry out a similar comparison between each of the analyzed options it is necessary to run the linear programming model.

Table 6-1
Technical coefficient summary for the linear programming matrix for the Rio Indio Basin

	Option 1	Option 2	Option 3	Option 4	Option 11	Option 12
	Rio Indio 80-40	Rio Indio 45-40	Alto Indio 50-40	Alto Indio 45-40	Rio Teria Sub - Basin	Rio Teria + Deriv. Rio Indio Cabecera
Displaced families	327	199	72	67	171	181
Lockages / day	15.5	1.4	0.7	0.3	5.1	5.3
Avg. Flow (m^3/s)	25.8	25.8	17.7	17.7	7.41	13.86
Water production (10^6 m^3/yr)	1,177	106	53	23	387	402
Recovery time (yrs)	1.59	0.14	0.09	0.04	1.24	1.13
Direct cost of construction (x $1,000)	230,430	185,000	184,650	145,000	350,180	401,210
Unitary cost by lockage (miles $/Lockage)	14,866	132,143	263,786	483,333	68,663	75,700
Cost of annual operation (x $1,000)	1,940	1,390	1,250	1,250	3,980	4,375
Social – environmental management costs	33,146	18,346	12,307	11,985	23,273	23,000
Unitary cost by lockage (miles $/Lockage)	2,138	13,104	17,581	39,950	4,563	4,340
Basin Area - Km^2	381	381	262	262	94	155
Reservoir Area - Km^2	45.6	20.9	8.5	7.8	15.8	16.9
Area of affected forests - Km^2	11.48	5.41	3.51	3.37	2.25	2.37
Proportion of affected forests %	24.28%	22.30%	25.18%	25.27%	19.46%	19.45%
Proportion of affected area %	12.0%	5.5%	3.2%	3.0%	16.8%	10.9%
Families in the basin area	1,291	1,291	907	907	382	564
Proportion of displaced families %	25.3%	15.4%	7.9%	7.4%	44.8%	32.1%
Risk of eutrophication - µg P/lt	0.0017	0.0025	0.0027	0.0028	0.0016	0.0012

6.2.3 Preferred Option

The results indicate that Rio Indio 80-40 option is the preferred alternative for the additional supply of water for the canal (table 6-2), even though the social costs are higher than the other options. The number of lockages per day for Rio Indio 80-40 is greater than the minimum required to reach the water confidence level: 15 additional lockages. However, this reservoir affects 327 families that would have to be evacuated, resettled and compensated. The cost per lockage for other options to reach significant water contributions for the canal operation, more than 5 lockages per day, is considerably higher than the Rio Indio option.

6.2.4 Sensitivity Analysis

If Rio Indio 80-40 was not feasible for non-technical reasons, a feasible solution that could reach the approximate value of 15 lockages per day as indicated as desirable by the ACP does not exist among the considered options, at the Rio Indio basin. However, if the limiting factors for the model related to desired water production are reduced considerably, to a level of 5-6 lockages per day, the sensitivity analysis indicates that options 11 and 12 are capable of supplying this amount of water although at a significantly higher cost than that of the preferred alternative, selected as optimal by the model, which is Option 1: Rio Indio 80-40.

Table 6-2
Selected options at Rio Indio Basin

Number of displaced families		**327**		
Selected Option				
Option 1: Rio Indio 80-40				
Limiting factors				
Variable	**Value**	**Limit**	**Status**	**Remainder**
Social – environmental costs (x $1,000)	33,146	<= 40,000	Does not limit	6,854
Proportion of affected forests %	24.28%	<= 30.0%	Does not limit	5.72%
Proportion of affected area %	11.97%	<= 15.0%	Does not limit	3.03%
Proportion of displaced population %	25.33%	<= 35.0%	Does not limit	9.67%
Risk of eutrophication - µg P/lt	0.0017	<=0.03	Does not limit	0.0283
Displaced families	327	<=400	Does not limit	73
Production of water (106 m3/yr)	1,177	>=0	Does not limit	1,177
Recovery time (yrs)	1.59	<=2	Does not limit	0.41
Direct cost of construction ($ K)	230,430	<=400,000	Does not limit	169,570
Lockages / day	15.5	>=15	Does not limit	0.5

Between options 11 and 12, the former has a lower cost for lockage per day and directly affects a lower number of families. Therefore, this option is considered the next most feasible as long as Option 1 could not be implemented for other reasons, and the level of 5.1 lockages per day is attractive enough for the ACP. However, the large difference between lockage costs must be pointed out, and their most significant aspects are described below.

- The total direct construction cost is higher for Option 11 than for Option 1. When calculating lockages, the results for option 1 are estimated at $14.6 millions for lockage per day, whereas for option 11, the same cost increases to $68.7 millions, more than four times the cost of Option 1.

- The total environmental management cost is slightly higher for Option 1. However, when estimating unit costs, Option 1 results in $2.14 millions per daily lockage whereas for Option 11, the cost is $4.56 millions, more than double.
- Finally, even regarding the number of displaced families, the performance per unit for Option 1 is better. Even though the total amount for option 11 is only 52% of Option 1, when it is estimated per unit; the number of displaced families per lockage for Option 1 is equivalent to 20.7, and for option 11 it is 33.5.

Another exercise carried out within the context of the sensitivity analysis consisted in changing the objective function to maximize water production for the operation of the canal, keeping the same restrictions previously applied. The solution yielded by the model was exactly the same, which demonstrates the confidence level of selecting Option 1: Rio Indio as the preferred option among those that are feasible.

6.3 Conclusions of Water options Comparison

In general terms, Option 1, Rio Indio 80-40 is the recommended option under different model scenarios and restrictions. This option is very solid related to the other considered alternatives since it provides sufficient water for the canal operation at a relatively low cost, with a relatively intermediate impact on population and modest impact to biodiversity. Although there are options that affect fewer families, the water production capacity is a fraction of what Rio Indio 80-40 can provide.

Selection of water options by the model are driven by two main variables: (i) the number of required lockages to improve and maintain the level of water reliability of the Canal, and (ii) minimization of the impact on the number of families displaced by each of the options. These two variables have environmental and financial restrictions, which could affect the selection of a particular option.

In order to keep focused on the results, several different scenarios were run with the model, simulating variations in the limitations vector to examine the stability of the results. The simulations indicate that for the case of Rio Indio Basin, the strength of the Rio Indio 80-40 option is not questionable.

As a final conclusion, it can be established that Option 1: Rio Indio 80-40 is the best considering water production, costs, and social – environmental impacts. In second place, Options 11 and 12 could be considered only if the production of 5-6 lockages per day becomes attractive for the

ACP, within the effort for the modernization and expansion of the Canal. The other options should not be considered feasible, either because of their poor water contribution to the system or because of the implementation costs.

7.0 CITIZENS' PARTICIPATION PLAN

7.1 Introduction

The Panama Canal Authority (ACP – Autoridad del Canal de Panama) is currently carrying out a series of studies that will provide the necessary information, for the preparation of the Panama Canal Modernization Master Plan. Within this context, URS Holdings, Inc. (URS) was retained by the ACP to perform the environmental analysis for the water source options at the Occidental Region of the Panama Canal Watershed (ROCC – Región Occidental de la Cuenca del Canal de Panamá).

The current task, at this moment, is the preparation of a citizen participation plan for the water options at the Indio River watershed, in order to facilitate the incorporation of the local communities' opinions during the conceptualization process and final selection of the water option, or options, that would be included as part of this Master Plan.

Even though an Environmental Impact Assessment is not being prepared at this time, according to the study's scope of work, the environmental analysis for the water source options must be in accordance with the guidelines set forth in ANAM's Environmental Impact Assessment Operating Manual. Regarding citizen participation, the previously mentioned manual requires a Citizen Participation Plan through which all significant changes that this project could cause to the communities must be informed. This plan must provide a forum for discussion and analysis of the advantages, disadvantages, and opportunities that the proposed action will have on the local communities. The objective of citizen consultation is to obtain information from the communities in order to identify problems and reasonable alternatives for the action or set of proposed actions. This type of consultation provides a useful tool for those in charge of the decision making process, and it also allows the general public to be sure that all concerns and/or interests will be taken into account during the environmental evaluation process.

Following ANAM's guidelines, the following aspects will be taken into account:

- Active promotion of citizen participation through encouragement, since the success of community participation needs incentives such as acknowledgement to their effort and commitment.
- Develop diffusion mechanisms of relevant elements from the Master Plan for the Modernization and Expansion of the Panama Canal, and the additional potential water sources at the ROCC.

- Promote the importance of cooperation and team work to reach the desired goals. The objective is to create awareness through social participation.
- Anticipate conflicts.

Citizen participation is crucial; involving all stakeholders in the execution of the project that have the capacity to affect their surroundings, resources, and possibilities to improve their quality of life, create new mutual relations, promote respect and the exchange of ideas and knowledge. It is a process through which communities are united with decision making centers, the exclusion of potentially affected people is avoided and the proper environment for participation within the community is created.

It must be pointed out that this citizen participation plan is not geared towards schemes of sustainable development for the ROCC. URS considers that, at this moment, the ACP is carrying out other studies that are more directly related to this subject, especially the study for the analysis of sustainable development scenarios and regional planning for the ROCC.

7.1.1 Background

The first meetings between representatives of ACP and local communities took place during the last months of 1999, shortly after the approval of Law No. 44 (Ley 44). During these meetings a group of farmers openly declared their discomfort and their position against the construction of the reservoirs. They formed a group called "Coordinadora Campesina Contra los Embalses", Farmers Coordination Against the Reservoirs.

Since 2001 the ACP established, under the coordination of a social workers team, a wide path for communication between the communities within the ROCC. A series of meetings / workshops were promoted at these communities through which data regarding the problems and expectations for solutions and reactions towards the presence of the ACP at the ROCC was gathered. Through these meetings, valuable data was collected for diagnosing the situation in the area, specifically regarding attitudes, expectations and fears of possible changes that could be introduced.

The first gathering took place in September 24, 2001 at the town of Sonadora, Penonome. During this first meeting, communities from the four Watershed areas were represented: Indio River, Cocle del Norte River, Caño Sucio River, and Toabre River; these were divided into micro-Watersheds. Total attendance was 104 representatives from the communities (99 men and 5 women), distributed as follows: 59 community delegates, 15 members of Caritas

Arquidiocesana, 8 members from the "Comisión para la Defensa de los Derechos Campesinos (CDDC)", 6 members of the local authorities, 13 members from other organizations, and 3 that had no specific affiliation.

The methodology followed at this first meeting established three phases. First, the promotion of interaction among participants and identification of expectations, both shared by the different communities as well as particular expectations for each of them.

Second, four work groups were formed mixing farmers from different ROCC areas in a summary workshop scheme, with discussion and presentation sessions for all the groups. As a result of the attendees' discussion, the work agenda was established for the meeting. This agenda included the inhabitants demands, the quality of the meetings, farmers expectations, follow up implementation mechanisms and finally, the commitments.

The third phase opened the discussion session and the subject of the land was the center of the debate. Among the questions raised, the concern with land ownership: types of land titles, land legalization costs, and status of land possession rights (derechos posesorios) was predominant. Other questions involved the subject of environmental conservation, and finally Laws 44 and 19 were discussed.

Following this meeting, four workshops were conducted between the months of March and august 2002. The workshops consisted of discussions about pre-agreements between ACP and the communities' representatives and farmers organizations from the ROCC. The participation from the communities responded to criteria related to the definition of spatial limits of a Watershed, a sub-Watershed or micro-Watershed, found within the boundaries of the ROCC.

These workshops were carried out on a three day timeframe, which required previous planning and organization both from the ACP and the communities that expressed their willingness to actively participate in the future of the ROCC. The work groups were formed by delegates elected in democratically held community meetings, which represented their communities before the ACP, in order to present the reality of their environmental, social and production problems. This way they created an active participation between the ACP and the farmers' communities, towards the diagnosis, elaboration, planning, implementation, and evaluation of programs and projects for the protection of water resources. This process of citizen participation and disclosure between the ACP and the farmers' communities was carried out after the First Farmers Encounter; ACP – Farmers from the ROCC, held in September, 2001. The following information summarizes the work carried out by the work groups:

- The first work group session was carried out from March 16 to 18, 2002; with the participation of 52 delegates from 21 communities and farmer organizations from 4 micro Watersheds of Cocle del Norte River.

- The second work group session was carried out from April 26 to 28, 2002; with the participation of 70 farmer delegates from 35 communities from Toabre River watershed and the San Miguel River watershed.

- The third work group was carried out from June 7 to 9, 2002; with the participation of 34 delegates from 21 communities from Miguel de la Borda River Watershed, Caño Sucio River watershed and the higher portion of Taobre River Watershed. This Work session was held in Penonome.

- In the fourth work session the 54 farmer delegates represented 22 communities from the Indio River, Teria and Uracillo watersheds. It was held in Penonome from august 9 to 11, 2002.

An open participation methodology was used throughout the work groups. The session started based on the participants expectations, a social-environmental diagnosis was performed for the Watersheds, sub-Watersheds and micro-Watersheds, identifying natural resources, its uses and threats. The most significant social problems pointed out by the communities were discussed. At these four work groups, the participants had a chance to express their concerns for the problems that they considered most relevant, some of these are: indiscriminate forest logging, water contamination, lack of roads, and poor conditions of health and education facilities. In summary, the following topics were discussed: land ownership, environmental problems, problems related to the social situation in their communities, Law 44 and Law 19.

A second gathering was carried out on November 15, 2002. The main objectives were to revise and evaluate the agreements reached during the first ACP – Farmers gathering, during the period between of October 2001 and October 2002; submit the results obtained from the four work groups for Watersheds and sub-Watersheds developed between March and august 2002, and establish a joint action plan to direct work for the years 2002 – 2003. During the second gathering 208 delegates participated, distributed as follows: 47 delegates from 5 micro-Watersheds of Cocle del Norte, 70 delegates from 7 micro-Watersheds of Toabre, 34 delegates from 4 micro-Watersheds of Caño Sucio, and 57 delegates from 5 micro-Watersheds of Indio River.

It must be pointed out that the problems of the region in general were discussed during all these meetings, as well as the promotion of a general Farmers Law but the specific topic regarding water source options, was not discussed since the studies, and technical, economical, environmental and social feasibility analysis, were at a preliminary stage.

7.1.2 Assessment of ACP – Community Meetings

ACP has carried out a significant number of meetings in the area, visiting practically all the communities. They have carried out two major gatherings in which delegates from different communities have actively participated in work groups. Most participants, were members of functional organizations, characterized by surfacing when specific problems affect the community. However, social segments do not seem to be represented, those groups that come from the communities' dynamics (family alliances, marriage associations, relatives), or in other words, social capital elements. A small participation from women was noted during these events. It was also observed that, regarding the farmer groups, their questions were quite basic and mostly for information purposes.

On the other hand, the workshops and consultations have been held in a way that people are encouraged to speak about their problems and needs. Due to the fact that the solutions to problems presented required a coordination and institutional planning process, the events sponsored and developed by ACP since 2001 have been forums in which farmers, the ACP and other members present in the ROCC have been able to exchange information, talk, and make consultations. This way, social and environmental problems have been identified, upon which thoughts have been placed and initiatives proposed geared towards the promotion of community development, and to establish alliances between ACP and farmer communities in order to ensure the sustainable use of natural resources within the Watershed, specially water resources.

In general terms, it can be indicated that the participation process has generated many expectations, that for now, have not been satisfied because the process to establish the mechanisms needed to supply answers has not yet concluded. ACP continues to maintain close communication with the communities in the region, in order to identify feasible actions and mechanisms that could benefit the communities (CICH could play an important role in expediting the actions and proposals in benefit of the region). Other interested parties / groups have taken advantage of the situation, and use it to their own benefit.

The environmental problems discussed reflect the general situation of the watershed. It is a reality that all inhabitants must face. On the other hand, the situation is about communities that

live on an informal subsistence economy with few possibilities for development without active participation from the government. There are many basic infrastructure projects needed in the area, in order to provide the local inhabitants with the minimum required to fulfill basic needs. Permanent access roads that could allow access to other public services such as electricity, potable water and modern transportation, are of special need and importance.

Other functions, achieved by the public gatherings were informing the communities, which is fundamental in creating participation forums. Consultations were carried out by the delegates, which allowed a more profound discussion on critical subjects such as land ownership. The explanations assisted the farmers in the decision making process regarding land legalization. Within the framework of the current situation, the gatherings and its work groups are initiatives that offer suggestions to resolve problems. On the other hand, taking into account that traditionally the authorities have neglected this region, the ACP's interest could generate false expectations. ACP can not interfere to solve socioeconomic, infrastructure development and product commercialization problems. This is a task for the corresponding government authorities, which in one way or another are represented in the CICH.

From a sociological stand point, these meetings constitute important social transformation factors, since they have created conditions to develop changes in the local communities. Keeping proper proportions, since the delegates do not necessarily represent everyone, room was given to discuss and present the most important problems in the region, as well as the opportunity to establish possible solutions. In consequence, by establishing and defining their needs, communities are conscious of them. The participation environment also indicates the importance of cooperation and solidarity.

Since, during the citizen participation events carried out to date, no decision on the Panama Canal Expansion had been taken, subjects such as possible relocations due to a water project were not discussed. Once the Citizen Participation Plan is performed, there will be a clearer vision of the of the viable options for the region, therefore the subject of relocations will have to be addressed in meeting and work group sessions. This subject is considered of importance because due to the extreme poverty level in the region and communities, any change produced in the area without the proper consultation process and precautions could present a major risk for creating even higher poverty levels due to the loss of a known habitat and solidarity networks that emanate from social segments. These are units of families, marriage alliances, that ensure the stability of social life.

7.2 Participation Plan Purpose and Objectives

The purpose of the citizen participation regarding the water options of the Indio River watershed should include the tasks currently being carried out by the ACP, such as the preparation of the Master Plan and the search for other water source alternatives. Within this framework, the purpose of the consultation is to enrich with comments, concerns and suggestions by the local communities, their organizations and the general public, the socially feasible water source options selection process. The implementation of this participation plan, in case the Plan for Expansion and Modernization of the Panama Canal is approved, does not substitute the need to carry out a public consultation once the viable option, or options, have been clearly defined and selected. The objectives of the Citizen Participation Plan can be summarized as follows:

- Inform on the possible water source options.
- Inform on the possible compensation mechanisms if the project is implemented in the Indio River watershed.
- Promote public citizen participation during the environmental evaluation process.
- Obtain opinions and/or concerns from the local inhabitants about the specific water source options, in order to incorporate them during the Impact Evaluation process.
- Communicate the results from the public participation process to the involved communities.

From URS' perspective, in order for the implementation of one or more water source options to be considered socially feasible, they must comply, with at least three conditions:

- Existence of a clear, realistic, concise, compensation mechanism, and widely accepted by the involved parties.
- Participation of one or more efficient, trustworthy and publicly accepted institutions (i.e. CARE, Fundación Natura, private contractors) to assure the implementation of the compensation mechanism, and
- Establishment of formal agreements in order to ensure compliance with the agreed schedule of implementation.

If these three conditions are met, those who have had certain apprehensions, but not a negative position towards the development of water source options might turn to support the idea decisively. Moreover, those who have shown strong systematic opposition might reconsider their stand. Therefore, these elements must have priority within the consultation process.

Since the water source options are still projects under study, the three above mentioned elements have not yet been structured. As the consulting jobs advance, a first estimate will be obtained for the compensation plan and implementation, control and follow up procedures, that could be consulted to determine the degree of acceptance. This would form part of the information to be communicated as part of the Citizen Participation Plan.

On the other hand, there is still an additional complication, which is that the place and time of implementation of the water source options is still unknown. Moreover, there is a possibility that this will not occur at least within the first phase of the Modernization of the Panama Canal, which is associated to the construction of the third set of locks. Consequently, the mitigation mechanisms that will be discussed as part of the communication process will be conditioned, specially when related to the compensation mechanisms that would be applicable to particular individuals or families.

It is also important to point out that the Citizen Participation Plan described herein, can contribute to promote dialogue between the ACP and the communities located in the Indio River watershed. However, to assure that the communities provide positive elements for the best water source options, URS considers appropriate to consolidate the agreements and plans related to the needs identified by the work groups and farmers gatherings, and to implement the mechanisms to carry them out. With this action, it is not being suggested that the ACP become responsible for carrying out projects to improve the quality of life of the inhabitants, rather than to serve as a mean for these needs to be considered by the CICH members; who are the government entities responsible for providing basic public services.

7.3 Legal Framework for Participation

7.3.1 Background

The Republic of Panama has legislation that deals with environmental protection, conservation and recovery. Through Law 41 from July 1, 1998 it was established that environmental management is a government obligation. This law organizes all environmental related matters and integrates social and economical objectives with the goal of establishing policies for human sustainable development.

Executive Decree No. 59 of March 16 of 2000 establishes the procedures for Environmental Impact Assessments, whose main objective is to guide the application of preventive environmental impact assessment processes, and incorporate the environmental aspects into all

new projects, and modifications of existing ones, in the Republic of Panama. According to this decree, the Environmental Impact Operating Manual is adopted on September 10 of 2001, as a guideline for the preparation and evaluation of environmental impact studies.

7.3.2 Citizen Participation

Citizen participation is a mechanism that allows the population to be informed about possible projects that could potentially affect the environment, quality of life, as well as to gather information from the local inhabitants regarding their concerns and observations on the study, as well as on the proposed actions. The purpose of citizen participation is to improve transparency of the process and to ensure the citizens' interests and the protection of the environment within the context of sustainable development.

The Development of a citizen participation plan must include the means to inform the population about the project and the procedures to be used to encourage participation, and the aspects that will be considered for the execution of the plan. The Citizen Participation Plan is based on two main guidelines: The Environmental Impact Operating Manual, Resolution No. AG – 0292 – 01 from September 10, 2001, and The World Bank Guidelines for Environmental Assessments, that include recommendations for citizen participation (see section on Legal Framework in the Project Description Chapter). Both documents agree that citizen participation must be elaborated in accordance to the following contents:

- Encouragement for citizen participation during the elaboration of the Environmental Impact Studies.
- Citizen participation through surveys, interviews, workshops, meetings and work groups.
- Mechanisms for communicating information to the population.
- Information request and response from the community, and particularly environmental groups and similar organizations.
- Ways to resolve potential conflicts.

Basically, a Citizen Participation Plan must have objectives such as: Promote citizen participation during the environmental impact analysis process, request information and help from the communities and interest groups regarding the proposed actions, inform on changes introduced to the proposed actions, and anticipate conflicts.

7.4 Design of a Citizen Participation Plan

Citizen participation is guided towards encouraging a proactive meditation process for all stakeholders regarding the problems ACP encounters in searching for water source options. It is about a process to establish a scenario of rights and obligations that would allow an unobstructed feedback process.

The citizen participation plan and public consultation must include a wide strategy, considering a conceptual definition of the objectives to be achieved, and a baseline questionnaire. Methods used for this process of creating the right conditions for public participation include: identification of main contacts, participation of the consultant's team at the meetings, community gatherings or forums, interviews with local inhabitants as well as representatives of local institutions, and interest groups involved in the project development.

For the design of this particular citizen participation process on the possible implementation of the water source options at the Indio River watershed, the following elements are proposed:

- Establish a dialog content
- Identify legitimate participants
- Exteriorize underlying premises
- Establish the "rules of the game"
- Expand public communication forums
- Make decisions
- Share participation results with the communities, and
- Identify additional participation / coordination opportunities

7.4.1 Dialog Content

First, the consultation objective has to be clearly identified, which must focus on discussing the water source options at the Indio River watershed in order to avoid confusing this scenario with the modernization of the Canal; evaluating the environmental impact of the selected option, or public consultation on formulating sustainable development scenarios. It must be pointed out that, the legitimate participants, formats, and other aspects of this participation process to decide on the Panama Canal Modernization, are very different to those required to analyze the social and environmental feasibility of the water source options.

In the case of modernization, all Panamanians are legitimate participants, the executive branch is who makes the consultation, and the format is a referendum that includes popular vote. As a result, the decision to proceed or not with the modernization of the canal will be made. However, this is not the participation process proposed at this moment.

This citizen participation process is much more limited, and the decision to be taken is to simply recommend one or more options as part of the plan. If the modernization plan is not approved, the water options or options included in the plan will not be implemented. On the other hand, if the decision for the modernization of the canal is accepted, changes regarding the water sources options could still be made.

Another concept that must be clarified is that the Citizen Participation Plan will not only involve the communities that could potentially be affected, but also government entities and non-government organizations with certain interests in the area or subjects. Therefore, meetings carried out as part of the plan could include towns and residents outside the Indio River watershed.

With this background, the list of topics for public consultations with the local communities and interested groups can be established. Following the objectives set forth for the Citizen Participation Plan, the table of contents will be oriented to divulge information and obtain the necessary feedback from the population, specifically for the water source options.

However, as previously explained, it is considered necessary to provide proper continuity to the efforts carried out by the ACP, in order to strengthen the communication ties with the local communities. Proper follow up is necessary so the communities do not feel that the important topics established at the work groups (i.e. lack of basic infrastructure) are being abandoned. This could result in an unsuccessful public participation plan for the water source options. The Appendix suggests a specific table of contents, which emphasizes that it would not be part of the citizen participation process for the analysis of the options, but its implementation is necessary for the process to have greater probabilities of success. This table of contents is later referred to as a "Precursor Content" to indicate that its implementation is important for the citizen participation process' success, and that it must be implemented prior to the citizen participation plan for the water options. The specific table of contents for the citizens' participation, in the environmental analysis of the water options considered for the Indio River watershed, are described below:

- Introduction. The objective of the meeting will be outlined in clear and concise terms. The special interest of the ACP in the Indio River watershed and its importance for the Canal Modernization Plan will be explained as part of the introduction. It will be indicated that the water source options at the Indio River watershed are only some of the alternatives being considered, for the Canal Modernization Plan, but not all. It will be emphasized that the Modernization of the Canal is a decision to be made by the Government of Panama and the Panamanians.

  The main reasons that motivated the interest in the ROCC and the creation of Law 44 will be described: Water and the need to protect its quality from potential threats that could affect it. The excessive damage produced at the Watersheds, caused by deforestation as in other regions of the country and the risk of mining activities, could be mentioned. To this respect, the ROCC could be considered as the most important water reserve in the Republic of Panama due to its closeness to the canal. Similarly, Law 44 must be seen as the mechanism to maintain this reserve, and the ACP as the responsible party to achieve this goal along with the local communities. This reserve, even though after carrying out the studies could not be used during the first stage of the modernization process, must be protected for the future.

- Water source options. Clear and graphic information will be presented on the preferred options for the Indio River watershed. It is recommended not to present all possible options being considered, but only those preferred by the ACP after carrying out a preliminary analysis. Presenting options that could potentially be discarded could produce unnecessary concern within the communities.

- Identification and evaluation of impacts. The main impacts that could be generated with the implementation of the chosen options will be presented in a simple way, through graphs and figures whenever possible.

- Mitigation and compensation mechanism. The actions guided towards avoiding, compensating or mitigating all identified impacts will be explained. This is a vital and important aspect because the mechanisms through which mitigation or compensation will be implemented must be made very clear.

- Work group – Identification of critical community aspects. After the presentations, discussion groups will be established. The number of groups will depend on the amount of participants, but will most likely be formed by five or six members each. The main

purpose of these discussion groups is to analyze the information presented regarding environmental evaluation, in order to obtain feedback on the impacts and mitigation formulas proposed, and to determine if these are adequate from the participants' point of view. The section related to workshop development explains the work group mechanism in greater detail.

- Identification of opportunities and recommendations. The community representatives will present the results from the discussion and workgroups to all workshop participants. As indicated previously, this will be carried out for the physical, biological and socioeconomic environments.

- Closure. After the participants present all the recommendations, the facilitator will present a summary of observations and recommendations before formally closing the event. Commitment from the ACP will be mentioned during the event closure, stating the intention to follow up on the observations and recommendations by including them in the Environmental Impact Study, to be prepared when a decision on the specific project is made. It shall also be indicated that when the observations and recommendations performed at the workshop have been taken into consideration, a summary of the comments considered relevant and how they were taken into account in the Environmental Assessment will be sent to each participant. This summary could also include clarifications to the impact evaluation and mitigation alternatives, agreements between the communities and the ACP, and a detailed compensation plan, among other aspects.

- Report. The results and conclusions will be summarized in a report that will be prepared after the workshop closure. The report will narrate all activities carried out during the workshop, and will clearly and concisely present the main subjects discussed, along with the conclusions that were agreed for the presented options. When necessary, the workshop report summary will detail specific recommendations that must be included, or not, as part of the scope of the environmental evaluation for the water source options. This is clarified because it is likely that during workshops, proposals and recommendations are made that are not necessarily related to the environmental evaluation of the water source options, nor to the mitigation or compensation alternatives associated to them. Therefore, those recommendations that are clearly not covered in the scope of the environmental evaluation must be identified, and the best course of action must be defined for them to be taken into account under a different work scheme. Section 5.7 of this document suggests a structure for the workshop report.

- Follow up. In order to close the participation cycle, follow up must be provided to the suggestions made during the workshops. In other words, a second session must be coordinated once all consultations and recommendations have been satisfied, in order to present how they were handled, and how they affected the environmental, social and economical evaluation of the water source options. During the event, an effort should be made to inform all participants about the consultations, results and how it affected the decision making process and the environmental evaluation document (including management plans, and mitigation and compensation mechanisms). Also, during the event, it is important to obtain feedback from the participants regarding the impact of the Participation Plan. In other words, it should be determined if the Plan was successful from the participants' point of view.

The information URS has reviewed to date, indicates that even though there is opposition from some sectors towards possible water source options, the attitude (in general terms) towards an open dialogue is positive. Taking this as our starting premise, the objective will be to minimize the risk of rejecting the participation agenda towards a previously agreed dialogue with the communities. To reduce even further a possible rejection to open dialogue by the community, a mediator that provides trust among the participants will be involved during the implementation of the Plan.

7.4.2 Participant Identification

Adequate identification of the potential participants is vital, and will avoid the exclusion of groups or interested individuals and consequently, potential conflicts. It also contributes to determine the contents of the invitation and the selection of techniques to be used to promote participation. Without a doubt, the most important consultations will be carried out with the farmers' families whose land, homes, schools, churches and health care units will be directly, and indirectly, affected by the water source options. Because of all this, the participants can be classified as follows:

- *The Displaced:* those residents with homes that will be relocated due to land flooding or construction of channels or other infrastructure elements.
- *The Isolated:* those whose homes and lands will not be flooded but whose access to public services and infrastructure will be flooded (roads, education or health facilities, etc.)
- *The communities located downstream* from the civil structures and whose water supply will decrease.

- *The receptor communities:* communities inside or outside the region to be flooded, and that will be forced to receive those relocated.
- *The affected neighbors:* households that without having to lose land, homes or access roads, but will suffer other economic or epidemiological impacts; or households that could benefit from new services made possible because of the implementation of one of the water source options.
- *Interested parties:* persons or groups that either due to their origin, or by the nature of their organization are interested in the activities that will be developed at the ROCC, and that want to see a sustainable development region, with or without the implementation of any of the water source options. This category is not limited to the and it is considered that different types of organizations nationwide (NGO's, universities, civic groups, government entities, research institutes, etc.) would form this group of "interested parties".

The identification of social subjects to participate in this citizen consultation, is part of a process through which the objective population under study is defined according to their race, culture, endogamic group, kinship units and associations. For this purpose the following concepts must be differentiated: functional organizations and social segments.

Type of Organization	Level of Participation
Functional organizations	• Community delegate who has participated in ACP events • Civic, sport, religious and political groups • Authorities • Local Governments
Social segments	• Key or outstanding community persons • Family clans • House wives

Functional organizations are defined as those organizations that originate when a specific problem arises; regarding the community / area. These organizations characterize themselves for originating within the context of a problem, so urgent to the community that it creates opportunities for discussion and participation. This allows these organizations to be platforms for consultations where alternatives can be presented.

Social segments are those units particular to a community, that condition social life and social organizational style. These are units of kinship and alike (marriage alliances) from which a social scheme is elaborated. These units can have a strong influence within larger groups, or they could operate independently. Each traditional community has its own association system, because there are various ways of tracing back their kinship and marriage alliances.

Working with social segments facilitates the process of identifying and anticipating possible conflict situations, because they could be antagonistic among themselves, therefore facilitating, or truncating, possible agreements within the local community. It must be reminded that in small rural communities, the primary bonds are fundamental because all inhabitants know one another and maintain numerous personal contacts.

7.4.3 Exteriorize premises

For the dialog to be beneficial all participants in the consultation process must share some basic premises, which are described below:

- **Obligations and rights.** Establish obligations and rights of the participants.
- **Legitimate agendas.** Each participant has a legitimate agenda to follow, derived from their rights and obligations.
- **Conflicting agendas.** Even when considered that an agenda is legitimate, they can be different.
- **Alternate negotiation route.** In case of any discrepancy between agendas, alternative negotiation paths will be explored to facilitate dialog. Negotiations are based on the premise that each and every one must modify their original position.
- **Good will.** All parts must act on good faith.
- **Intention to comply.** All parts should have the intention to comply with the agreements; but given the case, legal and moral mechanisms could be used to protect the participants if any fails to comply.

All these premises must be previously agreed with all participants for the dialogue to be successful and within the limits of the previously agreed topics. This could be developed during the introductory phase for the meetings, as indicated in the Subject List.

7.4.4 Rules of the game

The rules of the game refer to the scope of the consultation objectives, which in this case mainly refers to the identification of new potential water sources within the Indio River watershed. It is in the best interest to carry out an ample consultation that includes all interested parties in order to: inform on the plans and expectations of the ACP within the context of Law 44, promote discussions where expectations and concerns can be presented, gather opinions that enrich the environmental impact evaluation process taking into account all expectations and concerns from the interested parties.

7.4.5 Communication formats

Understanding and interpreting the actions proposed by the ACP in search of water source options by both parties must be an integral part of the citizen participation plan. According to the Environmental Impact Evaluation Operating Manual, the following question must be answered at this level: How is the population going to be informed of the project? The inhabitants of the Indio River watershed cannot be interested, much less support it, if they do not understand it or know it. This demands time, dedication, effort, and presenting the information in terms that can be easily understood and accepted by the community.

What kind of procedures will be used for participation? This question is not easy to answer because, on one hand due to the regions' poor access conditions, media such as radio and handing out pamphlets could be convenient to communicate information, however, this indiscriminate way of spreading information could potentially introduce more confusion in a region, that already is being misinformed by groups with particular interests. Therefore, it is considered that informing about the water source options must be carried out in person, through work groups and workshops. Typically, communicating information is performed separately from the gathering of opinions about the project. However, due to the above-mentioned reasons, it is considered more appropriate that the disclosure of information and the gathering of opinions about the water source options be part of the same event. Because of this, it can be noted in the contents and planning of consultation events that a designated time has been allocated to present information on the water source options. Mass communication media should only be used whan carrying out invitations to citizen participation. In other words, once the participants have been established, mass communication media could be used. However, information will be given only during the workshops, and not through mass media communications.

Since many residents of this region do not receive information through newspapers, and many do not have radios, it is very important to include, during the promotion phase for citizen participation, those individuals who the communities commonly listen to (i.e. local authorities, doctors, nurses from health care facilities, small store owners, religious leaders, heads of traditional families, etc.). To carry out this activity, first, invitations are handed out to the different communities that should participate in the consultation events. During this process, a social team (assisted by the ACP's social group) will visit the chosen communities to personally hand out the invitations for the citizen participation event (see section on invitations). During these trips to hand out invitations, the social team will identify (if it is not know previously) who is the person, within the community, that possesses the characteristics previously mentioned. Once identified, the team will proceed to hand him/her out an invitation and indicate, depending on the case, the number of persons from that particular community that could attend to the citizen participation event. The social team would also take the opportunity to communicate the place, date, time, and other details related to the event (i.e. transportation and lodging) to all participants.

The contents of the information to be disclosed must consider the type of participant for the event. According to the proposed classification to identify the type of participant (displaced, isolated, downstream communities, receptor communities, affected population, interest groups, etc), their interests and concerns will vary: What will be done?, How will they be affected ?, What type of compensation will be given ?, How and when will they receive it ?.

7.4.6 Dialogue format

Dialogue format is the basic relation between all participants. There are three formats that are generally used when representatives from government institutions or NGO's want to talk to rural communities.

- **Command format:** This format is used by government entities when they inform about a decision already taken. In this case, decisions are usually made without previously consulting the affected parties. The communities simply receive the information from the authorities about the decision.

- **Pedagogic format:** This format implies that the institutions take on a "teaching" role, as they transmit the knowledge, gather opinions and create awareness in interested groups. The basic premise for this approach is that the farmers lack the knowledge that the "teachers" can transmit.

- **Negotiator / contractual format:** In this format an equal interaction between participants using the "you give, I give" approach. It is a totally horizontal / negotiating form.

It is recommended to use the negotiation / contractual format, which implies, at first, acceptance from both parts that the ACP is the government institution in charge of managing, improving and overseeing the proper operation of the Panama Canal. If divergences regarding the obligations and rights from the ACP as well as the communities located within the watersheds should occur within this negotiation format, then alternatives shall be searched for in order to obtain possible convergences.

7.4.7 Decisions and Agreements

The results obtained during the Citizen Participation Plan must be systematic regarding the initial objectives: the search for water source options at the Indio River watershed, which must be consistent and provide feedback for the tasks currently being carried out by the ACP such as the preparation of the Master Plan. Within this framework, the purpose of the consultation is to enrich with the comments, concerns and suggestions from the local communities, their organizations, and the general public, the selection process of the water source options that are socially feasible.

7.5 Implementation of the Participation Plan

Once the persons and groups that will participate, the topics and the consultation objectives have been identified, it is necessary to choose the dialogue format, the places where the meetings will be carried out, and a general schedule for the execution of the consultation activities.

7.5.1 Participants

In order to size the consultation meetings, it is important to review the composition of the Indio River watershed from the demographic and political – administrative standpoint. The ROCC has an extension of 2,131 Km^2 and comprises about one half of the total region, comprised of 17 corregimientos located in the provinces of Cocle (9), Colon (4), and the Town of Capira (4) at the Province of Panama. Within the ROCC, the Indio River is the second largest watershed (387 Km^2) and it comprises a third of the region of eight corregimientos involved: 3 at the province of Cocle, 1 at the province of Colon, and the 4 remaining at the town of Capira, Province of Panama. Here, the percentage of territory within the specific areas of interest is only 18% of the total area of the watershed.

The analysis by corregimiento presents different situations. For example, the corregimiento of Santa Rosa has about 70% of the total area within the watershed, followed by Ciri Grande which has 66%, Indio River de Penonome with 47%, and Ciri de los Sotos with 38%; the other 4 corregimientos are below the average. On the other side, the territory that could be flooded has greater importance at Ciri de los Sotos (16%), followed by La Encantada (Chagres), and Indio River (Penonome) with 12% each.

The population located at Indio River represents a fifth of the total population of the ROCC. A similar percentage is observed at the province of Colon (20%), and to a slightly less proportion, the province of Cocle (11%). On the other hand, within the ROCC, this watershed comprises 100% of the corregimientos of El Valle, La Encantada, and the 4 corregimientos of Capira. It also includes a significant percentage of the population of Indio River (Penonome – 55%).

The identification of towns, that should be included in the participation process for the water source options, was carried out based on the type of participant. In other words, first it was necessary to identify who was going to be displaced, who was going to be isolated, etc. This exercise was carried out for the watershed region, using the database information from the Collection and Presentation of Socio-Economic Data Project for the ROCC. The results obtained are presented as follows:

Type of Participant	Watershed	Towns
Displaced	Indio River	Boca de Uracillo, El Aguila, El Barrero, Pon la Olla, El Silencio N° 1, Las Quebradas de Uracillo, Manguesal , Quebrada el Macho, Quebrada Jacumilla, Quebrada la Conga, Coquillo de Uracillo, Silencito, Pueblo Nuevo, Piedra Amarilla, Los Frailes, La Arenosa, La Sardina, Las Postreras, San Cristóbal, La Mina, Cerro el Clavo, Los Uveros (P), Teria N° 3, Tres Hermanas, Quebrada la Conga Abajo, El Zahino, El Limón N°1, El Limón, Palma Real, El Harino, Torno Abajo, El Tornito, Tres Hermana, El Torno.
Isolated	Indio River	El Silencio Arriba, Los Uveros Arriba, Riecito Abajo (P), El Hinojal Arriba, Los Santos
Downstream	Indio River	Tres Hermanas, El Dominical, El Jordan La Tortuga, El Castillo Santa Rosa, La Pólvora, Quebrada Bonita, El Pepito, El Guasimo (P), Loma de Piloncito, Sancuderito, Cerro Pelao, La Cerdeña, Las Delicias, Ventura (P), La Cañaza, Chilar (P), El Charcón, Terminal del Plan, El Cajón, Pueblo Viejo, El Valle o Bajo Grande, Santa Elena, Guayabalito o Boca del Jobo, El Cacao, El Jobito, Piguila o Pinguila, La Tuza, La Puerca, Barnizal, Nueva Unión, La Paila, Los Órganos, La Cecilia, La Tigrita, Castillito, Alcarreto, Mi Campo Ranguillero, Torno Roto, El Berraco, Vista Alegré, La Encantada, El Jobo de Indio River, Charcón, Boca de Indio River.

Type of Participant	Watershed	Towns
Neighbors and receptors	Indio River	Boca del Silencio, El Ladrillal de San Cristóbal, El Ají, Coquillo Centro, El Espavelar, Cerro Miguel Nª 2, La Mona, Loma de la Cigarra, Los Molejones, Tierra Buena, Tres Hermanas, El Limite, La Negrita, Los Naranjitos, Los Rastrojos, Cigua, Coquillo Abajo, El Silencio Arriba, Alto del Naranjo, Los Uveros Arriba, Quebrada la Conga Arriba, Riecito Arriba (P), Tres Hermanas Arriba, El Hijonal Arriba, Nuevo Limón, Quebrada Limón, Riecito Abajo (P), El Dominical, El Jordan, Quebrada los Cedros, Cerro Benito, Boca del Paso Carnal, El Ahogado, Cerro Hinojal, Ciricito Arriba, La Bonga o el Cruce, La Encantada, Los Cedros, Los Santos, La Puerca Gorda, El Nancito, Nueva Arenosa, El Jobo Arriba, Nuevo San José, El Campano, Nueva Unión, La Paila El Berraco.
Interested parties		Government Entities Representatives, NGO's like: ANAM, MIDA, MOP, MIVI, IPAT, AMP, MICI, ARI, CARITAS Arquidiocesana, NATURA, MINSA, MEDUC, FIS, Cities, PANAIDIS, ANCON, CICH, Universities

It is recommended to carry out one workshop for each type of participant. This event could gather participants from different watersheds, if there are several watersheds involved in the water source options. Events by type of participant are listed below:

Event 1 --- Workshop for all possible "displaced" at the Indio River watershed (between 75 and 100 participants).
Event 2 --- Workshop for all possible "isolated" at the Indio River watershed (between 20 and 40 participants).
Event 3 --- Workshop for all "downstream communities" (between 50 and 75 participants).
Event 4 --- Workshop for all possible "neighboring and receptor communities" (between 50 and 75 participants).
Event 5 --- Workshop for all possible "interested groups or organizations" (between 20 and 40 participants).
Event 6 --- Workshop to the present results obtained from the participation process and to collect the participants' feedback (between 150 and 200 participants).

Note: No decision has been made at this moment regarding the water source option, or options that should be consulted. Therefore, the Indio River watershed is referred to, in general terms, to reflect that the participation could include one of the options from this watershed, depending on the option, or options, to be selected.

7.5.2 Meeting Places

Experience within the ROCC has demonstrated that there are a limited number of towns that are suitable for events such as meetings or seminars. Therefore, at the moment of the Plans' implementation, a location with all required and adequate facilities for this type of activity must

be identified. The town of Sonadora at Penonome has adequate facilities to accommodate participants and carry out workshops and seminars. The ACP has used this town for this purpose in the past. Therefore, this town could be a good selection to carry out meetings, as part of the Citizen Participation Plan. When implementing the Participation Plan, while delivering invitations, other places that hold the previously mentioned characteristics could be considered.

7.5.3 Invitation

As previously mentioned, the invitation for citizen participation could be made through mass communication media like radio, dissemination of pamphlets, and visiting the areas where the participants will come from. Below is the suggested text for the invitations:

Dear resident of Community <name of community> Watershed <name of watershed>:

The Panama Canal Authority (ACP) is currently analyzing the water source options within the Western Region of the Panama Canal Watershed (ROCC). As part of this effort, the ACP wishes to count on your participation in a presentation of the possible water source options, its possible environmental impacts, mitigation alternatives, and / or identified compensation mechanisms. The objective of this meeting is to encourage your participation as a citizen of the Region, to obtain your opinion and recommendations for the options that are currently under study.

It is recommended that your community appoints <amount> participants for the meeting, preferably local representatives from civic, sport, religious, political groups, authorities, local governments, natural leaders, or elderly community leaders.

The meeting will take place at <place>, <date>, starting at 9:00 a.m. until 4:00 p.m. Attached to this invitation you will find the program for the citizen participation meeting.

Your assistance to this event is greatly appreciated.

Yours truly,

ACP

The described invitation could be broadcast during radio shows, and handed out at the relevant communities before the scheduled events.

7.5.4 Methodology

Experienced Environmental Evaluation personnel will conduct the citizen participation events in Spanish. This personnel has vast experience in Environmental assessments and knowledge of common practices, and of local government institutions. The methodology that will be used can be summarized in two portions: presentations, and discussions / negotiations.

7.5.4.1 Presentations

The mornings and afternoons will be used to present information on the different water source options, their possible impacts and mitigation alternatives.

7.5.4.2 Discussion Groups

After closing the presentation sessions, discussion groups will be established. The number of groups will depend on the amount of participants, but most probably will be comprised of five to six members per group. The purpose of the discussion groups is to analyze the information presented in regards to the environmental evaluation, in order to obtain the necessary feedback about the options and possible impacts, formulate questions, and make all necessary comments.

To initiate the session, each group will designate a leader and a spokesperson, who will have specific functions. The responsibility of the group leader is to facilitate a proper discussion, while the spokesperson will document the consolidated standpoint from the group. The group will be requested to evaluate the following subjects:

Discussion Subject no.1: List effects (positive or negatives) that you consider the water source options could cause, and that have not been taken into account. Consider the possible effects on towns, environment and the local economy.

Discussion Subject no.2: For the above-mentioned purposes, recommend or suggest any mitigation alternative that you consider will help reduce the possible effects. Also recommend mitigation alternatives that you consider should be applied to compensate for the impacts that the water source option could cause.

Each group will have a total of 3 hours and 45 minutes to discuss and develop the required information for the physical, biological and socio-economical aspects. The groups will be given the option to develop all aspects, or only those that are of particular interest. The spokesperson for each group will present the results.

The intention of the workshop is to have the participants feel responsible, to some extent, for the identification of possible impacts, and to suggest mitigation alternatives. In this way they validate the Environmental Evaluation carried out.

This methodology, or technique, to be used during the consultation, is the "brainstorming" of ideas. The goal is to use this as a tool to encourage the work group effort, facilitating the development of new ideas on a specific problem or subject. This technique is particularly beneficial when the goal is to motivate creativity among the participants, and thus generate a good amount of ideas. The main goal is to work as a team to identify a problem and find, through proactive participation, the best group decision for an action plan that will solve a particular problem.

In the particular case on consulting the ROCC's water source options, this method clearly contributes to:

- Establish and solve existing problems
- Propose alternative solutions
- Encourage creativity
- Discuss new concepts
- Overcome conflict and contradictions

Brainstorming is inserted during the consultation process. It revolves around the following steps:

Presentation of alternatives	• **Evaluate** the proposals according to the interests and impacts caused (displaced, isolated, downstream communities, receptor communities, affected neighbors, other interested parties)
Brainstorming	• **Identify** the problems that could affect them (how) • **Expose** their expectations (what I want) • **Present** possible economical solutions (how) • **Establish** levels of responsibility (who, when, where) • **Determine** order of priorities during the decision making process after the consultation (who, when, where) • **Elaborate** a tentative action plan that considers: activities, resources needed and responsibilities

The consultation supported by the brainstorming process has a positive effect on the participants. When the process finishes, they have a better idea of what they want, the resources needed, how to take advantage of them, and the possible consequences.

This brainstorming methodology has been previously used in Panama, specifically in the "Corredor Biológico Mesoamericano del Atlántico Panameño" Project carried out by ANCON – CEPSA during 2002 and financed by ANAM. Also, it was used for the preparation of the Management Plans for La Amistad International Park, and Volcan Baru National Park.

It must also be mentioned that the brainstorming method to be used is very similar to the established tool known as "Participatory Rural Appraisal" (PRA). The former is the name used for the scope of participation and methods that emphasize local knowledge, **and allows the local population to make their own appraisal, analysis and plans**. The PRA methodology uses lively groups and exercises to facilitate the presentation of information, analysis and interaction between the interested parties. The objective is to allow developers, government entities and local communities to work together in order to generate appropriate programs within the context of the local reality.

The PRA methodology for local community participation in this type of activities is essential because of its value as a planning method, as well as for disseminating the scope of participation. The same is applicable for the brainstorming methodology, in which the peoples' participation is essential to reinforce the value of responsibility when they create programs for the identification of possible impacts, and when they suggest mitigation alternative ideas within the context of their local reality.

7.5.5 Event Program

The citizen participation events will be developed in a two-day work schedule. The program for each specific event will vary depending on the type of participants. For example, the group of displaced inhabitants will be more interested in listening to topics dealing with their relocation, rather than to topics related to inhabitants located downstream of the water source option. Below is a typical program example for citizen participation (Events 1 – 5).

Time	Content	Description
Day 1		
9:00 – 10:00 AM	Introduction	Establish purpose of meeting, rules of workshop, underlying premises
10:00 – 11:00 AM	Watershed conditions	Presentation of existing Watershed conditions (socio-economical, environmental)
11:00– 11:15 AM	Break	
11:15 AM–12:00 PM	Water Source Options	Presentation of preferred water source options for the watersheds. Use of maps, posters, transparencies, etc.
12:00 – 1:00 PM	Lunch	
1:00 –3:00 PM	Identification and evaluation of impacts	Present impacts of main interest to the type of participant
3:00 – 4:30 PM	Mitigation and compensation alternatives	Present mitigation and compensation alternatives of special interest to the type of participants
Day 2		
9:00 – 10:00 AM	Review of Day 1	Summary of information presented on day 1
10:00– 10:15 AM	Break	

Time	Content	Description
10:15 – 12:00 PM	Work group. Identification of critical aspects for the communities	Selection of primary impacts by the work groups (positive and negative), as perceived by the participants
12:00 – 1:00 PM	Lunch	
1:00 – 3:00 PM	Identification of opportunities and recommendations	Presentation of recommendations by the work groups in order to make the project socially and environmentally acceptable
3:00– 3:15 PM	Break	
4:30 – 5:00 PM	Closure	Closure speech

A recommended program for a workshop to communicate the results from the Participation Plan (Event 6) is presented below:

Time	Content	Description
Day 1		
9:00 – 10:00 AM	Introduction	Establish purpose of meeting, rules of workshop, underlying premises
10:00 – 10:45 AM	Summary of participation plan	Review of activities carried out as part of the participation plan
10:45– 11:00 AM	Break	
11:00 AM–12:30 PM	Results of the participation plan	Presentation of specific aspects that were modified as a result of citizen participation plan
12:30 – 1:30 PM	Lunch	
1:30 –3:00 PM	Identification of ways to participate	Work meetings will be carried out with the participants in order to identify adequate ways to provide proper process follow up
3:00 – 4:30 PM	Evaluation of participation plan	A questionnaire will be given to all participants to evaluate the success of the participation plan
4:30 - 5:00 PM	Closure	Closure speech

The previously mentioned evaluation for Event no. 6 will be carried out through a simple questionnaire that will be given to all participants of the Plan. Below is a list of questions that will be given as part of the evaluation of the Citizen participation plan:

1. Do you consider that your opinions were taken into consideration as part of the evaluation process for the water source options? yes / no
2. Do you consider that the presentations and the work groups established were enough to evaluate the subjects of interest? yes / no
3. Do you believe that the invitation for the workshop was adequate? yes / no
4. Do you think that a water source option could be successfully implemented? yes / no
5. Please rate as good, regular or bad the following aspects of the Participation Plan:
    a. Invitation
    b. Facilities (meeting room, rooms, bathrooms, etc.)
    c. Food
    d. Personnel in charge
    e. Material presented
    f. Obtained results
6. Do you consider that you know more about the water source options that are being considered within the ROCC? yes / no
7. Do you think that the proposed mitigation and compensation alternatives are appropriate? yes / no
8. Would you support a water source option if the mitigation and compensation mechanisms established in the workshops are assured? yes / no

The results from this evaluation will be processed and consolidated in a report.

7.5.6 Schedule

The Citizen participation plan must be carried out during a six month period, as established in the project schedule at the end of this chapter. The logic for the execution of the Plan includes performing a citizens' participation process related to the first table of contents, before the table of contents established for the water source options. The execution of the first one will facilitate the implementation of the second. The meetings associated with the first contents will be implemented in a period of approximately two months, while it is proposed that the meetings associated with the second content, related to the water source options, be carried out in a period of four months.

7.5.7 Evaluation and Analysis

During a consultation there are always diverse opinions that must be respected. These could be a positive factor if they are used in a constructive way, because often they reveal aspects that should be considered as important input for the environmental evaluation. Different groups of persons bring to the meetings many different needs, experiences and information.

The results of the citizens' participation are analyzed by the following indicators:

- **Motivation:** What drives it? In other words, which elements are considered important in order to participate in the consultation, and within the context of their particular reality. Some aspects are: perspective to land ownership, urban planning, legal aspects that could give access to credits and use of natural resources.

- **Opposition:** What drives it? It is interesting to learn the factors that limit positive participation in the discussion and the search of solutions. Some factors are: loss of socio-economic security, uncertainty upon an unknown world, and loss of routine spaces. Others could be political positions.

- **Converging points:** As a result of the discussion process, some paths or procedures to solve problems and different opinions are created in order to implement constructive activities:

It is proposed that, as result of the citizen participation plan to be conducted, reports have the following content:

Introduction. Relevant background for the event will be presented; the context of the event will be explained.
Participants. A list of current and past participants will be presented.

Objective. The objective of the event will be explained. General and specific objectives of the event will be pointed out.

Work methodology. The methodology used to conduct the event, to present information and to receive recommendations or suggestions from the participants will be presented.

Presented information. Any information presented during the citizen participation event will be attached to the document.

Suggestions and results. It will summarize the main results of the event, and contain the suggestions made by the participants.

7.5.8 Implementation Strategy

This section will present some important aspects for the execution of the citizen participation plan, such as budget, human resources, organization, and expected results.

Budget

The estimated budget for the execution of the Citizen participation plan is summarized as follows:

Description	Cost
Delivery of invitations	$12,000
Workshop agenda	$6,000
Development of workshop materials	$7,500
Execution of Participation Workshop	$20,000
Participation Plan Report	$4,500
Development of Material for Results Disclosure Workshop	$3,500
Execution of Results Disclosure Workshop	$4,500
Conduct Opinion Questionnaire on the results of the Participation Plan	$1,500
TOTAL	$59,500

Human Resources

The human resources required for the implementation of the Citizen participation plan is described as follows:

Director. A professional related to environmental and social sciences that will be leading the execution of the Participation Plan. This person must have ample experience in the elaboration of Environmental Impact Studies and the execution of Participation Plans associated to environmental evaluations. The Director will coordinate all members of the work team to ensure the compliance of tasks.

Social Science Technician. The technicians will be primarily responsible for the delivery of invitations to the participation events. They must be persons with field expertise, preferably from the region where the participation activities will take place.

Social worker / sociologist. The main responsibility of the sociologist or social worker includes the coordination of field technicians during delivery of invitations, and consolidating the agenda, in addition to executing the participation workshops.

Environmental Sciences Specialists. The project will require at least two environmental science specialists, which must be fully acquainted with the contents that will be presented during the workshops. In other words, they must fully understand and know the identified impacts for the physical, environmental and socio-economic aspects, as well as the recommended mitigation and compensation alternatives.

Engineering Specialist (Project Description). Personnel with engineering experience will be required to present the different water source options. They must have advanced knowledge of the projects under consideration. This personnel could be from the ACP's Capacity Department, or someone they designate.

Support Personnel. The task will require support personnel for the coordination and event logistics, facility acquisition, transport coordination, etc.

ACP Personnel. As interested parties and possible developers of the water source options, ACP personnel must be present during the participation events. They must also monitor the identified activities in the Participation Plan to ensure they will be carried out according to the established parameters.

An organizational chart is presented at the end of this chapter; illustrating the human resources required for the execution of the Participation Plan.

Expected Products

The products mentioned below will be generated during the execution of the Participation Plan:

- Invitation
- List of Participants
- Presentations for the Participation Workshops

- Participation Workshop results
- Presentation for the Disclosure of Results Workshop
- Participants Opinion Analysis

7.6 Expected Results

Even when the Citizen Participation Plan presented in sections 7.1 to 7.5 was not executed as part of this contract; this section presents a forecast of the expected results. To carry out this forecast, existing data from the citizens' participation process and information disclosure performed by the ACP through meetings and workshops was used. From this data, the positions or expected results from those affected once the Citizen participation plan is executed, were deduced.

The general objective for this forecast is to extrapolate, or extract, the possible answers or reactions from the specific affected areas in view of the foreseen situations established in the Citizen participation plan for the water source options. Also, it will take into account the acquired knowledge during citizens' participation and during the disclosure of information carried out by the ACP.

7.6.1 Interpretation of the applicability of the performed activities vs. The Proposed Activities

During the meetings sponsored by the ACP, with ample participation from the communities within the ROCC, the attendees were primarily members of functional organizations (local authorities, community delegates, Caritas, members of committees and clubs, etc.) which are characterized by emerging when faced by specific problems that affect their communities.

These meetings contributed to create conditions for dialogue within the context of an encouraging environment. The problems of the region were openly discussed during these meetings, and promotion of a farmer's law was also discussed. The subjects related directly to the specific water source options were not discussed. Due to the fact that the ACP was, and is still, studying the different options, it was not considered appropriate to expose the topic on the specific water source options. Therefore, the questionnaires conducted during the meetings are quite basic and only informative. The environmental problems discussed reflect the general situation of the Watershed. However, during different events some of the impacts, if the project of any of the viable water source options was implemented, that could potentially affect the inhabitants from the regions, were exposed. From this perspective, some important elements

could be inferred to extrapolate results for a possible citizens' consultation specific to the subjects related to the reservoirs.

For the proposed citizens' participation, first, proper reference to the concerns and proposals stated in the gatherings and workshops in order to provide continuity to the efforts of cohesion conducted by the ACP, and to take advantage of the consultation exercise carried out, is to be presented. On the other hand, the message must be sent out that the subjects discussed have not expired and proper follow up will be given through proper channels.

7.6.2 Risk Analysis and Limitation

Some of the limitations and risks foreseen that could be generated from the proposed analysis are:

- The process of information disclosure and participation carried to date has not been specific for the water source options. The persons that would truly be affected in case one of the water source options is implemented have not been consulted. Therefore, the estimated results are only an extrapolation of the results obtained from the persons consulted up to date. As previously identified, the conducted citizens' participation (to date) has not included the subject of water source options to increase the capacity of the Panama Canal. Summarizing, it is not the right time yet to conduct a consultation about the water source options.
- The information that is currently available is the product of the citizens' participation, and the disclosure of information carried out to date by the ACP; which is general, in nature. From this generic information, the proposed analysis extracts specific results.
- When the results are extrapolated, there is the risk of not taking into consideration the positions and concerns of the population segment that could most be affected.

7.6.3 Analysis of the Consultation According to: Motivation, Opposition, and Possible Convergence

The subjects described below have been widely described in chapter 4. Therefore, proper reference will be made in order to explain the forecasted position of those affected when faced by these topics, based on existing documents from consultations conducted in the area by the ACP.

Environmental Impact of Possible Reservoirs

Based on the comments and positions identified during the process of citizens' participation, and from the disclosure of information, it can be stated that, in general terms, the environmental impact that could be caused by an option, or options, would not be a matter of significant concern from the population within the ROCC. This statement is based on the fact the inhabitants' from the region acknowledged that the resources available in the area are greatly degraded. Therefore, when the information regarding the possible water source options is analyzed in the near future, it is not anticipated that the environmental topic will be of great importance to them.

Additionally, the topic of the degradation of the natural resources is a factor that has not motivated participation at the gatherings. On the contrary, the participation of the farmers was motivated by the interest of exposing their problems, and to assess the possibility of solving some of them. Their concern was focused on situations related to the problem of land ownership, legalization of land, and the coordination with other institutions in order to deal with the problems within the communities.

In general terms, the conclusion is that the farmers are motivated by the perspective of land legalization, and the construction of infrastructure that would allow access to resources and social benefits. However, this is a delicate matter that, at another moment, will generate opposition, considering the input of "other" interested parties, as in the case of political groups outside the ROCC.

Environmental and Economic Impact of the Decrease in the Rivers' Water Flow

This subject is of great importance because it will affect communities located downstream, which constitute a significant number of towns. This towns will be affected due to the decrease in water flow from the rivers, because their way of life could be seriously impacted, specifically their means of transportation and trade. It is expected that this will be an important subject for discussion when more details about the water source options are given out. It is assumed that this will generate uncertainty, which could lead to serious questionings.

Loss of Land and Resources

During all the meetings and workshops carried out, the loss of land and resources has been the main topic of discussion. Therefore, this is expected to be the impact of most concern to the

residents, because the land is their only source of income for survival. For the farmer, the aspect of land legalization has been a fundamental concern; therefore, the land legalization program was created. However, this motivation has been limited because of apprehension towards ACP, since the land legalization program is seen by some, specially the Farmer Coordination against Reservoirs (Coordinadora Campesina Contra los Embalses), as a mechanism for the ACP to quantify the land owned by the farmers, and a baseline to design a compensation program.

The consensus gained during from the consultations conducted among the residents reflects their concern for the subject of land ownership, and the goal of acquiring a land ownership title.

It is foreseen that this impact will particularly affect the displaced residents, who will have to be relocated because of future flooding. The loss does not only involve their land for crops and game, but the area they are familiar with and gives them a sense of protection and confidence. It is a matter that will affect their lives as a whole. The isolated residents will suffer the loss of some vital social benefit or resource when the access paths are eliminated, as well as the loss of hunting grounds and land destined for crops. For the small farmer this situation is particularly tied to the loss of a food source, and income. Even the partial loss of land or access to them could economically affect the families of small farmers.

A direct consequence from the loss of land and resources is the relocation of the affected residents, which presupposes the availability of land to be given to these families. On the other hand, the impact these families will have on their new relocation sites must be pointed out, because they will put pressure on the scarce resources they have. Relocation, especially of the residents that depend on the surroundings, implies the loss of a familiar and comfortable place with solidarity networks that could not be easily created again. Therefore, it is necessary to identify all possible risks that the residents will face, and quantify with greater precision the number of persons that will be affected by a specific water source option. The attitude and expectations of the affected population will vary according to the social and cultural obstacles that emerge to successfully carry out the process of relocation. This subject in particular is widely discussed in the chapters that deal with the identification and evaluation of impacts and the Environmental Management Plan.

Loss of Socio – Cultural Identity

If the reservoirs are built, these could produce a series of impacts or consequences that are quite difficult to quantify, which will affect the social and cultural conditions of the communities. Extracting the results obtained to date, it is clear that this matter is of great concern for the

residents. The displacement and relocation of the population carries consequences such as the loss of family bonds, friendships, sense of belonging to a place, and it also generates uncertainty. The farmers, residents from these communities, have been residing in the region for many years, many of who were born there, and will therefore be affected because of the rupture of these support networks, and for venturing from a known to an unknown site.

Loss of Other Sources of Income Different from Agriculture

The loss of other sources of income is a factor that will motivate the participation of the population during the consultation process, because just as the farmers may lose their land and homes, artesians and small business owners could loose their source of income. Moreover, some groups will loose access to their sources of income if they are relocated to another place. The loss of access to common resources such as grazing land, forests, and fishing areas could greatly affect the income and stability for subsistence of some groups, especially small traditional farmers. The impact that will be caused by the loss of production has been evaluated in the chapter on impacts, and the mitigation / compensation alternatives have been presented in the Environmental Management Plan.

Possible Types of Compensation

It is anticipated that this will be one of the most problematic subjects, because it supposes the consideration of not only tangible goods: land, homes, belongings, etc., but also social and cultural losses, that are very hard to quantify.

It is expected that the members of the affected communities will request that the distance from the affected homes to the work places, basic services like schools, health care facilities, community centers and stores, be considered in the compensation plan. Another element to be considered in this process is the use of the land; crop lands, grazing lands and of other commercial use. Also, common lands, rivers, and creeks, whenever applicable; with a proper inventory of the flora and fauna that could potentially have economic and food source impact, will most likely be requested for consideration.

Compensation is a very delicate and conflicting process. The interested parties could generate negative attitudes and expectations that could not be satisfied, for example in terms of relocation sites, home solutions and new economic opportunities. On the other hand, social and cultural obstacles, such as cultural importance and feeling of belonging to a particular area, could arise and could hinder the relocation process.

In order to mitigate the conflicts that could potentially emerge in this situation, conducting an inventory of land and personal goods that would be affected by a particular water source option is suggested. This could be done in anticipation with all affected communities. The inventory must contemplate: physical characteristics of the land, infrastructures, homes, other properties, estimated size, years and type of construction, structural characteristics, maintenance conditions, and estimated substitution value. This must also include an inventory of public or common places, infrastructure or other productive or social resources that would be lost: schools, health care facilities, churches, common grazing land, access to forest areas, and fishing zones.

Other Subjects Proposed by the Participants

Another situation that worries the participants is the sanitary conditions of the communities. This is one of the most important needs, because there are only a few health care centers, some distant, forcing some residents to walk for more than two hours to reach them. Moreover, some of the health centers do not have personnel or medicines to offer basic first aid services to the patients.

Due to the difficult access to the area, these populations lack adequate educational infrastructure. Current facilities are very deteriorated and lack resources such as books, basic school materials and more importantly, teachers. This is a situation that must be improved, and the residents are very interested in taking advantage of this situation to obtain a better education service for the kids in the region.

Water quality is another important issue for the residents. The rural aqueducts that supply water do not assure it is potable. They do not have an adequate process or equipment for water chlorination. Moreover, they have stated that the quality of water is affected by the contamination of nearby rivers due to the use of pesticides in the surrounding areas. Both situations cause serious health problems like diarrhea, vomits and parasites.

Another important aspect is the creation and rehabilitation of access roads; this is a vital aspect to gain access to health care services, education, and for the commercialization of their products. This is a subject that will emerge within the context of discussion on the water source options.

7.6.4 Expected Results from the Execution of a Participation Plan

Once the work conducted for the participation plan is analyzed, and the ACP has carried out the disclosure of information, and evaluated the proposal for the scope of the Citizen participation

plan for the water source options, some assumptions could be made about the possible results that would be expected from the implementation of the Plan.

Proposals

As a result of the consultations, proposals that facilitate the convergence or agreements between the ACP and the residents must emerge. Taking as a baseline the performed consultations and the scope of the Citizen participation plan for the water source options, the following proposals could be expected:

- Creation of a committee that will ensure compliance of the agreements reached during the meetings must include: the farmers, ACP staff, and authorities
- Continue with the land legalization process.
- Promote improvement of infrastructure such as access roads.
- Improve health cares services and education.
- Sign an agreement between both parties, which describes and assures the application of the mitigation and compensation mechanisms, where the real needs of the affected communities are considered, and where an open participation in the decision making process is offered.

Oppositions

Taking into account the participation and disclosure information process conducted by the ACP up to date, and analyzing the proposals and oppositions stated by the participants, during the execution of the Citizen participation plan, the following objections could be expected:

- The reservoirs are not necessary for the expansion of the Canal.
- Uncertainty and doubts on an acceptable relocation for the displaced residents within the ROCC
- Inconformity from the degree of compensation for affected families that are not displaced.
- Not only the loss of land, but a decrease in the amount of available water for navigation, crops and consumption.
- Lack of compensation for non-quantifiable impacts related to social and cultural aspects.
- Strong opposition among those that openly accuse the ACP of manipulating the land ownership program as a strategy for claiming their land.

- Opposition to the environmental impacts, especially by interested political groups outside the ROCC.
- Opposition due to the distribution of benefits from the Canal and the project, because local communities and their advisors feel that even though the Canal brings social and economic benefits to the country, they have not received these benefits since they feel abandoned by all government institutions.
- The feeling that they are the only ones affected by the project, since the presence of the Canal by itself restricts access to the northern coast. This has halted the communities' development; therefore it is difficult to accept that they will benefit by the project once the Canal is expanded and modernized.
- Arbitrary institutional power of decision, since the residents consider that the decision to approve Law no. 44 without their opinion was done arbitrarily.
- Institutional ambiguity, because the residents consider that, between the ACP and the Government, there is a lack of agreement in terms of who is directly responsible for not conducting prompt activities to improve the quality of life in the communities.
- Lack of trust, since all previous topics generate distrust among those who openly accuse the ACP of manipulating the land ownership program, and those who are willing to cooperate but want to see something tangible in order to believe.

7.6.5 Specific Results: Benefits and Damage

Among the specific (benefits and damage) results expected, due to the implementation of the Participation Plan for the water source options, these are the most relevant:

The benefits associated to the implementation of the Participation Plan are presented below:

- It will facilitate the design, presentation and discussion of mitigation and compensation plans, as well as the resettling process. It will also set the grounds for commitments and conditions for their implementation.
- It will allow a more active participation of the different social segments (women, youth groups, and elders) because they will be identified during the invitation process for the scheduled events.
- It will allow for clarification of questions and doubts among the residents, for all aspects related to the water source options, mitigation and compensation plans, and relocation programs.
- It will allow a direct path for dialogue and open communication between both parties.

- It will establish subjects related to the expansion of the canal, and the water source options that are being considered within the region (the objective is to stop any speculation).
- It will establish formal commitments and a plan for the implementation of activities.
- It will facilitate the creation of a new farmer leadership with greater will to establish a dialogue.

The damage that could be associated to the implementation of the Participation Plan include:

- It could deepen or reactivate conflicts between groups or persons that are clearly opposed to any form of dialogue, and/or water source options in the region.
- It could polarize the population when faced by the proposals.
- Creation of new conflicts among the residents.
- Emergence of a new, more radical, farmer leadership
- Emergence of new "interested" groups (outside the communities) looking for self benefits.

7.6.6 Conclusions and Recommendations

The following sections describe the conclusions and recommendations extracted from the analysis conducted; it takes into account the reactions and answers obtained during the process of information disclosure and citizen participation carried out by the ACP in the ROCC, and the analysis of the Citizen Participation Plan developed for the water source options.

Conclusions associated to the execution of the Participation Plan:

Once the proposed Citizen participation plan is implemented, the following objectives could be attained:

- Identification of the most representative social individuals, and the achievement of a wide participation.
- Expansion of the consultation process to the lower levels of the communities.
- Misinformation control through the presentation of the real impacts of the specific options.
- Establish direct contact and open communication between both parties, and
- Establish mechanisms and commitment schedules between both parties.

Conclusions associated to the analysis conducted:

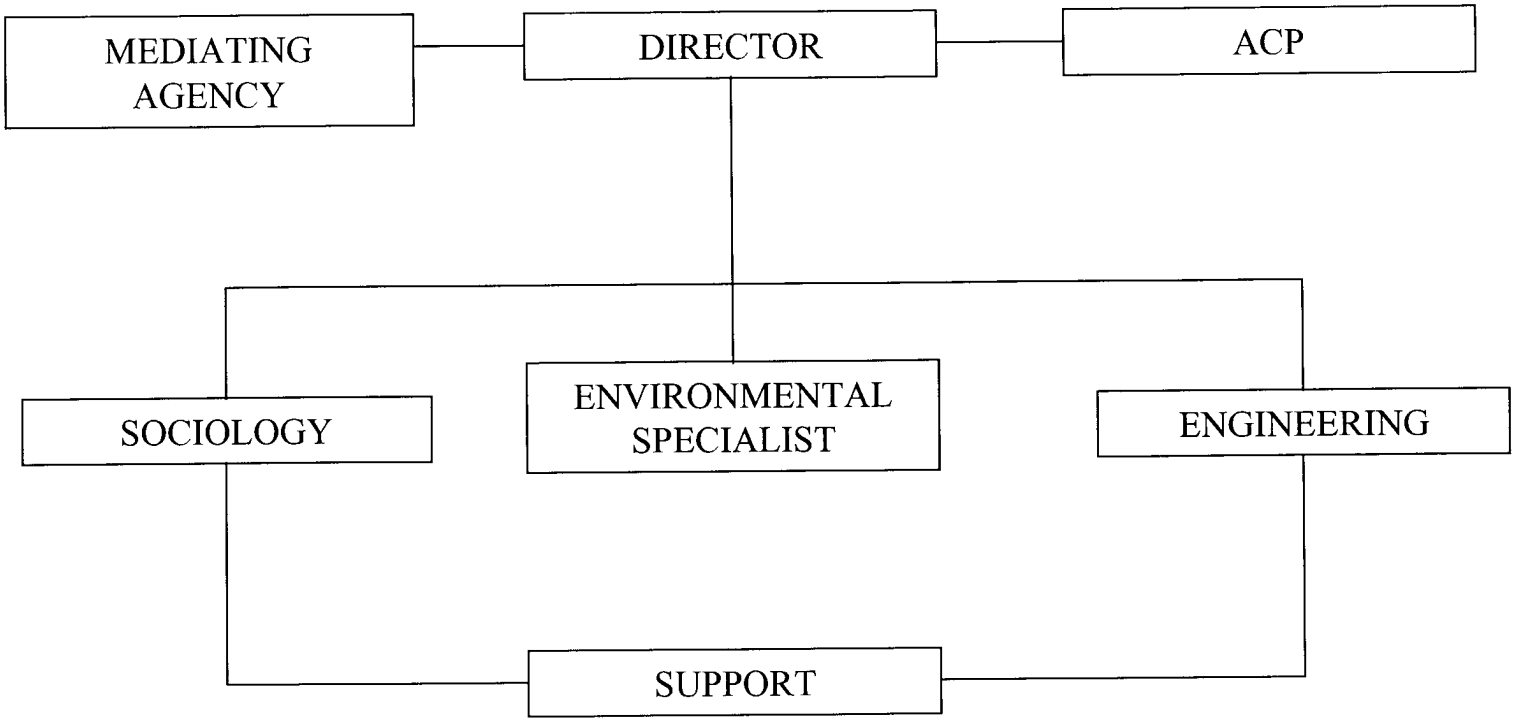
The following conclusions are extracted from the analysis conducted on the obtained results from the participation and information disclosure process carried out by the ACP in the ROCC:

- The existing information, generated by the process of participation conducted up to date, allows the identification of some positions that could surface during the execution of the Plan
- The positions that have been identified do not necessarily encompass the positions or opinions of all the identified groups that participated in the consultation process (i.e. displaced, isolated, downstream communities, etc.)
- The analysis conducted is a good indicator of the subjects that should receive special attention during the execution of the Participation Plan.
- In general terms, the concerns of the residents are centered on topics related to land ownership, land legalization, and construction of infrastructure to cover basic needs, above environmental issues.

Recommendations:

After analyzing the existing information, and carrying out the previously described analysis, the following recommendations can be made in virtue of the success of the participation process:

- It is recommended to implement a Citizen participation plan once the decision making process about the canal expansion advances.
- Carry out an Regional Planning Program as an integral part of the Region's Sustainable Development Program.
- Develop a Comprehensive Management Plan for the Panama Canal Watershed.
- Continue the citizen participation process and dissemination of information at the ROCC.
- Identify possible institutional mechanisms to offer solutions to problems identified by the Region's residents during the process of participation and information dissemination process carried out by ACP.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ENVIRONMENTAL SPECIALIST
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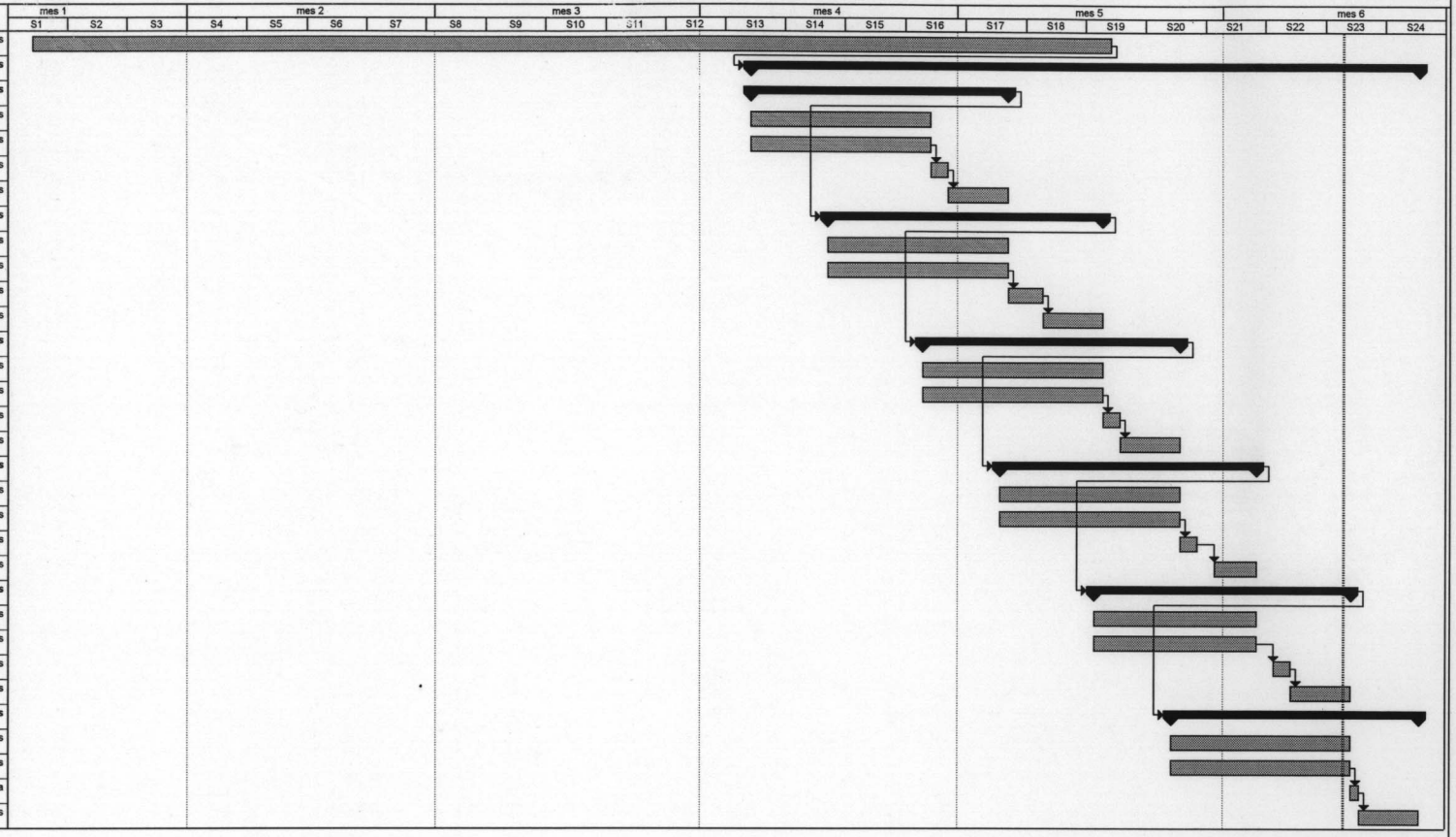
SUPPORT

CITIZEN PARTICIPATION PLAN SCHEDULE

Id		Nombre de tarea	Duración
1		**Precursor Topics - Dialogne Continuation**	90 días
2		**Topic - Water Options**	**56 días**
3		**Event 1 - Displaced Group**	**22 días**
4		Document Preparation	15 días
5		Invitation	15 días
6		Execution	2 días
7		Report	5 días
8		**Event 2 - Isolated Group**	**22 días**
9		Document Preparation	15 días
10		Invitation	15 días
11		Execution	2 días
12		Report	5 días
13		**Event 3 -Dounstream Group**	**22 días**
14		Document Preparation	15 días
15		Invitation	15 días
16		Execution	2 días
17		Report	5 días
18		**Event 4 - Neighbors & Receptors Groups**	**22 días**
19		Document Preparation	15 días
20		Invitation	15 días
21		Execution	2 días
22		Report	5 días
23		**Event 5 - Interested Parties Group**	**22 días**
24		Document Preparation	15 días
25		Invitation	15 días
26		Execution	2 días
27		Report	5 días
28		**Event 6 -Information Dissemination**	**21 días**
29		Document Preparation	15 días
30		Invitation	15 días
31		Execution	1 día
32		Report	5 días



Tarea | Progreso | Resumen | División resumida | Progreso resumido | Resumen del proyecto
División | Hito | Tarea resumida | Hito resumido | Tareas externas

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