ACP

AUTORIDAD DEL CANAL DE PANAMA
Oficina de Proyectos de Capacidad del Canal

# THE PANAMA CANAL

## Work Order No. 1
## EVALUATION OF LOCK CHANNEL ALIGNMENTS

## CONTRACT NO. CC-5-536

## Final Evaluation and Optimization
## Part 3 of 4

**August 2000**

HARZA Engineering Company, Inc.
In association with
**TAMS Consultants, Inc.**

# THE PANAMA CANAL
# EVALUATION OF LOCK CHANNEL ALIGNMENTS

# PART 3 – FINAL EVALUATION AND OPTIMIZATION

## TABLE OF CONTENTS

CHAPTER PAGE

# TABLES



# FIGURES

# EXHIBITS

## APPENDICES

This part is comprised of two chapters. This first, Final Evaluation of Lock Channel Alignments, documents the final evaluation of the alignments carried forward from the Initial Evaluation of Lock Channel Alignments (Part 2). It recommends four alignments for further study, two at the Atlantic Entrance and two at the Pacific Entrance. The second chapter, Optimization of Layouts, examines these four final alignments in greater detail and recommends and presents potential layouts for proposed future lock and shiplift complexes and auxiliary structures.

# 1.0 FINAL EVALUATION OF LOCK CHANNEL ALIGNMENTS

## 1.1 Introduction

In the Initial Evaluation, concepts were identified for the eight alignments to carry forward. Because these concepts represented combinations and optimizations of the original proposed alignments, new numbers have been assigned to each alignment. The new alignment numbers are summarized in Table 1 below.

**Table 1**

**Summary of Alignment numbers**

| New Alignment Number | Old Alignment Number |
|---|---|
| A1 | 6 |
| A2 | 4,5 |
| A3 | 18 |
| P1 | 8, 14 |
| P2 | 3, 7, 15 |
| P3 | 42 |
| P4 | 3 |
| P5 | 11 |

The first step taken in final evaluation of the proposed lock channel alignments was preparation of standard footprints for typical lock complexes. For the Atlantic entrance, a single three-lift lock complex was laid out for all three alignments analyzed. For the Pacific entrance, a three-lift complex was laid out, similar to the Atlantic layout, for use with the bypass alternatives. In addition a single-lift lock and a double-lift lock, mirroring the current lock arrangements, were laid out. The single-lift footprint would be used for the new third lane at Pedro Miguel under the dual lock complex scenarios that traverse Lake Miraflores. The double-lift footprint would be used at Miraflores under the same scenario.

Next, the eight channel alignments were laid out with the standard lock complex features. At this stage the alignments were partially optimized. As part of the partial optimization, some alignment azimuths were changed slightly to reduce excavation quantities and to avoid interference with existing infrastructure. Once the new alignments were laid out, quantity calculations were performed for each alignment. Then, using the layouts, a construction sequence was developed for each alignment. Finally, with the results of these analyses, the alignments were re-evaluated both quantitatively and qualitatively and the final recommendations of which alignments to carry forward were made.

Comparative excavation cost estimates were performed as part of this task and are provided in Appendix A. Appendix B provides the detailed quantity comparisons for each alignment using the same design standards. Appendix C gives station-by-station quantity calculations for the phased construction approach discussed in Section 2.4.2. Appendix D documents the references used in researching this part.

## 1.2 Preliminary Lock Layouts

### 1.2.1 General Criteria

In order to evaluate and compare the eight alignments carried forward from the Initial Evaluation, a preliminary standard lock layout was developed. The three Atlantic and five Pacific alignments were evaluated using variations on the preliminary standard layout. For the Atlantic entrance, the three-lift lock variation shown on Exhibit 1 was applied to each of the three remaining alignments. For the Pacific Entrance, the bypass alignments were evaluated with a similar three-lift lock while the dual lock complex alignments were evaluated with a standard two-lift lock at Miraflores and a one-lift lock at Pedro Miguel. Typical two-lift and one-lift lock complexes for alignments west of the existing locks are shown on Exhibit 2. A typical cross section of the three-lift and two-lift lock complexes at the Pacific entrance is presented on Exhibit 3. For the alignment east of the existing locks (Alignment P3), the two-lift and one-lift lock complexes are shown on Exhibit 4. In developing the standard lock layouts, the following eight criteria were used.

1. Locomotives will continue to be used for vessel guidance on the new third and fourth lanes.

2. The proposed third and fourth lane will both be constructed with Post-Panamax dimensions. The new design vessel dimensions are 350 meters long, 46 meters in beam and 14 m in draft. Accordingly, each new lock chamber will measure 381 meters long, 49 meters wide and 17 meters deep.

3. New guide walls will be 450 m long and approximately 18 m wide on both the upstream and downstream sides. That length is 120% of the chamber length. This is consistent with the existing guide walls that are 365 m long, or 120% the length of existing chambers. Guard walls are placed at the outside approach to each lock complex. Guard walls are 100 m long and taper out at a 1:4 ratio.

4. The right of way for the approach highways and bridges over the Miraflores and Gatun locks will be maintained. New swing bridges would be required over the third and fourth lock lanes at both Miraflores and Gatun. The costs of the new roads or bridges were not considered in this analysis.

5. Each water saving basin is laid out with a footprint of 58 m x 400 m. This is an area of approximately 120% of a new individual lock chamber. Three basins are required for each lock chamber. Thus a total of nine basins are required for a three-lift lock complex. For alignments A1, P1 and P2, the basins are constructed on three levels and laid out in a staircase arrangement with the top of each basin open to facilitate maintenance. The nine basins required for each three-lift lock would require a total of 21 hectares. For all other alignments, the three levels of basins are stacked one on top of another and supported by internal columns. Thus, they require only one third of the land area of the "staircase" structures. The basins will be founded on rock or on driven piles.

6. Where feasible, water saving basins will be placed between the existing second lane of locks and the proposed third lane. They will be shallow structures and will be situated far enough from the existing lock wall that excavation for their construction will not require anchoring of the existing lock wall. It may be possible to integrate the basins into the existing second lane operations. This would require additional culverts and concrete work in the existing lock wall during annual maintenance periods.

7. The alignment excavation will assume an initial width of four times the design vessel beam (184 m) with future expansion to six times the design vessel beam (276 m).

8. The third and fourth lane lock complexes are completely separate structures divided by 30 m. It may be possible to construct the outside third lane wall such that it could be integrated as the inside wall of a fourth lane later. However, as the dimensions of the fourth lock are not set, a shared center wall between the third and fourth lanes has not been considered at this stage.

### 1.2.2 Atlantic Entrance Layouts

For the Atlantic Entrance, three alignments were evaluated. The layouts are shown on Exhibits 5 through 7.

#### 1.2.2.1 Alignment A1 – East Bank Alignment Through the 1939 Third Lane Excavation

**General Layout.** The proposed alignment is located approximately 1.5 km east of the existing Gatun Locks and is shown on Exhibit 5. The fourth lane would be constructed east of the proposed third lane. The three water saving basins are placed parallel to the proposed locks on their west side. The water saving basins are too far from the existing locks to be integrated into existing operations. A complete new set of support buildings and facilities will be required at the proposed location. The locomotive support operations will be located between the third lane and the anticipated fourth lane. Based on a review of the available geotechnical data, the locks and guide walls are expected to be founded on sound rock. Within Gatun Lake, this alignment bisects the existing anchorage basin, requiring its relocation.

**New Third Lane of Locks.** The west lock wall of the three-lift lock is situated approximately 20 m from the east edge of the water saving basin. Dimensions and spacing are as described above.

**New Fourth Lane of Locks.** The fourth lane of locks is situated east of the proposed third lane. Dimensions and spacing are as described above.

#### 1.2.2.2 Alignment A2 - East Bank Alignment Adjacent to the Existing Locks

**General Layout.** The proposed alignment is shown on Exhibit 6. It is situated immediately east of the Gatun Locks at a distance sufficient to build water saving basins between the new and existing facilities. The proposed fourth lane could be built simultaneously or at a later date to the east of the proposed third lane. New locomotive support operations would be sited on the east side of the third lane in anticipation of the fourth lane. The proposed water saving basins could be connected to the existing Gatun Locks. In order to avoid an interruption of traffic, connection to the existing locks would be made during regular maintenance periods. Alternatively, the connection could be scheduled after the completion of the third lane construction.

Most of the structures would be founded on sound rock, with the exception of the southern end of the upper chamber and the guide wall in Gatun Lake. A cofferdam would be require in Gatun Lake to maintain construction in the dry. Because of the limited construction area, a cellular type cofferdam is recommended.

**New Third Lane of Locks.** The west lock wall is situated approximately 20 m from the east edge of the water saving basin. Dimensions and spacing are as described above.

**New Fourth Lane of Locks.** The fourth lane of locks is situated west of the proposed third lane. Dimensions and spacing are as described above.

#### 1.2.2.3 Alignment A3 – West Bank Alignment Through the French Canal and Gatun Dam

**General Layout.** This alignment, shown on exhibit 7, utilizes the French Canal alignment on the west side of the existing Gatun locks and joins Gatun Lake through the Gatun Dam. The water saving basins could be located on the east of the new alignment. However, the basins are too distant from the existing locks to consider integration of the basins in the existing locks. The anticipated difficulties in construction through the dam and the space limitations would prevent further expansion of a fourth lane adjacent to the proposed one. Because the entire locks and guide walls would be founded on overburden and hydraulic fill major difficulties are anticipated during construction. Two lines of cellular cofferdams will have to be installed on the upstream slope of the dam to allow for construction of the approach on the Gatun Lake side. These cofferdams will have to be left in place to prevent jeopardizing the integrity of the dam. They can be used as part of the new guide walls.

**New Third Lane of Locks.** The east lock wall of the lock complex is situated approximately 20 m from the west edge of the water saving basin. Dimensions and spacing are as described above.

### 1.2.3 Pacific Entrance Layouts

For the Pacific entrance, five alignments were evaluated. The two bypass alignments are shown on Exhibits 8 and 9, and the three dual lock alignments are shown on Exhibits 10 through 12.

#### 1.2.3.1 Alignment P1 – Far West Bypass

**General Layout.** This alignment, shown on Exhibit 8, passes through part of the 1939 Third Locks Project excavation and continues on a single azimuth until it intersects the Gaillard Cut. Alignment P1 was partially optimized after the initial evaluation and avoids the unexploded ordinance (UXO) area. The new three-lift lock is situated west of the existing 1939 Third Locks Project excavation. Three water saving basin structures are placed parallel to the proposed locks on their east side. The new basins are too distant from the existing locks to be used by the existing locks. New locomotive support operations will be sited on the west side of the new third lock so that they may be later integrated with a new fourth lock.

**New Third Lane of Locks.** The east lock wall of the three-lift lock complex is situated approximately 20 m from the west edge of the water saving basin. The lock dimensions are typical Post-Panamax as detailed in section 2.1.

**New Fourth Lane of Locks.** The fourth lane of locks is situated west of the proposed third lane. A distance of 115 m separates the centerlines of the two new lock complexes. The fourth lane lock has identical dimensions to the third lane.

### 1.2.3.2 Alignment P2 – Near West Bypass

**General Layout.** The new three-lift lock, shown on Exhibit 9, is situated west of the existing Miraflores Locks in the 1939 Third Locks Project excavation. Three water saving basin structures are placed parallel to the proposed locks on their east side. The new basins are too distant from the existing locks to be used by the existing locks. New locomotive support operations will be sited on the west side of the new third lock so that they may be later integrated with a new fourth lock.

A barrier dam will be constructed to separate the existing Miraflores Lake (El. 16.5 m PLD) from the newly expanded Gatun Lake (El. 25.9 m PLD). A typical cross section through Alignment P2 is shown on Exhibit 13. Four alternative barrier dam concepts are shown on Exhibit 14. Type 1 is a basic layout of the dam whose cost is estimated in Appendix A, Attachment 2. The dam would be constructed in the wet. First the sheetpile cells would be placed. Then tremie concrete would fill the cells up to elevation 16.5 m PLD. Normal concrete would follow up to elevation 30.0 m PLD. Finally rip rap protection would be placed on both sides of the dam. See Appendix A for further details on the dam construction.

**New Third Lane of Locks.** The east lock wall of the three-lift lock complex is situated approximately 20 m from the west edge of the water saving basin. Dimensions and spacing are as described above.

**New Fourth Lane of Locks.** The fourth lane of locks is situated west of the proposed third lane. Dimensions and spacing are as described above.

### 1.2.3.3 Alignment P3 – Dual Lock East of Existing Locks

#### 1.2.3.3.1 Miraflores Locks

**General Layout.** The new two-lift lock on the east side of the existing Miraflores Locks, shown on Exhibit 10, was sited so as not to interfere with existing operations. The water saving basins are placed closest to the existing east lock. This may allow use of the water saving basins by the existing east lock up to the time that the new locks come into service. The western edge of the water saving basins is approximately 45 m east of the inside lock wall of the east lock. This leaves room for the existing locomotive operation and leaves the access roads to existing operations in place.

**New Third Lane of Locks**. The west lock wall of the third lane of locks is situated approximately 20 m from the east edge of the water saving basin structure. Dimensions and spacing are as described above.

**New Fourth Lane of Locks**. The fourth lane of locks is situated east of the proposed third lane. Dimensions and spacing are as described above.

1.2.3.3.2 Pedro Miguel Locks

**General Layout**. The new single-lift lock on the east side of the existing Pedro Miguel Locks was sited so as not to interfere with existing operations. A three-level water saving basin structure is placed adjacent to the existing east lock. This may allow use of the water saving basins by the existing east lock up to the time that the new locks come into service. The western edge of the water saving basins is approximately 45 m east of the outside lock wall of the east lock. This leaves room for the existing locomotive operation and access roads.

**New Third Lane of Locks**. The west lock wall of the third lane of locks is situated approximately 20 m from the east edge of the water saving basin structure. Dimensions and spacing are as described above.

**New Fourth Lane of Locks**. The fourth lane of locks is situated east of the proposed third lane. Dimensions and spacing are as described above.

### 1.2.3.4 Alignment P4 – Dual Lock West of Existing Locks

As shown on Exhibit 11, the west side alignment is laid out as a mirror image to that described above for the east side alignment (Alignment P3). Water saving basins are placed between the existing lock complex and the new third lane complex.

### 1.2.3.5 Alignment P5 – Dual Lock Using 1939 Excavation

1.2.3.5.1 Miraflores Locks

**General Layout.** The new two-lift lock is situated west of the existing Miraflores Locks in the existing 1939 Third Locks Project excavation. Alignment P5 is shown on Exhibit 12. Two water saving basin structures are placed parallel to the proposed locks on their east side. The new basins are too distant from the existing locks to be used by the existing locks. New locomotive support operations will be sited on the west side of the new third lock so that they may be integrated with a new fourth lock in the future.

**New Third Lane of Locks.** The east lock wall of the two-lift lock is situated approximately 20 m from the west edge of the water saving basin. Dimensions and spacing are as described above.

**New Fourth Lane of Locks.** The fourth lane of locks is situated west of the proposed third lane. Dimensions and spacing are as described above.

1.2.3.5.2 Pedro Miguel Locks

The new single-lift lock on the west side of the existing Pedro Miguel Locks was sited so as not to interfere with existing operations. Water saving basins are placed between the existing western lock complex and the new third lane complex.

## 1.3 Quantity Takeoffs

Excavation quantities were estimated for the Atlantic and Pacific entrances alignments using mapping and radar imagery (IFSAR) provided by the ACP. For both entrances, the data was used to construct a Digital Terrain Model (DTM). The quantity calculations assume the initial construction of a 184 m wide channel to accommodate one way traffic. This width represents four time the beam of the design Post-Panamax vessel (See Part 2, Appendix C). The ACP selected this channel width for the final evaluation quantity takeoffs and cost estimates. The channel width was a design parameter not determined as part of this study

For the Atlantic entrance the digital topographic data was limited to the IFSAR model. A close comparison of the model and other non-digital information such as the 1947 maps (scale 1:3,000) clearly shows that the IFSAR model does not differentiate between the ground surface and the top of the trees. For that purpose the digital information was adjusted where possible to reflect a more accurate ground surface. Other information used to create the DTM includes approximately 500 boreholes performed prior to the 1939 Third Lane Excavation and design drawings of the excavation. The DTM was created with AutoCAD 2000 and the associated software LANDDEVELOPMENT. A summary of the excavation quantities for the Atlantic Entrance is given in Table 2 below.

**Table 2**

**Summary of Excavation Quantities - Atlantic Entrance Alignments**

| Alignment | Approx. Length (km) | Approx. Volume (million $m^3$) |
|---|---|---|
| A1 - East Bank Alignment Through 1939 Excavation | 5.4 | 12.4 |
| A2 - East Bank Alignment Adjacent to Existing Locks | 4.4 | 12.1 |
| A3 - West Bank Alignment Through the French Canal and Gatun Dam | 4.0 | 14.0 |

For the Pacific entrance, detailed excavation takeoffs were performed using an InRoads DTM constructed from 3-D contours provided by the ACP. The DTM was created from the ASCii and DTM data from the 1993 Mobile District USACE survey and bathymetric data provided by the ACP's engineering division.

Once constructed, the DTM was used to calculate excavation quantities for each alignment. Each of the proposed alignments assumes a bottom channel width of 184 m or four times design vessel beam (4B). As was the case in the Initial Evaluation, the slope cuts detailed in the Canal Alternatives Study (CAS) were applied to the alignments. The transition points between the slope types are indicated at the bottom of Exhibits 5-12. InRoads software was used to create cross sections at 100 m intervals. The average end area method was employed to calculate gross excavation volumes for each alignment. The spreadsheets used to calculate the excavation quantities are included in Appendix B.

A summary of the excavation quantities for the Pacific entrance is given in Table 3 below.

**Table 3**

**Summary of Excavation Quantities - Pacific Entrance Alignments**

| Alignment | Approx. Length (km) | Approx. Volume (million $m^3$) |
|---|---|---|
| P1 - Far West Bypass | 9.3 | 70 |
| P2 - Near West Bypass | 9.5 | 37 |
| P3 - Dual Lock East of Existing Locks | 8.2 | 36 |
| P4 - Dual Lock West of Existing Locks | 6.9 | 38 |
| P5 - Dual Lock Using 1939 Excavation | 9.5 | 47 |

In addition to calculating gross excavation volumes for each of the alignments, approximations of the quantity of rock and overburden to be excavated were made. These calculations were based on geotechnical data provided by the ACP. Most of the boring logs provided were from the 1939 Third Locks Excavation Project and thus focused on the sites of those new locks at each entrance. For the Atlantic Entrance, these borings provided sufficient information to estimate rock and overburden quantities for each alignment station. However, for the Pacific Entrance, the borings provided did not sufficiently cover all of the alignment areas to provide a breakdown of rock and overburden for each station. Instead, for the two alignments with the best data, Alignments P1 and P2, an analysis was made of the percentage of sound rock, weathered rock and overburden over the entire length of the two alignments. These percentages were then applied equally to all five Pacific alignments. The percentages of each material, given in Table 4 on the next page, were applied for comparative purposes based on the best boring data available at the time. Any alignments being further considered will require additional boring data to better determine the quantities of sound rock, weathered rock, and overburden.

**Table 4**

**Breakdown of Material Types - Pacific Entrance Alignments**

| Material Type | Overall Percentage |
|---|---|
| Sound Rock | 65% |
| Weathered Rock | 15% |
| Overburden | 20% |

The percentages of wet and dry excavation were also estimated in order to provide more detail for estimating relative costs for each alignment excavation. The wet/dry estimates were made by reviewing the alignment layout on the existing topography and estimating on a station by station basis what percentage of the excavation would be wet or dry. These estimates assumed that earth plugs would be left in place to provide dry excavation conditions whenever possible. The estimates also assumed that easily dewatered areas, such as the existing 1939 Third Locks Project excavation cuts, would be excavated in dry conditions.

Finally, the excavation volumes of Alignments P2, P4 and P5 were reduced 2.3 million $m^3$. This quantity represents the amount of material removed from the area around the Cerro Paraiso as part of the Gaillard Cut widening project. This quantity was removed after the surveys used as baseline data for the quantity takeoffs. The reduction is denoted by an asterisk (*) for the affected stations on Alignments P2, P4 and P5 in Appendix B.

## 1.4 Refined Alignment Screening

The refined screening of the alignments included both quantitative and qualitative elements. The scoring by the Kepner-Tregoe method was reviewed in order to quantify the final evaluation of the alignments. For the Atlantic Entrance, the alignments had undergone little modification between the initial and final evaluations. Thus the scores changed little. For the Pacific Entrance, the partial optimization of alignments P1 and P2 raised their scores and left them in the top two positions. Table 5 and Table 6 provide the revised raw and weighted scores and ranking for the final evaluation.

# Table 5

## Revised Kepner-Tregoe Raw Scores for Final Evaluation

| | | | Raw Scores for each Alignment | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atlantic Entrance | | | Pacific Entrance | | | | |
| **Evaluation Category** | **Evaluation Criteria** | **Importance Coefficient** | **A1** | **A2** | **A3** | **P1** | **P2** | **P3** | **P4** | **P5** |
| **Technical** | Maintain Stability of Bank Slopes | 1.0 | 5 | 5 | 5 | 1 | 3 | 5 | 2 | 2 |
| | Potential for Future Expansion | 7.8 | 5 | 5 | 3 | 4 | 4 | 3 | 3 | 3 |
| | Special Site Considerations e.g. Susceptibility to Catastrophic Events | 3.0 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 |
| **Operational** | Maximize Navigational Safety and Ship Maneuverability | 9.1 | 4 | 3 | 3 | 5 | 5 | 3 | 3 | 4 |
| | Maximize Integration with Existing Operations | 3.8 | 2 | 5 | 3 | 2 | 3 | 5 | 5 | 3 |
| | Operational Accessibility of Equipment, Materials and Personnel. | 3.2 | 3 | 5 | 3 | 3 | 3 | 5 | 4 | 3 |
| | Minimize Maintenance Dredging | 2.5 | 3 | 5 | 4 | 1 | 2 | 5 | 5 | 2 |
| **Constructibility** | Impacts on Existing Canal Operations During Construction | 10.0 | 4 | 3 | 4 | 5 | 3 | 1 | 2 | 3 |
| | Accessibility of Construction Equipment, Materials and Personnel | 2.7 | 5 | 4 | 2 | 2 | 3 | 3 | 2 | 3 |
| | Ease of Construction (e.g. Proximity to unexploded ordinance) | 1.9 | 5 | 4 | 2 | 4 | 3 | 4 | 4 | 3 |
| **Economic** | Relative Cost of Locks and Special Features | 5.8 | 5 | 5 | 3 | 5 | 2 | 2 | 3 | 3 |
| | Excavation Cost (incl. Temporary Works) | 8.0 | 5 | 3 | 4 | 2 | 4 | 5 | 4 | 4 |
| | Minimize Construction Time | 4.7 | 5 | 3 | 5 | 2 | 4 | 5 | 4 | 3 |
| **Other Impacts** | Environmental | 6.0 | 4 | 5 | 3 | 3 | 3 | 3 | 3 | 4 |
| | Socio-Economic | 2.8 | 4 | 1 | 5 | 4 | 4 | 2 | 4 | 4 |
| | Relocations (e.g. Utilities, Infrastructure) | 2.5 | 2 | 2 | 4 | 2 | 3 | 1 | 4 | 3 |

## Table 6

## Revised Kepner-Tregoe Weighted Scores and Rankings

| | | | Weighted Scores for each Alignment | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Atlantic Entrance | | | Pacific Entrance | | | | |
| Evaluation Category | Evaluation Criteria | Importance Coefficient | A1 | A2 | A3 | P1 | P2 | P3 | P4 | P5 |
| Technical | Maintain Stability of Bank Slopes | 1.0 | 5 | 5 | 5 | 1 | 3 | 5 | 1 | 2 |
| | Potential for Future Expansion | 7.8 | 39 | 39 | 23 | 31 | 31 | 23 | 23 | 23 |
| | Special Site Considerations e.g. Susceptibility to Catastrophic Events | 3.0 | 15 | 15 | 12 | 12 | 12 | 12 | 12 | 12 |
| Operational | Maximize Navigational Safety and Ship Maneuverability | 9.1 | 36 | 27 | 27 | 45 | 45 | 27 | 27 | 36 |
| | Maximize Integration with Existing Operations | 3.8 | 8 | 19 | 11 | 8 | 11 | 19 | 19 | 11 |
| | Operational Accessibility of Equipment, Materials and Personnel. | 3.2 | 10 | 16 | 10 | 10 | 10 | 16 | 13 | 10 |
| | Minimize Maintenance Dredging | 2.5 | 7 | 12 | 10 | 2 | 5 | 12 | 12 | 5 |
| Constructibility | Impacts on Existing Canal Operations During Construction | 10.0 | 40 | 30 | 40 | 50 | 30 | 10 | 20 | 30 |
| | Accessibility of Construction Equipment, Materials and Personnel | 2.7 | 13 | 11 | 5 | 5 | 8 | 8 | 5 | 8 |
| | Ease of Construction (e.g. Proximity to unexploded ordinance) | 1.9 | 10 | 8 | 4 | 8 | 6 | 8 | 8 | 6 |
| Economic | Relative Cost of Locks and Special Features | 5.8 | 29 | 29 | 17 | 29 | 12 | 12 | 17 | 17 |
| | Excavation Cost (incl. Temporary Works) | 8.0 | 40 | 24 | 32 | 16 | 32 | 40 | 32 | 32 |
| | Minimize Construction Time | 4.7 | 23 | 14 | 23 | 9 | 19 | 23 | 19 | 14 |
| Other Impacts | Environmental | 6.0 | 24 | 30 | 18 | 18 | 18 | 18 | 18 | 24 |
| | Socio-Economic | 2.8 | 11 | 3 | 14 | 11 | 11 | 6 | 11 | 11 |
| | Relocations (e.g. Utilities, Infrastructure) | 2.5 | 5 | 5 | 10 | 5 | 7 | 2 | 10 | 7 |
| SUM OF WEIGHTED SCORES | | | 315 | 287 | 261 | 261 | 260 | 241 | 248 | 249 |
| RANK | | | **1** | **2** | **3** | **1** | **2** | **5** | **4** | **3** |

Following the revised quantitative analysis, a qualitative analysis of the eight alignment alternatives was conducted to identify the two most desirable alternatives for each entrance. The qualitative screening used the five categories introduced in the Development of Evaluation Criteria:

- Technical;
- Operational;
- Constructablity;
- Economic; and
- Other Impacts.

### 1.4.1 Atlantic Entrance Alignments

Alignments A1, A2 and A3 were analyzed on the Atlantic entrance.

#### 1.4.1.1 Alignment A1 – East Bank Through the 1939 Third Lane Excavation

**Technical**

- A future fourth lane would be placed to the east of the proposed third lane.
- The entire facility is founded on sound rock.

**Operational**

- Navigation in Gatun Lake will interfere with the existing anchorage basin.
- The operation of the third lane will require separate facilities and equipment from the existing Gatun operation.
- Traffic congestion in the existing approach channel is avoided.

**Constructability**

- The construction of the new facilities will have no impact on the existing operations.
- There is available space for staging and storing materials.

### Economic

- Excavation volume for the third lane is approximately 12 million $m^3$.
- There are no major construction difficulties anticipated.
- The expansion to the fourth lane will involve relatively high excavation volumes.

### Other Impacts

- Construction of the fourth lane may require the relocation of the Panama Railroad Concession.

## 1.4.1.2 Alignment A2 - East Bank Alignment Adjacent to the Existing Locks

### Technical

- A future fourth lane would be placed to the east of the proposed third lane.
- Difficult foundation conditions on the Gatun Lake side.

### Operational

- All the operations are concentrated in one complex.
- Possibilities to share tug boats and other equipment with the existing operation.
- Efficient usage of the newly built water saving basins if used for the existing locks.
- Traffic congestion in the Atlantic approach channel.

### Constructability

- Large volume to be dredged in the approach may interfere with operations in the existing locks.
- Requires relocation of ACP facilities.
- Staging areas are not readily available.

### Economic

- Excavation volume will be approximately 12 million $m^3$.
- A required cellular cofferdam in Gatun Lake will be an added cost.

### Other Impacts

- A few houses may need relocation particularly for the fourth lane.

### 1.4.1.3 Alignment A3 – West Bank Alignment Through the French Canal and Gatun Dam

### Technical

- None of the structures will be founded on sound rock.
- A fourth lane is not viable at this location because of foundation conditions.

### Operational

- The operation of the third lane may require a separate fleet of tugboats.
- A separate control center will be necessary.
- Traffic congestion in the existing approach channel is avoided.
- Traffic congestion may occur in the vicinity of the Guarapo Island.

### Constructability

- Maintaining the integrity of the dam may require special consideration.
- A permanent cellular cofferdam will be used as guide walls to form the approach channel in Gatun Lake.
- Difficult vehicular accesses through the Gatun locks.

### Economic

- Excavation volume will be approximately 14 million $m^3$.
- A required cellular cofferdam in Gatun Lake will be an added cost.
- Some special considerations relating to construction through the dam may create additional costs that are difficult to quantify at this time.

## Other Impacts

- The alignment borders environmentally sensitive wetland area.
- Minimal relocations of infrastructures.

### 1.4.2 Pacific Entrance Alignments

For the Pacific entrance Alignments P1, P2, P3, P4 and P5 were further analyzed. The first two, P1 and P2, are bypass alignments that utilize a single three-lift lock to raise vessels from tidewater to Gatun Lake level. The other three, P3, P4, and P5, are dual lock alignments. They utilize two separate locks and the existing Miraflores Lake. Exhibit 15 shows the estimated navigation periods for the various new lock complexes. In general, the bypass alignments offer a substantial time saving over the dual lock complex alignments.

All five alignments affect the proposed Miraflores Lake Highway Bridge. However, this long-term planning issue has not been considered as a differentiating criterion among the alignments. Similarly, a new swing bridge would be required over all new Miraflores lock complexes in order to maintain the present little-used highway connection.

The ACP selected a 184 m channel bottom width, initially creating a one way channel for the third lane expansion stage. Expansion would take place incrementally. Construction of the new third lane of locks and the 184 m approach channels would be followed later by a widening of the approach channels to 276 m allowing two way traffic as demand increased. Finally, when warranted by vessel traffic, a fourth lane of locks would be added.

#### 1.4.2.1 Alignment P1 - Far West Bypass Alignment

## Technical

- Future widening would take place to the west of the existing channel and would be accomplished largely by wet excavation techniques.
- A future fourth lane would be placed west of the new third lane.

**Operational**

- The single three-lift lock would simplify new operations.
- One way traffic would be required for approximately 5.5 km from the merge with the Gaillard Cut to the entrance to the new locks.
- All new azimuth changes are less acute than the 26 degree turn on the Pacific side of the existing Miraflores locks.

**Constructability**

- The new alignment construction would have no impact on existing operations.
- The alignment does not pass through the unexploded ordinance (UXO) area. However, the cut slopes of a fourth lane may include a small section of the UXO area.

**Economic**

- Excavation volume would be approximately 70 million $m^3$.
- No barrier dam is required between Miraflores Lake and Gatun Lake.

**Other Impacts**

- New inundation of low-lying areas west of the new alignment will take place.
- No significant relocations required.

### 1.4.2.2 Alignment P2 - Near West Bypass Alignment

**Technical**

- The initial bottom excavation 184 m wide requires that some future excavation for a fourth lane be done in the wet.
- A future fourth lane would be placed west of the new third lane.

**Operational**

- The single three-lift lock would simplify new operations.
- New mooring areas may be constructed along the new barrier dam.

- One way traffic would be required for approximately 4.5 km from the merge with the Gaillard Cut to the entrance to the new locks.
- All new azimuth changes are less acute than the 26 degree turn on the Pacific side of the existing Miraflores locks.

**Constructability**

- The barrier dam construction may require some construction equipment to use the existing Lake Miraflores channel. Berthing areas in Lake Miraflores will be permanently lost and replaced with rip rap protection for the new barrier dam.
- The alignment does not pass through the UXO area.

**Economic**

- Excavation volume would be approximately 37 million $m^3$.
- A 2.25 km barrier dam must be constructed between Miraflores Lake and Gatun Lake.

**Other Impacts**

- New inundation of low-lying areas west of the new alignment.

**1.4.2.3 Alignment P3 - Dual Lock Alignment East of Existing Locks**

**Technical**

- New excavation through Miraflores Lake would have to be performed in the wet by a hydraulic dredge. There is no way to haul spoil with dump barges from between the Miraflores and Pedro Miguel locks without passing through the locks and interfering with existing operations.
- A future fourth lane would be placed east of the new third lane. At Pedro Miguel, this would require very high excavation volumes since the fourth lane would pass through much of the Cerro Luisa.

### Operational

- New operations would mirror existing ones. The imbalance would continue to exist between lifting and lowering time for the Atlantic and Pacific locks.
- Two-way traffic would be possible in the entire operations area.
- The azimuth change on the Pacific side of the new Miraflores locks is approximately 34 degrees. This requires widening of the channel in this area to allow safe approach to and egress of the new locks.

### Constructability

- The new alignment construction may impact existing operations if the new locks are placed very close to the existing locks. Construction of the new locks, as shown, would cause minimal disruption to existing operations.
- The alignment does not pass through the UXO area.
- The construction laydown area would be limited in comparison to the west side alignments.

### Economic

- Excavation volume will be approximately 36 million $m^3$.
- No special structures are required.

### Other Impacts

- Relocation of the Miraflores Spillway and powerplant are required. Access to existing canal operations would be hampered by construction.
- The Panama railroad would have to be relocated.

## 1.4.2.4 Alignment P4 - Dual Lock Alignment West of Existing Locks

### Technical

- New excavation through Miraflores Lake would have to be performed in the wet by a hydraulic dredge. There is no way to haul spoil with dump barges from between the

Miraflores and Pedro Miguel locks without passing through the locks and interfering with existing operations.

- A future fourth lane would be placed west of the new third lane.

**Operational**

- New operations would mirror existing ones. The imbalance would continue to exist between lifting and lowering time for the Atlantic and Pacific locks.
- Two-way traffic would be possible in the entire operations area.
- All new azimuth changes are less acute than the 26 degree turn on the Pacific side of the existing Miraflores locks.

**Constructability**

- The new alignment construction may impact existing operations if the new locks are placed very close to the existing locks. Construction of the new locks, as shown, would cause minimal disruption to existing operations.
- The alignment does not pass through the UXO area.

**Economic**

- Excavation volume would be approximately 38 million $m^3$.
- No special structures are required.

**Other Impacts**

- Minimal relocations are required for the new locks.
- Environmental impacts are minor.

### 1.4.2.5 Alignment P5 - Dual Lock Alignment Using 1939 Third Locks Excavation

**Technical**

- New excavation through Miraflores Lake would have to be performed in the wet by a hydraulic dredge. There is no way to haul spoil with dump barges from between the

Miraflores and Pedro Miguel locks without passing through the locks and interfering with existing operations.

- A future fourth lane would be placed west of the new third lane.

**Operational**

- New operations would mirror existing ones. An imbalance would exist between lifting and lowering time for the Atlantic and Pacific locks.
- Two-way traffic would be possible in the entire operations area.
- All new azimuth changes are less acute than the 26 degree turn on the Pacific side of the existing Miraflores locks.

**Constructability**

- The new Miraflores locks construction will have no impact on existing operations. The new Pedro Miguel locks construction may impact existing operations if the new locks are placed very close to the existing locks. Construction of the new locks, as shown, would cause minimal disruption to existing operations.
- The alignment does not pass through the UXO area.

**Economic**

- Excavation volume would be approximately 47 million $m^3$.
- No special structures are required.

**Other Impacts**

- Minimal relocations are required for the new locks.
- Environmental impacts are minor.

## 1.5 Construction Sequence Analysis

For each of the eight alignments, a construction sequence was developed and mapped. Since the project start date is unsure, the sequence is laid out as ordinal years. The plans were developed in Microsoft Project 98. While the schedule was prepared to give approximations of construction periods for each alignment, the focus of this analysis was on the sequencing of operations. For each sequence, assumptions were made about the number of independent work crews and their capacity. In general, dry excavation production was assumed at approximately 500,000 $m^3$ per month per work crew. Wet excavation production was assumed as 120,000 $m^3$ per month in rock and 550,000 $m^3$ per month in overburden for each dredging plant. These productions are based on historical data for the equipment specified in Part 4 – Review of Excavation Methodologies. The preliminary phase includes investigation, design, preparation of plans and specifications, bidding and award of the contract. Table 7 below summarizes the construction duration for each alignment.

**Table 7**

**Summary of Construction Duration (years)**

| Alignment | Prelim. Phase | Construction Phase | Total Duration |
|---|---|---|---|
| A1 - Alignment Through 1939 Excavation | 2.25 | 4.5 | 6.75 |
| A2 - Alignment Adjacent to Exist. Locks | 2.25 | 5.0 | 7.25 |
| A3 - Alignment Through the Gatun Dam | 2.25 | 4.5 | 6.75 |
| P1 – Far West Bypass | 2.25 | 6.5 | 8.75 |
| P2 – Near West Bypass | 2.25 | 5.5 | 7.75 |
| P3 – Dual Lock East of Existing Locks | 2.25 | 4.5 | 6.75 |
| P4 – Dual Lock West of Existing Locks | 2.25 | 4.25 | 6.5 |
| P5 – Dual Lock Using 1939 Excavation | 2.25 | 5.0 | 7.5 |

The preliminary construction sequence for Alignment A1 is illustrated on Exhibit 16. Construction will start with the dry excavation at the location of the lock and guide wall structures. It is anticipated that a cofferdam will be built at the Atlantic entrance of the approach channel. This excavation will proceed in the dry. The cofferdam will be removed during the final dredging of the approach. On the Gatun Lake side the existing plug can be largely excavated in the dry. Final dredging will be completed after completion of the locks and the installation of the gates.

Exhibit 17 shows the construction sequence for Alignment A2. Excavation in the dry at the location of the locks and the water saving basins will be the initial task. A temporary cellular cofferdam will be required on the Gatun Lake approach to build the guide wall in the dry. A large portion of the Atlantic approach will be dredged, as the alignment essentially requires a widening of the channel. Dredging can proceed in parallel with the lock construction and gate installation.

The construction sequence for Alignment A3, shown on Exhibit 18, is similar to that of Alignment A2. However, a significantly smaller volume of material will be dredged. The construction will start with the dry excavation of the lock structures. The permanent cofferdam to be used as guide walls over the Gatun Dam will then be built. This would be followed by the construction of the locks and installation of the gates. Removal of a smaller earthfill cofferdam at the entrance of the French Canal and dredging of the entrance will be the final steps of the construction.

The preliminary construction sequence for Alignment P1 is given on Exhibit 19. The sequence assumes that two high-capacity spreads of dry excavation equipment are on site and used simultaneously. One backhoe or cutter suction dredge with attendant plant performs all wet excavation. Finally, lock construction is performed as a single operation, completely in the dry.

Alignment P2's construction sequence is given on Exhibit 20. This plan also assumes that two high-capacity spreads of dry excavation equipment are on site and used simultaneously. One backhoe or cutter suction dredge with attendant plant performs all wet excavation. First, excavation for the locks begins in the dry, concurrent to construction of the barrier dam. Then, excavation for the new bypass channel along the existing west bank of Miraflores Lake is performed in the dry after dewatering behind the barrier dam. As with Alignment P1, the single three-lift lock construction takes place in the dry.

Exhibit 21 shows the construction sequence for Alignment P3. Dry excavation begins simultaneously for the new Pedro Miguel and Miraflores third lane of locks. A cofferdam is used to dewater the north end of the Miraflores excavation. Lock foundations are constructed as the excavation progresses at each site. The sequence assumes that two independent construction operations construct the new single-lift lock at Pedro Miguel and the new double-lift lock at Miraflores. Either one or two large capacity dredges may perform wet excavation at the Pacific Entrance, in Miraflores Lake and in the Gaillard Cut. Because there is no bottom dump spoil ground within Miraflores Lake, a backhoe dredge loading dump scows is not appropriate for that phase of work. The final phase of work consists of removal of the Miraflores cofferdam and excavation of the plugs that maintained dry conditions for excavation and construction at both Pedro Miguel and Miraflores.

The construction sequence for Alignment P4 (Exhibit 22) is nearly identical to that of Alignment P3. A cofferdam is again required at the north end of the new Miraflores locks. Excavation and new lock construction take place simultaneously at both Pedro Miguel and Miraflores. As with Alignment P4, a sizeable portion of the excavation must take place in the wet.

Alignment P5 follows a construction sequence (Exhibit 23) combining elements of P2 and P4. As with Alignment P4, excavation and construction take place simultaneously at Pedro Miguel and Miraflores. However, like Alignment P2, the existing 1939 Third Locks Project excavation must be dewatered prior to excavation and construction activities at Miraflores. Like Alignments P3 and P4, this construction sequence requires use of a cutter suction dredge within Miraflores Lake.

## 1.6 Conclusions

For the Atlantic entrance the final evaluation reveals significant differences among the three alignments. Technically, Alignments A1 and A2 present small differences; the best foundation conditions are found on A1 while Alignment A2 requires a more complex arrangement of cofferdam (cellular) and a larger quantity of wet excavation. Alignment A3 presents a significantly higher technical risk because the construction goes through the Gatun Dam. Operationally, Alignment A2 has the advantage of allowing a combined control center, and sharing of the tugboat fleet. The expansion of Alignment A1 to a fourth lane involves a large quantity of rock excavation while Alignment A2 is the most suitable for the construction of a fourth lane. A fourth lane does not appear to be feasible for Alignment A3. The construction of Alignment A2 will have the most impact on the Canal operation with the potential for delays particularly during the dredging operations. All three alignments have similar excavation quantities for the third lane; however, cofferdam arrangements and dredging add significant cost to Alignment A2. For Alignment A3, the measures to be taken for construction through the dam, if feasible, will also increase the construction cost significantly. Alignment A1 requires the relocation of the anchorage basin in Gatun Lake and possibly the railroad concession for the implementation of a fourth lane.

For the Pacific entrance, the final evaluation of the proposed alignments highlighted the long-term benefit of bypassing Lake Miraflores with a single lifting operation. As shown on Exhibit 15, having a single three-lift lock instead of two separate lock complexes significantly reduces navigation time through the new locks. Further separation of the Post-Panamax vessels that would be the primary users of the new locks from the smaller vessels using the existing locks would simplify operations. Both the new and existing locks would become specialized for their respective vessel types, allowing them to use the most efficient schedule and equipment.

In conclusion, for the Atlantic Entrance, Alignments A1 and A2 should be carried forward for optimization as these alignments present the overall best opportunity for third and fourth lane expansion. For the Pacific Entrance, the results of the final evaluation combined with the initial evaluation indicate that the two bypass alignments, Alignments P1 and P2, should be carried forward for optimization. These two will offer the most efficient operations combined with good potential for future expansion to a fourth lane and beyond. They both utilize the area west of the existing locks that offers sufficient open land for staging, construction and expansion.

# 2.0 OPTIMIZATION OF LAYOUTS

This report section examines the two alignments recommended for each entrance to the Canal in greater detail. The analysis was divided into three stages. First, standard lock features were laid out for each of the three lock sizes being considered. Second, the layouts developed in Section 1.0 Final Evaluation were modified to reflect the results of re-evaluation of the two selected alignments for each entrance. Third, quantity take-offs and cost estimates were developed for several different design scenarios.

## 2.1 Preparation of Standard Layouts

New lock layouts were developed for the three lock sizes being considered for the third and fourth lanes. The standard layouts for Post-Panamax, Panamax and smaller-than-Panamax locks are provided on Exhibits 24, 25 and 26, respectively. The layouts assumed a phased construction sequence in which a third lane is constructed initially. Later as traffic demands warranted, a fourth lane would be constructed in parallel. While a combined center wall might be feasible between the third and fourth lanes, the layout is shown with completely separate lock structures for each lane. The locks are separated by a 30 m gap. This layout lessens the chance of interfering with third lane operations during construction of a fourth lane. It also lowers the first cost of the third lane since the third lane lock wall closest to the proposed fourth lane can be smaller and have fewer culverts and valves than if the wall were to later service a fourth lane as well. The layout could be easily modified to accommodate features necessary to combine the third and fourth lane guidewalls and lock walls should it be decided at a later stage of study that this is warranted.

The dimensions of the new locks were developed from the design criteria developed in the Initial and Final Evaluation sections. In general, the existing two lanes of lock were used as a guide in developing the dimensions for the new lanes. Table 8 below details the dimensions for the three lock sizes.

## Table 8

### Comparison of Lock Layout Dimensions

| | Small Locks | Panamax | Post-Panamax |
|---|---|---|---|
| Chamber Dimensions | | | |
| Length | 225 m | 304 m | 381 m |
| Depth | 10 m | 13 m | 17 m* |
| Width | 26 m | 33.5 m | 49 m |
| Design Vessel Dimensions | | | |
| Length | 183 m | 294 m | 350 m |
| Depth | 8.7 m | 12 m | 14 m |
| Width | 24 m | 32.3 m | 46 m |
| Distance Between Double Miter Gates | 22 m | 28 m | 41 m |
| Guidewall | | | |
| Length | 270 m | 365 m | 450 m |
| Width | 18 m | 18 m | 18 m |
| Guardwall | | | |
| Length | 60 m | 75 m | 100 m |
| Width | 8 m | 8 m | 8 m |
| Approximate Length including Guidewalls | 1300 m | 1800 m | 2200 m |

*Depth over the sills. Actual chamber depth is 17.75 m.

- Chamber Dimensions were agreed upon and recorded as part of the Initial Evaluation.
- Distance between miter gates is proportional to the existing locks. The proportion is based on the width of the miter gates so that there will be sufficient clearance between the tip of one gate in the open position and the hinge of the adjacent gate.
- The guidewalls are 120% of the length of an individual lock chamber. The 18 m width assumed is equivalent to the existing guidewall width.
- The guard walls are designed to accommodate two locomotive towing tracks.

- The length overall measures the length from the nose piece of one approach wall to the nose piece of the opposite guidewall.

## 2.2 Preparation of Site Specific Layouts

### 2.2.1 Introduction

It is probable that incremental increases in Canal capacity will be implemented to anticipate rising Canal traffic. Based on traffic projections currently being updated, the ACP will select the size and type of structure that will best meet the forecasted demand. These projections will include forecasts of the total number of transits and the vessel size distribution. The Canal capacity improvements will be phased to accommodate these forecasts and the expansion could consist of a third lane or third and fourth lanes. A greater demand in Panamax size vessels could also be addressed by building a smaller-than-Panamax size passage such as a shiplift that would free some capacity for Panamax size vessels in the existing locks. A possible first phase of capacity improvement would include construction of a third lane of locks and associated channel, and a nearby ship lift for vessels up to approximately 200 m in length. The locations and arrangements of the proposed lock complexes for the best alignments were investigated along with the regional geology. Proposed optimized sites of locks and shiplifts are presented in the sections below pertaining to the Atlantic and Pacific entrances.

### 2.2.2 Water Saving Basins

Increased Canal capacity, and the associated increased number of transits, will increase the demand for water in the Canal system. The proposed new alignments incorporate water saving basins so that some of the water used in each lock filling/emptying cycle can be recycled. Gravity drives the water flow into and out of the basins. The layouts presented in this report contain three water saving basins for each lock chamber. In general, there are two possible arrangements for the basins, stacked or stepped. If the basins are stacked, the land requirement is less, but maintenance of the structures can be hindered by the low clearance between the basins. Utilizing a stepped design requires more land. During the Initial Evaluation a stacked arrangement was used, but after further analysis in the Final Evaluation, a stepped layout was selected.

Use of water saving basins can increase the time required to complete a lock filling/emptying cycle since the head differential driving the filling/emptying is reduced. Preliminary calculations suggest that the use of three water saving basins could approximately double the filling/emptying time. However, the overall transit time through the locks is not only a function of the filling/emptying time, but also the approach and maneuvering time. The impact of the increased filling/emptying time on the overall transit time will be much less than the impact on just the filling/emptying cycle. The construction and use of water saving basins will be determined by other on-going studies. These studies are addressing future water availability, demand and value. Water saving basins are included at this stage to verify that they could be constructed as part of the Canal expansion plan, if required.

### 2.2.3 Atlantic Entrance

#### 2.2.3.1 Introduction

The two preferred alignments at the Atlantic entrance are located to the east of the existing Gatun Locks. The most eastern alignment, A1, would use the 1939 Third Locks Project Excavation. As such, the location of a new lock complex should be adjusted along the alignment to best use the geological conditions and the level of excavation previously achieved. For the other alignment, A2, which is adjacent and parallel to the existing Gatun locks, the location of the complex along the alignment will mostly be selected as a function of the Canal operation to accommodate traffic (including vehicular), maintenance and access to utilities. Preliminary considerations are identified in the following paragraphs.

#### 2.2.3.2 Geologic Considerations

The topography of the Atlantic entrance area is dominated by alluvial sediment plains and punctuated by gently rolling hills. The ground elevation gradually slopes down to the north-northwest. The ground elevation is highest along the shoreline of Lake Gatun, with a local maximum in the vicinity of Alignment A1.

The bedrock of the area is reported to be made up of the Gatun Formation and Undivided Holocene Sediments (CAS, 1993). The Gatun Formation consists of sandstone, siltstone, tuff and conglomerate. It has a rock classification of intermediate quality. The Undivided Holocene Sediments are alluvium in nature, or fill.

Geological profiles along Alignments A1 and A2 were constructed using the borehole data from the 1939 Third Locks Project. The borehole data were entered into the computer program gINT (a geotechnical computer application). Using gINT, an axis for each alignment was drawn and a number of selected boreholes were projected onto each axis. The geological profiles for alignments A1 and A2 are shown on Exhibits 27 and 28 respectively. For Alignment A1, once the basic profile was obtained, the excavation limits of the 1939 Third Locks Excavation were overlaid as well as the profile of the proposed third locks and excavation limits. Once the existing geologic and topographic conditions were established, the profile of the proposed third locks could be superimposed onto the geologic profiles to select the best location.

#### 2.2.3.3 Alignment A1

Although the Atlantic entrance presents relatively few places to site a new alignment, several scenarios can be considered to meet the growing demand of the Canal traffic. For Alignment A1 two of these scenarios are shown on Exhibits 29 and 30.

On Exhibit 29, the scenario shown would meet a moderate demand in Post-Panamax vessels. It would also address an increase in Panamax size traffic by building a shiplift for smaller vessels: the construction of the locks and the shiplift would likely be simultaneous, but it could be staged by taking appropriate measures. The scenario presented on Exhibit 30 could be developed if the demand is shown to be more significant. The Alignment A1 would be used to build up to two lanes for Post-Panamax size vessels. The construction could be simultaneous or staged. In addition, a shiplift would be built on Alignment A2 adjacent to the existing Gatun Locks. This scenario would separate the traffic of post-Panamax vessels from Panamax and smaller vessels. It would also allow a greater flexibility in the timing of development of each complex so as to meet the traffic demand with appropriate increase in Canal capacity.

#### 2.2.3.4 Alignment A2

Two similar scenarios can be planned for Alignment A2. On Exhibit 31, all the traffic would be concentrated through the existing approach channel. While this solution would maintain the operation of the Canal in a single location on the Atlantic side, it would also have the disadvantage of mixing all sizes of vessels at the same location that would create some operational difficulties. For a larger anticipated demand, two lanes of post-Panamax size vessels could be built adjacent to the existing Gatun Locks. A shiplift could be built at any time through the existing 1939 excavation: it could be built before the third lane, between the third and the fourth or even after both lanes. This scenario of development, as shown on Exhibit 32, would separate the smaller-than-Panamax vessel traffic from the rest and offer flexibility similar to that of the scenario shown on Exhibit 30.

The double post-Panamax lanes shown on Exhibit 30 (Alignment A1) requires 6.1 million cubic meters more excavation than that shown on Exhibit 32 (Alignment A2). For the development shown on Exhibit 30, the double post-Panamax lanes would require approximately 26.4 million cubic meters of excavation and the shiplift 5.7 million cubic meters. For the scenario shown on Exhibit 32, the excavation quantities would be approximately 20.3 million cubic meters for the third and fourth lanes and 3.3 million cubic meters for the shiplift. Overall the development shown on Exhibit 30 requires 32.1 million cubic meters, while that shown on Exhibit 32 requires 23.6 million cubic meters.

### 2.2.4 Pacific Entrance

#### 2.2.4.1 Introduction

At the Canal's Pacific Entrance, both of the best alignments feature a bypass of the existing Lake Miraflores and the proposed locks comprise three adjacent lifts. In general, locating the locks as far downstream (towards the Pacific) as possible reduces the overall volume of material to be excavated. The main limiting factors are geology and navigational safety. This report assumes that new locks would be founded on sound rock, and there must be sufficient maneuvering space for large vessels to enter and exit the entrance channel safely. Another consideration is whether or not a location for the lock results in additional cost or complexity of the construction.

#### 2.2.4.2 Proposed Lock Profile

During the Initial Evaluation, the longitudinal channel profile was approximated by assuming two elevations, upstream (Lake Gatun level) and downstream (sea level), with an instantaneous transition at the mid-point of the lock complex. For the optimization phase of the study, the profile of the alignments through the locks was refined to more accurately reflect the excavation volumes. The refined profile includes five elevations (bottom of upstream channel cut, bottom of upstream lock cut, bottom of middle lock cut, bottom of downstream lock cut, and bottom of downstream channel cut). The elevations for the bottom of the lock cuts were determined assuming that the lock structure would be

4.5 m thick and that a 17 m clearance would exist over the gate sills. The locks would be constructed 0.75 m deeper than the sills. The additional depth over the lock sills combined with future deepening of the entrance and Gatun Lake channels will allow deeper draft vessels to pass in the future.

The proposed lock excavation profile and corresponding excavation plan for the Pacific entrance is shown schematically on Exhibit 33.

### 2.2.4.3 Geologic Considerations

Profiles showing the ground surface and top of rock along alignment P1 are shown in Exhibits 34 and 35. The top of ground data is the same as used for all the quantity take-offs. The top of sound rock was determined using a 3-D model constructed using GEMCOM software. Future geologic data collected along the best alignments can be added to this database to increase the accuracy of the profiles. The two profiles differ only in the location of the proposed lock complex. Exhibit 34 shows the locks in the most upstream location, while Exhibit 35 shows the furthest downstream feasible location. A similar profile for alignment P2 is shown in Exhibit 36.

The proposed Miraflores locks layout of alignment P2 follows the 1939 Third Locks alignment. Assumptions regarding excavation conditions in the current planning study have closely followed the 1939 recommendations. In principal, the excavations are very much the same. However, the detailed engineering geologic characteristics of this area have yet to be worked out, especially as there are some basic differences between the 1939 Third Locks two-lift layout and the proposed new third and fourth lane three-lift lock.

One of the most important differences is that the water elevation in the Canal upstream (north) of the new Miraflores lock complex will be at el. 25.9 m PLD, i.e. 9.4 m higher than Miraflores Lake (el. 16.5 m PLD). Alignment P2 includes construction of a 2300 m long barrier dam to contain the Lake Gatun level water. Four alternative barrier dam concepts are shown on Exhibit 14. About 1300 m of the barrier dam will be founded on weak units belonging to the Cucaracha Formation and other formations. The Cucaracha formation provides notoriously poor foundation. The barrier dam foundation conditions should be studied in more depth in the alignment feasibility studies.

Consideration of leakage from the lock and from the Canal system between Miraflores and Lake Gatun should be studied prior to detailed design because of the importance of water control management and maintaining the safety of existing project features and of proposed structures. The impact of the relative hydraulic conductivities of the various formations that make up the foundation of this area and the Canal bottom have yet to be examined, in particular the impact of highly permeable basalt units. In view of the characteristics of the bedrock units, the merits of the various options founded on weak materials should be examined for potential differential settlement. Although grouting in the foundation of the barrier dam bounding the new Canal system has been included in the current cost estimates, the issue of Canal leakage losses should be an important topic for future studies. The issue pertains largely to the Alignment P2 because the Alignment P1 is situated further away from existing structures and Miraflores Lake.

#### 2.2.4.4 Alignment P1

Alignment P1 offers a number of possible lock locations. In general, there is a trade-off between locating the locks further upstream, which requires more excavation but provides more distance to maneuver between the ocean channel and the approach to locks. Siting the locks further downstream requires less excavation, but provides less distance in which to maneuver ships. The existing divide between the 1939 Third Locks excavation and the Pacific channel would act as a cofferdam for the construction of the lock complexes. Moving the locks south towards the Pacific would require a new cofferdam for construction of the locks. The furthest south that appears practical aligns the southern end of the guidewall with the entrance to the new channel. Moving the lock complex south also increases the distance between the center of operations for the existing Miraflores locks and the proposed new locks.

Exhibit 37 shows the range of possible locations for the lock complex with three proposed shiplift alignments (see Section 2.3.2.1 for further discussion of the shiplift alignments). On the exhibit the upstream end of the locks are shown at approximately Station 6+750, which is the furthest south that the locks could be located without construction of a cofferdam. Excavation volumes were computed (at Gatun Lake bottom elevation of 9.9 m PLD) with the upstream end of the locks at a total of 6 locations to investigate the potential reduction in excavation associated with moving the locks downstream. A summary of the excavation volumes is presented in Table 9.

**Table 9**

**Comparison of Excavation Volumes for Alignment P1**

| Upstream Location of Lock Complex | Total Excavation Volume ($m^3 \times 10^6$) | Net Excavation Reduction ($m^3 \times 10^6$) | Net Excavation Reduction as % of Total for Sta. 6+500 |
|---|---|---|---|
| Sta. 6+500 | 70.7 | 0 | 0 |
| Sta. 6+750 | 69.6 | 1.1 | 1.6 % |
| Sta. 7+000 | 68.3 | 2.4 | 3.4 % |
| Sta. 7+250 | 67.0 | 3.7 | 5.3 % |
| Sta. 7+500 | 65.8 | 4.9 | 6.9 % |
| Sta. 7+750 | 65.1 | 5.6 | 7.9 % |

Note:
1. The excavation volumes in this table are based on the excavation profile shown in Exhibit 33. The assumed bottom of channel at the upstream (Lake Gatun) end is El. +9.9.

As can be seen from Table 10, moving the locks south can reduce the overall excavation volume by approximately 8%. However, a more detailed investigation of the local geology and the navigational issues associated with the lock complex location may result in one location being more favorable.

### 2.2.4.5 Alignment P2

The existing third locks excavation limits the possible site of the locks along this alignment. Moving the locks upstream increases excavation. Moving the locks downstream would require that the intermediate and/or upper lock chamber be founded on piles, since some prior excavation occurred as part of the 1939 Third Locks Project. In order to provide suitable rock foundations, the locks must be sited similarly to those proposed in the 1939 project. The Third Locks Project excavation was nearly complete at Miraflores when the project was abandoned. At the time of final lock siting, a detailed study of the existing excavation should be made to verify the foundation conditions.

Exhibit 38 shows the preliminary layout of the locks and associated features for Alignment P2. Two shiplift alignments are shown on the same exhibit and are described in more detail in Section 2.3.2.2.

## 2.3 Location of the Ship Lift

Consideration was given to the most appropriate location for the proposed shiplift in relation to the third lane lock structures. In general, siting the ship lift further upstream (towards Lake Gatun) leads to greater excavation volumes. Siting the shiplift closer to the entrances can lower excavation quantity though it may also require additional retaining structures due to differences in water elevation between the shiplift channel and the new third lane channel. This issue is more pronounced for the Pacific entrance alignments than for the Atlantic entrance.

The shiplift alignments shown on Exhibits 29 through 32 (Atlantic entrance) and Exhibits 37 and 38 (Pacific entrance) represent some possible sites. They are discussed in further detail below. These sites have not been investigated for foundation conditions to determine whether appropriate foundations exist or if pile support would be required. Detailed excavation quantities have not been calculated for any of the proposed alignments either. If the shiplift study currently in process concludes that such a structure is technically and economically feasible, then these sites should be further investigated to determine their suitability.

### 2.3.1 Atlantic Entrance

Several alternate alignments for the shiplift were investigated. Advantages and disadvantages of each of the proposed alignments are presented below. The timing of the shiplift construction, relative to the third and fourth lanes would affect the comments on advantages/disadvantages of each of these alignments. It was assumed that the shiplift would be built prior to the fourth lane; no assumption was made regarding the construction sequencing of the third lane and the shiplift. The shiplift construction could take place prior to, simultaneous with or after that of the third lane. This decision could affect the comments related to the interference with the operation during construction.

#### 2.3.1.1 Alignment A1

**Shiplift Alignment 1 (SLA1-1) (Exhibit 29)**

Advantages:

- Operational efficiency from combined control with the new third lane; and

- Minimal interference with existing operation during construction.

Disadvantages:

- Large excavation quantity; and
- Interference with railroad alignment.

**Shiplift Alignment 2 (SLA1-2) (Exhibit 30)**

Advantages:

- Timing of construction is independent of the third lane implementation;
- Does not affect the constructibility of the fourth lane;
- Operational efficiency from combined control with the existing lanes;
- Good navigational safety features; and
- Relatively small excavation quantity.

Disadvantages:

- Potential interference with existing locks during construction (access to existing locks, cofferdam, etc.);
- Interference of operation with existing locks ( competition for right of way);
- Increased traffic in approach channel (especially on the Atlantic entrance);
- Interference with the anchorage basin nearest to the existing locks; and
- Requires removal or relocation of some existing and operating infrastructure including an electric substation, road; maintenance tracks, maintenance buildings, warehouse, water, telephone lines, electrical lines, launch docks at both ends and a locks parts storage yard.

### 2.3.1.2 Alignment A2

**Shiplift Alignment 1 (SLA2-1) (Exhibit 31)**

Advantages:

- Moderate excavation quantity; and

- Operational efficiency from combined control with the third lane and the existing lanes.

Disadvantages:

- Potential interference with existing locks during construction (access to existing locks, cofferdam, etc.);
- Interference of operation with existing locks ( competition for right of way);
- Increased traffic in approach channel (especially on the Atlantic entrance);
- Interference with the anchorage basin nearest to the existing locks; and
- Require demolition and relocation to accommodate Post-Panamax fourth lane, unless the fourth lane, when needed, is located in Alignment A1.

**Shiplift Alignment 2 (SLA2-2) (Exhibit 32)**

Advantages:

- Timing of construction is independent of the third lane implementation;
- Does not affect the constructibility of the fourth lane;
- Good navigational safety features;
- Separate traffic of smaller vessels away from the existing facilities and the Post-Panamax lane(s);
- Relatively small excavation quantity; and
- Minimal interference with existing operation during construction.

Disadvantages:

- Requires separate supporting facilities for the operation of the shiplift.

### 2.3.2 Pacific Entrance

Siting for the Pacific entrance shiplift alignments was constrained by topography, the existing Miraflores locks and lake, and the proposed third lane of locks. Both Alignment P1 and Alignment P2 could accommodate a shiplift west of the proposed third lane. Other possibilities on the east bank of the third lane are also discussed.

### 2.3.2.1 Alignment P1 (Exhibit 37)

**Shiplift Alignment 1 (SLP1-1)**

Advantages

- Relatively low extra excavation quantity;
- Operational efficiency from combined control with new third lane; and
- Good navigational safety features along a single azimuth.

Disadvantages

- Must be relocated or removed to accommodate Post-Panamax fourth lane economically; and
- Different elevations of shiplift guidewall and third lane lower and middle chamber new-three-lift lock wall require very high retaining walls.

**Shiplift Alignment 2 (SLP1-2)**

Advantages

- Uses the 1939 Third Locks Project excavation;
- Provides potential mooring area at the mouth of the Rio Cocoli; and
- Good foundation conditions in 1939 Third Locks Project area.

Disadvantages

- Potential conflict with third lane water saving basins;
- Requires additional barrier dam and/or levee structures; and
- Four azimuth changes in a short distance required to bypass third lane area.

**Shiplift Alignment 3 (SLP1-3)**

Advantages

- Good foundation conditions for shiplift structure;

- Does not interfere with water saving basins; and
- Provides potential mooring area at the mouth of the Rio Cocoli.

Disadvantages

- Potential construction impacts on existing locks;
- Sharp azimuth change required in upstream and downstream entrance channels;
- Relatively high excavation quantities through hilly terrain;
- Potential interference with existing locks during operation (i.e. competition for right of way); and
- Additional levees and/or barrier dams required located at the upper east side, founded on the bottom of an existing excavation and the bed of the Cocolí River.

**2.3.2.2 Alignment P2 (Exhibit 38)**

**Shiplift Alignment 1 (SLP2-1)**

Advantages

- Relatively low excavation quantity;
- Operational efficiency from combined control with new third lane; and
- Good navigational safety features along a single azimuth.

Disadvantages

- Must be relocated or removed to accommodate Post-Panamax fourth lane economically; and
- Different elevations of shiplift guidewall and third lane lock wall require high retaining structures.

**Shiplift Alignment 2 (SLP2-2)**

Advantages

- Good foundation conditions in hilly terrain (Cerro Cocolí); and
- Good navigational safety features (on a single continuous azimuth).

Disadvantages

- Requires 750 m extension of the barrier dam;
- Requires relocation/reassessment of water saving basins for third lane;
- Impacts on existing operations during construction; and
- Water saving basin north and east walls will need to be designed as retaining walls for the Gatun Lake elevation at one side and variable water elevations at the other side.

## 2.4 Excavation Quantity and Cost Comparison

### 2.4.1 Comparison of Excavation Quantities for Various Parameters

A number of channel design parameters were investigated in order to determine the relative difference of excavation quantities for various scenarios. Channel design widths were varied from 138 m (3B) to 276 m (6B). These widths represent the range of channel widths from the narrowest proposed one-way channel for a post-Panamax vessel to a two-way post-Panamax channel. Channel bottom depths were also varied to examine various design criteria. These included three bottom elevations considering a 16 m deep channel (14 m vessel draft + 2 m underkeel clearance) at design Gatun Lake elevations of 25.9 m (mean Gatun Lake level), 24.8 m (average annual low Gatun Lake level) and 23.9 m PLD (historic low Gatun Lake level). A fourth Gatun Lake channel bottom elevation, 7.16 m PLD, was also considered. This bottom elevation would accommodate a 15.24 m (50 ft) draft post-Panamax vessel with 1.5 m (5 ft) underkeel clearance at Gatun Lake level of 23.9 m PLD. Table 10 on the next page summarizes the range of possible channel bottom elevations examined.

**Table 10**

**Channel Bottom Elevation for Different Gatun Lake Levels and Channel Depths**

| Channel Dimensions | | | | Mean Gatun Lake Level | Mean Low Gatun Lake Level | Historic Low Gatun Lake Level |
|---|---|---|---|---|---|---|
| Draft (ft) | Draft (m) | Underkeel Clearance | Channel Depth | 25.90 m PLD | 24.84 m PLD | 23.92 m PLD |
| 46 | 14.00 | 1.50 | 15.50 | 10.40 | 9.30 | 8.40 |
| 46 | 14.00 | 2.00 | 16.00 | 9.90 | 8.80 | 7.90 |
| 50 | 15.26 | 1.50 | 16.76 | 9.16 | 8.08 | 7.16 |

The quantity take-off results are provided in Table 11 on the next page.

## Table 11

## Post-Panamax Channel Quantity Takeoffs

| | | | | Excavation Quantity (m³) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Overburden | | Rock | | Total |
| Alignment | Gatun Lake Elevation (PLD) | Channel Width (m) | Channel Bottom Elev. (m) | Wet | Dry | Wet | Dry | |
| A1 | 25.9 | 138 | 9.9 | 1,200,000 | 2,700,000 | 900,000 | 4,800,000 | 9,600,000 |
| A2 | 25.9 | 138 | 9.9 | 1,800,000 | 2,400,000 | 3,800,000 | 2,100,000 | 10,100,000 |
| P1 | 25.9 | 138 | 9.9 | 7,300,000 | 16,700,000 | 6,600,000 | 28,200,000 | 58,700,000 |
| P2 | 25.9 | 138 | 9.9 | 3,700,000 | 8,500,000 | 3,300,000 | 14,400,000 | 30,000,000 |
| A1 | 25.9 | 184 | 9.9 | 1,500,000 | 3,500,000 | 1,400,000 | 5,900,000 | 12,300,000 |
| A2 | 25.9 | 184 | 9.9 | 1,800,000 | 3,500,000 | 3,800,000 | 3,100,000 | 12,100,000 |
| A3 | 25.9 | 184 | 9.9 | 2,400,000 | 10,000,000 | - | 1,600,000 | 14,000,000 |
| P1 | 25.9 | 184 | 9.9 | 1,500,000 | 12,500,000 | 5,800,000 | 49,800,000 | 69,600,000 |
| P2 | 25.9 | 184 | 9.9 | 2,000,000 | 5,400,000 | 8,100,000 | 21,400,000 | 36,900,000 |
| P3 | 25.9 | 184 | 9.9 | 2,300,000 | 5,000,000 | 9,100,000 | 20,000,000 | 36,400,000 |
| P4 | 25.9 | 184 | 9.9 | 1,200,000 | 6,400,000 | 4,800,000 | 25,800,000 | 38,100,000 |
| P5 | 25.9 | 184 | 9.9 | 2,800,000 | 6,600,000 | 11,200,000 | 26,200,000 | 46,800,000 |
| A1 | 25.9 | 276 | 9.9 | 2,100,000 | 6,900,000 | 2,100,000 | 15,300,000 | 26,400,000 |
| A2 | 25.9 | 276 | 9.9 | 1,800,000 | 7,400,000 | 3,800,000 | 7,300,000 | 20,300,000 |
| P1 | 25.9 | 276 | 9.9 | 12,800,000 | 29,400,000 | 11,500,000 | 49,400,000 | 103,000,000 |
| P2 | 25.9 | 276 | 9.9 | 3,500,000 | 9,200,000 | 13,900,000 | 36,900,000 | 63,600,000 |
| A1 | 24.8 | 184 | 8.8 | 1,500,000 | 3,500,000 | 1,400,000 | 6,000,000 | 12,400,000 |
| A2 | 24.8 | 184 | 8.8 | 1,800,000 | 3,500,000 | 3,800,000 | 3,100,000 | 12,100,000 |
| P1 | 24.8 | 184 | 8.8 | 8,800,000 | 20,300,000 | 7,900,000 | 34,100,000 | 71,200,000 |
| P2 | 24.8 | 184 | 8.8 | 2,100,000 | 5,600,000 | 8,500,000 | 22,400,000 | 38,600,000 |
| A1 | 23.9 | 184 | 7.9 | 1,500,000 | 3,500,000 | 1,400,000 | 6,200,000 | 12,700,000 |
| A2 | 23.9 | 184 | 7.9 | 1,800,000 | 3,500,000 | 3,800,000 | 3,200,000 | 12,300,000 |
| P1 | 23.9 | 184 | 7.9 | 9,000,000 | 20,700,000 | 8,100,000 | 34,800,000 | 72,500,000 |
| P2 | 23.9 | 184 | 7.9 | 2,200,000 | 5,700,000 | 8,700,000 | 23,000,000 | 39,600,000 |
| A1 | 23.92 | 184 | 7.16 | 1,600,000 | 3,700,000 | 1,500,000 | 6,500,000 | 13,200,000 |
| A2 | 23.92 | 184 | 7.16 | 1,800,000 | 3,600,000 | 3,800,000 | 3,400,000 | 12,600,000 |
| P1 | 23.92 | 184 | 7.16 | 1,600,000 | 13,300,000 | 6,200,000 | 53,100,000 | 74,100,000 |
| P2 | 23.92 | 184 | 7.16 | 2,300,000 | 6,000,000 | 9,000,000 | 23,900,000 | 41,100,000 |

Figures 1 and 2 below provide a graphical illustration of the different excavation quantities required for construction of various approach channel widths for the new alignments. For the Atlantic Entrance, there is little difference between the two alignments for a 138 m or 184 m Post-Panamax channel. However, Alignment A1 requires significantly greater excavation for a 276 m channel width (the two-way traffic case). For the Pacific Entrance, the excavation quantity difference for the two alignments remains roughly proportional for each of the channel widths studied.

**Figure 1**

**Post-Panamax Excavation Comparison**
**Atlantic Entrance Alignments**

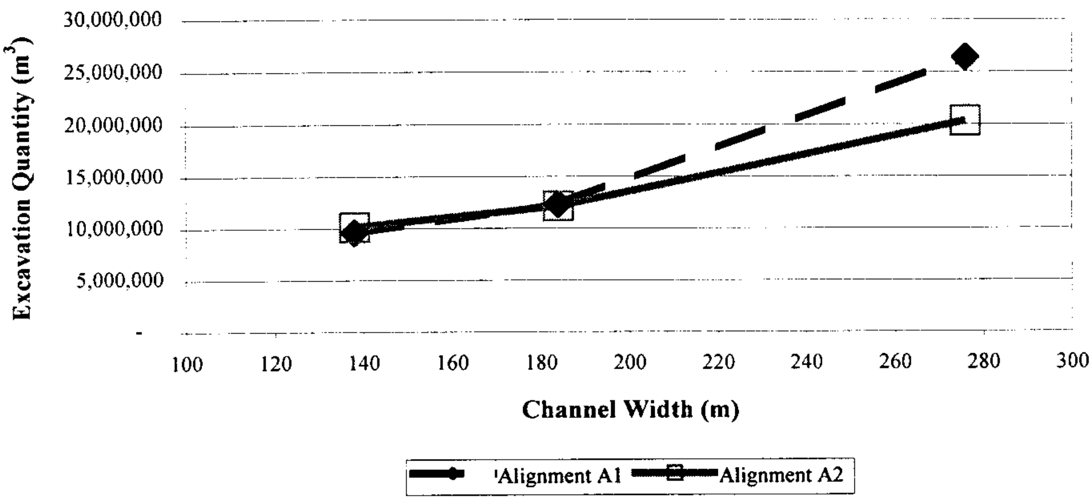
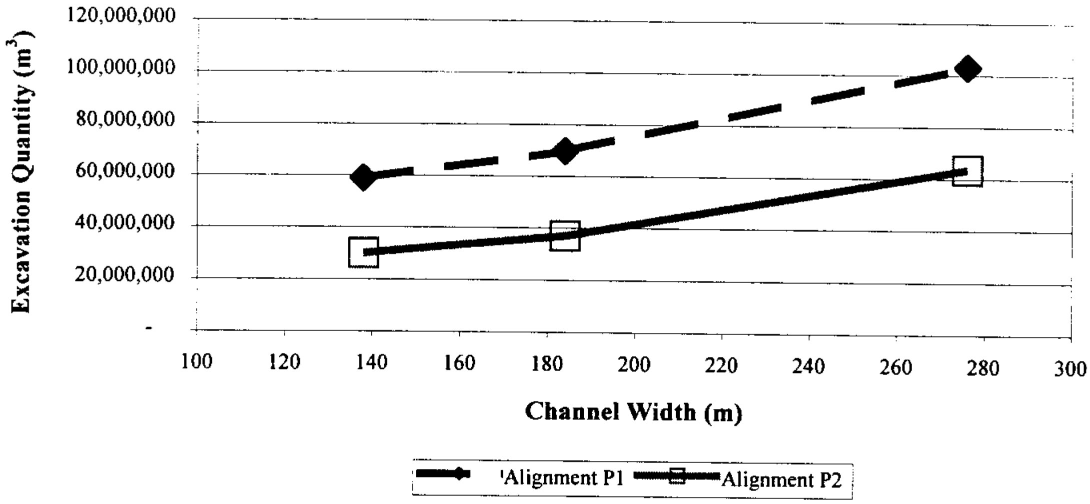


**Figure 2**

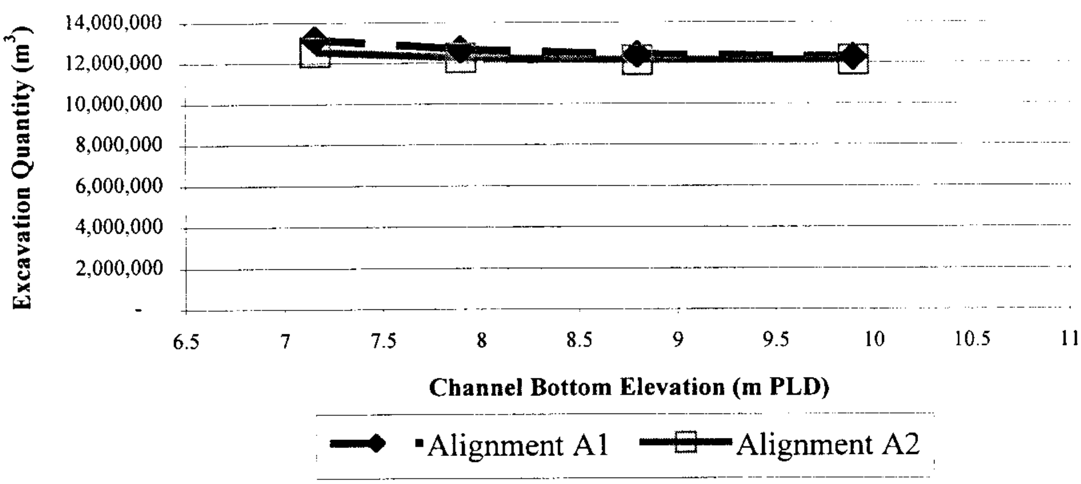
**Post-Panamax Excavation Comparison**
**Pacific Entrance Alignments**




Figures 3 and 4 on the next page illustrate the comparative excavation quantities to maintain a 16 m deep channel at three levels of Gatun Lake (23.9 m, 24.8 m, 25.9 m PLD). Excavation quantities are also shown for the proposed 7.16 m PLD bottom elevation channel. For each of these comparative estimates, a 184 m (4B) wide channel was used. The lower channel bottoms represent proposed scenarios to accommodate deeper draft vessels and to provide draft guarantees at low levels of Gatun Lake experience during dry conditions. For both the Atlantic and Pacific Entrances, the figures indicate that the channel deepening to accommodate traffic during low water periods would not require vast additional excavation for the new approach channels.

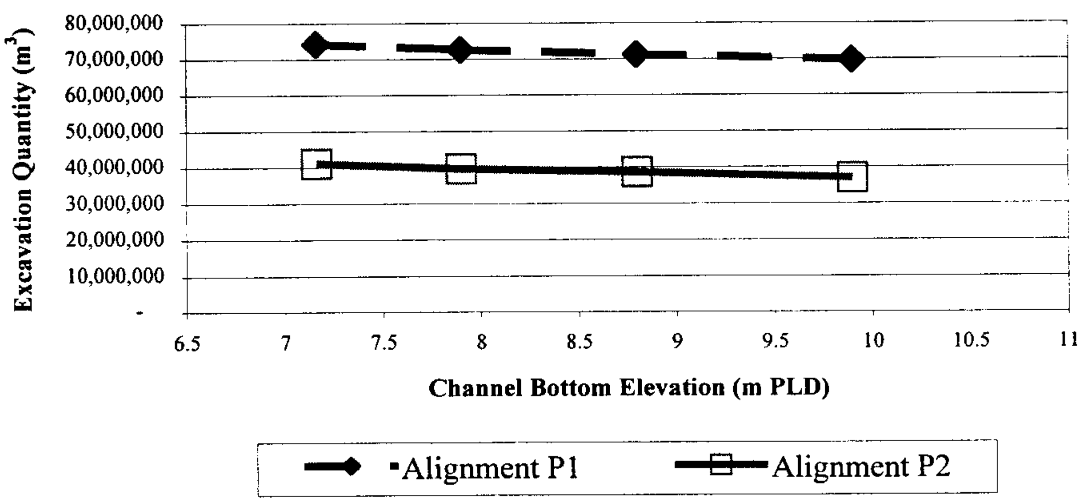
## Figure 3

### Excavation Comparison for Different Channel Bottom Elevations Atlantic Entrance Alignments




## Figure 4

### Excavation Comparison for Different Channel Bottom Elevations Pacific Entrance Alignments



### 2.4.2 Phased Channel Construction

Phasing construction of the navigation channel offers one method of reducing both initial cost and construction period for the third lane project. One scenario would involve the initial construction of a 10.36 m bottom elevation channel. This channel would accommodate vessels of 14 m draft at Gatun Mean Lake Level (25.9 m PLD) with a 1.5 m under keel clearance. Later, to improve reliability of the channel without draft restrictions in low water conditions, the channel could be deepened to 7.16 m or 8.08 m bottom elevation. These two depth options (indicated below as Phase II and Phase IIa, respectively) would provide the same 15.24 m draft and 1.5 m under keel clearance if Gatun Lake reached extreme or mean low water levels of 23.92 m PLD or 24.84 m PLD, respectively. The excavation quantities for these scenarios are summarized in Table 12 below. Station-by-station quantities for Phase I, Phase II and Phase IIA are provided in Appendix C.

**Table 12**

**Quantity Takeoffs for Phased Channel Construction**

| | | | Excavation Quantity ($m^3$) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Overburden | | Rock | | Total |
| Phase | Alignment | Channel Bottom Elev. (m) | Wet | Dry | Wet | Dry | |
| Phase I | A1 | 10.36 | 1,530,000 | 3,650,000 | 1,440,000 | 6,130,000 | 12,750,000 |
| | A2 | 10.36 | 1,810,000 | 3,580,000 | 3,790,000 | 3,380,000 | 12,560,000 |
| | P1 | 10.36 | 1,450,000 | 12,420,000 | 5,820,000 | 49,660,000 | 69,350,000 |
| | P2 | 10.36 | 2,050,000 | 5,430,000 | 8,200,000 | 21,730,000 | 37,410,000 |
| Phase II | A1 | 7.16 | 60,000 | - | 360,000 | - | 420,000 |
| | A2* | 7.16 | - | - | - | - | - |
| | P1 | 7.16 | 960,000 | - | 3,840,000 | - | 4,800,000 |
| | P2 | 7.16 | 730,000 | - | 2,930,000 | - | 3,660,000 |
| Phase IIa | A1 | 8.08 | 40,000 | - | 250,000 | - | 290,000 |
| | A2* | 8.08 | - | - | - | - | - |
| | P1 | 8.08 | 680,000 | - | 2,720,000 | - | 3,400,000 |
| | P2 | 8.08 | 520,000 | - | 2,070,000 | - | 2,590,000 |

*There is no additional excavation required to deepen Alignment A2 because the new channel joins the existing channel just outside of the locks. The cost of deepening the entrance to the locks will be covered in the cost of deepening the Gatun Lake channel.

The cost of the proposed initial excavation (to bottom elevation 10.36 m PLD) were calculated in the same way as the comparative cost estimates presented in Appendix A. The deepening project (Phase II and IIA) costs were calculated using the same spreadsheet and unit costs. However, since the deepening project would take place after the channel was flooded and in operation, mechanical dredging rates have been applied to the entire Phase II and IIA quantities. In addition, full dredging mobilization costs were applied for Phase II and IIA. The estimated costs for phased construction are summarized in Table 13 below.

**Table 13**

**Summary of Overall Excavation Costs**

| Alignment No. | Phase I ($ millions) | Phase II ($ millions) | Phase IIA ($ millions) | Overall Cost (I+II) ($ millions) | Overall Cost (I+IIA) ($ millions) |
|---|---|---|---|---|---|
| A1 | 92 | 10 | 7 | 102 | 99 |
| A2* | 141 | N/A | N/A | 141 | N/A |
| P1 | 660 | 160 | 120 | 820 | 780 |
| P2 | 840 | 120 | 90 | 960 | 930 |

*There is no deepening required for Alignment A2 because it does not contain any entrance channel in Gatun Lake.

Table 13 indicates that the excavation cost associated with deepening the proposed channel is equal to as much as one quarter of the cost of the initial excavation despite the fact that the quantity is as little as 5% of the initial excavation quantity. The high incremental cost of Phase II and IIA is due to the increased proportion of the work that would be carried out "in-the-wet". Phase I excavation would take place almost exclusively in the dry at approximately one quarter the unit cost.

However, this approach also offers definite advantages over, for example, an initial excavation to 7.16 m bottom elevation. The initial excavation to 10.36 m would have a lower first cost and construction duration than a comparable one-time effort to reach 7.16 m. That would result in the project coming on-line faster and at a lower first cost. The deepening project to 7.16 m would take place while a revenue stream was already present from the new locks.

Table 14 compares the cost of phased construction vs. all-at-once for channel excavation to Gatun Lake bottom elevations of 7.16 m and 8.08 m PLD.

**Table 14**

**Comparison of Excavation Costs ($ millions)**

| | Excavation to 7.16 m PLD (Phase I + II) | | | Excavation to 8.08 m PLD (Phase I + IIA) | | |
|---|---|---|---|---|---|---|
| **Alignment No.** | **All-at-once** | **Phased** | **Difference** | **All-at-once** | **Phased** | **Difference** |
| A1 | 126 | 140 | 14 | 125 | 136 | 11 |
| A2 | 181 | N/A | N/A | 181 | N/A | N/A |
| P1 | 710 | 820 | 110 | 700 | 780 | 80 |
| P2 | 890 | 960 | 70 | 880 | 930 | 50 |

*There is no deepening required for Alignment A2 because it does not contain any entrance channel in Gatun Lake.

To compare the phased construction approach to the all-at-once approach, the net present worth of the projects were compared for each alignment. The formula governing the comparison was:

Find n when

$$P_A = C_I + C_{II}(P/F,i,n)$$

Where

$P_A$ = Present Value of all-at-once construction approach
$C_I$ = Construction Cost of Phase I
$C_{II}$ = Construction Cost of Phase II
$i$ = Interest Rate in Percent
$n$ = Number of years

Table 15 below summarizes the results of these calculations for the best alignments. In each case, the number of years, n, represents the duration of time that would elapse between the center of construction period (in cost terms) of the initial excavation and of the second phase deepening. This comparison does not take into account the potential for lost revenue due to the reduced draft reliability at the initial excavation bottom elevation (10.36 m PLD) compared to the reliability provided at the final bottom elevation for both the phased and all-at-once approach (7.16 m PLD). Two interest rates were considered. The lower rate, 8%, is an estimated real cost of money for the project. The higher rate, 14%, represents the Minimum Attractive Rate of Return used by the ACP for capital projects.

**Table 15**

**Approximate Time Period for Phased Construction Cost to Equal All-at-once Construction***

| Alignment | | $P_A$ | $C_I$ | $C_{II}$ | i (%) | (P/F,i,n) | n (years) |
|---|---|---|---|---|---|---|---|
| A1 | Phase I/II | 125.9 | 122.3 | 17.9 | 14 | .2007 | 12 |
| | | | | | 8 | | 21 |
| | Phase I/IIA | 124.8 | 122.3 | 14.4 | 14 | .1768 | 13 |
| | | | | | 8 | | 23 |
| P1 | Phase I/II | 710 | 660 | 160 | 14 | .3125 | 9 |
| | | | | | 8 | | 15 |
| | Phase I/IIA | 700 | 660 | 120 | 14 | .3333 | 8.5 |
| | | | | | 8 | | 14 |
| P2 | Phase I/II | 890 | 840 | 120 | 14 | .4167 | 7 |
| | | | | | 8 | | 11 |
| | Phase I/IIA | 880 | 840 | 90 | 14 | .4444 | 6 |
| | | | | | 8 | | 10.5 |

*No comparison is provided for Alignment A2 because there is no additional excavation required in Gatun Lake to complete Phase II or Phase IIA.

**Table 16**

**Approximate Time Period for a More Attractive Phased Approach***

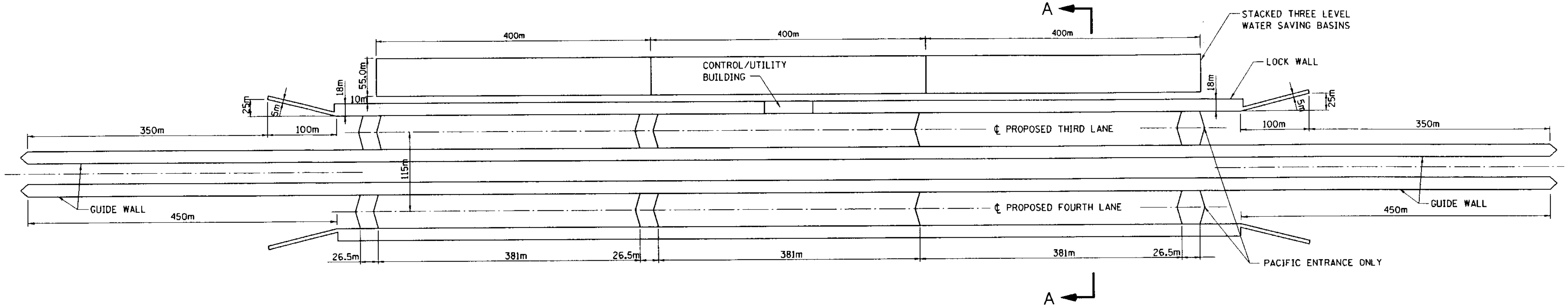
| Alignment No. | Bottom Elevation = 7.16 m PLD | | Bottom Elevation = 8.08 m PLD | |
|---|---|---|---|---|
| | Time Period at 14% Interest (Years) | Time Period at 8% Interest (Years) | Time Period at 14% Interest (Years) | Time Period at 8% Interest (Years) |
| A1 | 12 | 21 | 13 | 23 |
| P1 | 9 | 15 | 8.5 | 14 |
| P2 | 7 | 11 | 6 | 10.5 |

*No time period is provided for Alignment A2 because there is no additional excavation required in Gatun Lake to complete Phase II or Phase IIA.

Table 16 indicates that a delay of as little as six years between the center of construction periods (in cost terms) of the initial phase and a deepening to 8.08 m bottom elevation could be a more cost effective approach. The economic benefits of phased or all-at-once construction should be further examined in the feasibility study of the preferred alignments.

## 2.5 Conclusion

The Optimization of Alignments presented several different layout scenarios for the two best alignments at the Atlantic and Pacific entrances. For the Atlantic entrance, the final siting of Alignment A1 will be a function of a detailed study of the geology at the 1939 Third Locks Excavation site. Alignment A2's final site will be a function of access for Canal traffic, as well as operations and maintenance facilities. For the Pacific entrance, both best alignments feature a bypass of Lake Miraflores. For Alignment P1, excavation cost may be reduced by siting the locks closer to the Pacific entrance channel. Alignment P2's final site (like that of Alignment A1) will be a function of the existing excavation from the 1939 Project.




TYPICAL THREE-LIFT LOCK COMPLEX
WITH
THREE WATER SAVING BASINS PER LOCK

ATLANTIC AND PACIFIC ENTRANCES

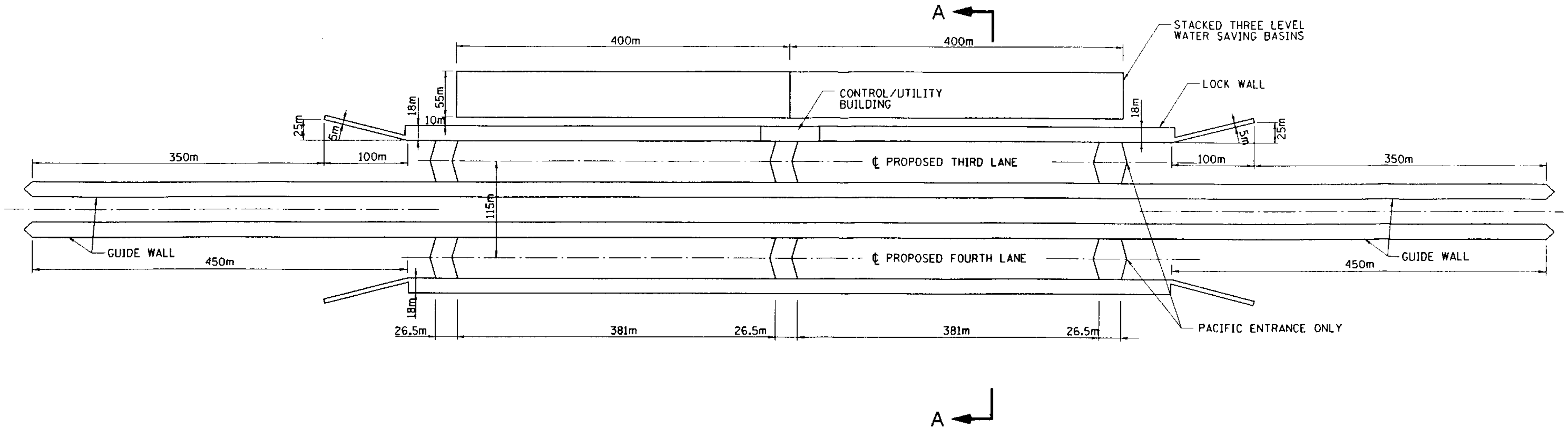
0 100 200

SCALE: 1: 6000

**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

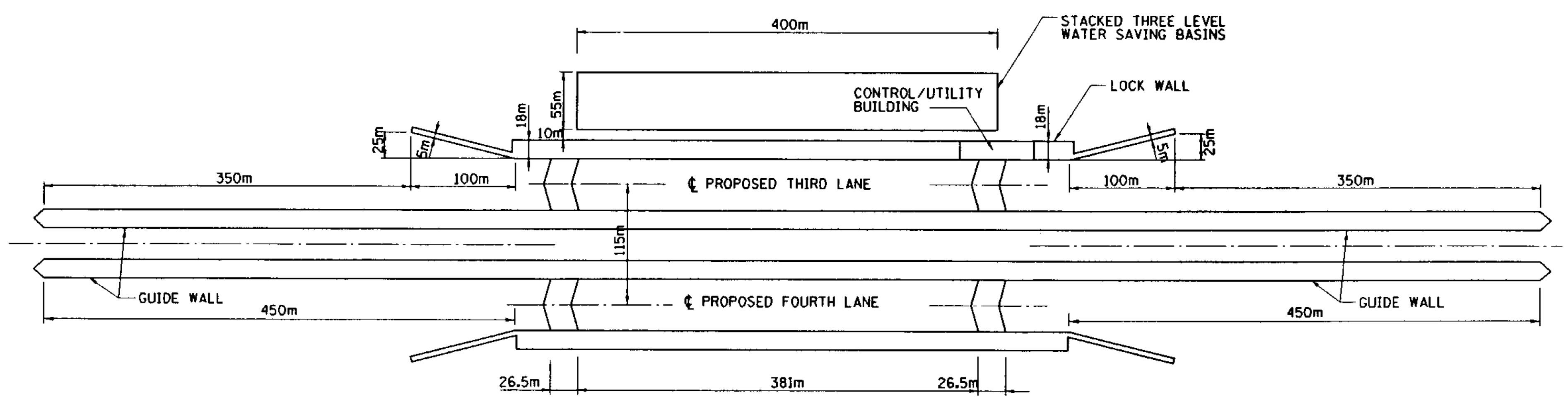
CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Typical Three-Lift Complex

| HARZA TAMS | August 2000 | Exhibit 1 |
| --- | --- | --- |




TYPICAL WEST SIDE TWO-LIFT LOCK COMPLEX
WITH
THREE WATER SAVING BASINS PER LOCK

PACIFIC ENTRANCE




TYPICAL WEST SIDE ONE-LIFT LOCK COMPLEX
WITH
THREE WATER SAVING BASINS PER LOCK

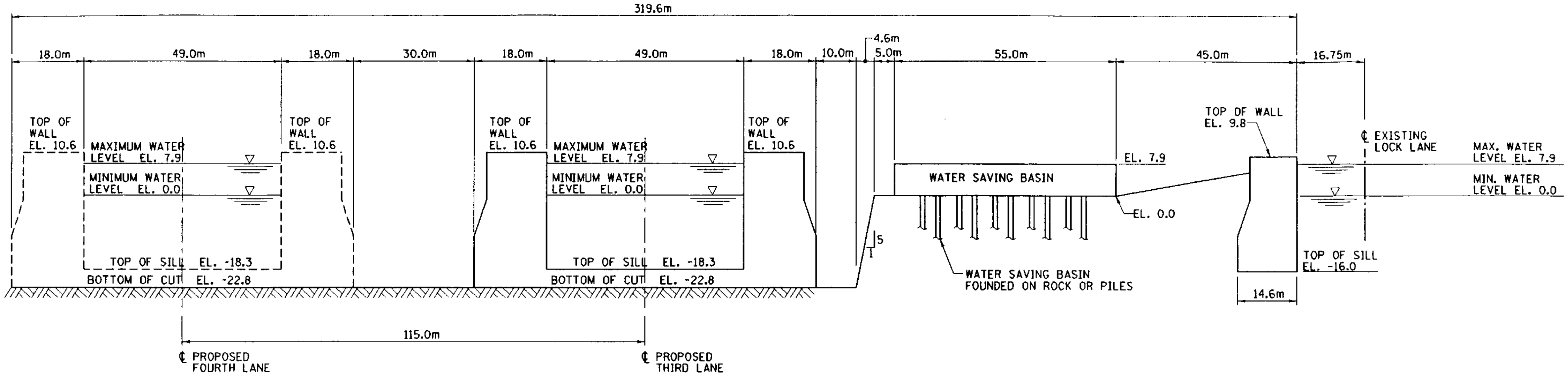
PACIFIC ENTRANCE

0 100 200
SCALE: 1: 6000

**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Typical West Side Two-Lift & One-Lift Complexes

HARZA TAMS | August 2000 | Exhibit 2




SECTION A – A
TYPICAL SECTION THROUGH MIRAFLORES LOCKS
POST PANAMAX DIMENSIONS

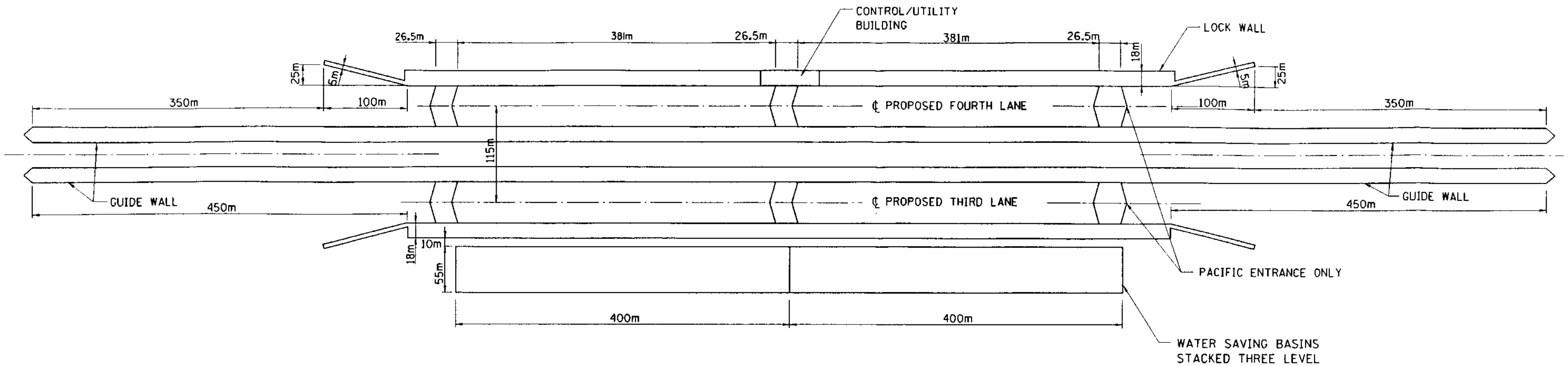
10m 0 50m
SCALE 1:1250

**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Typical Section Through Miraflores Locks

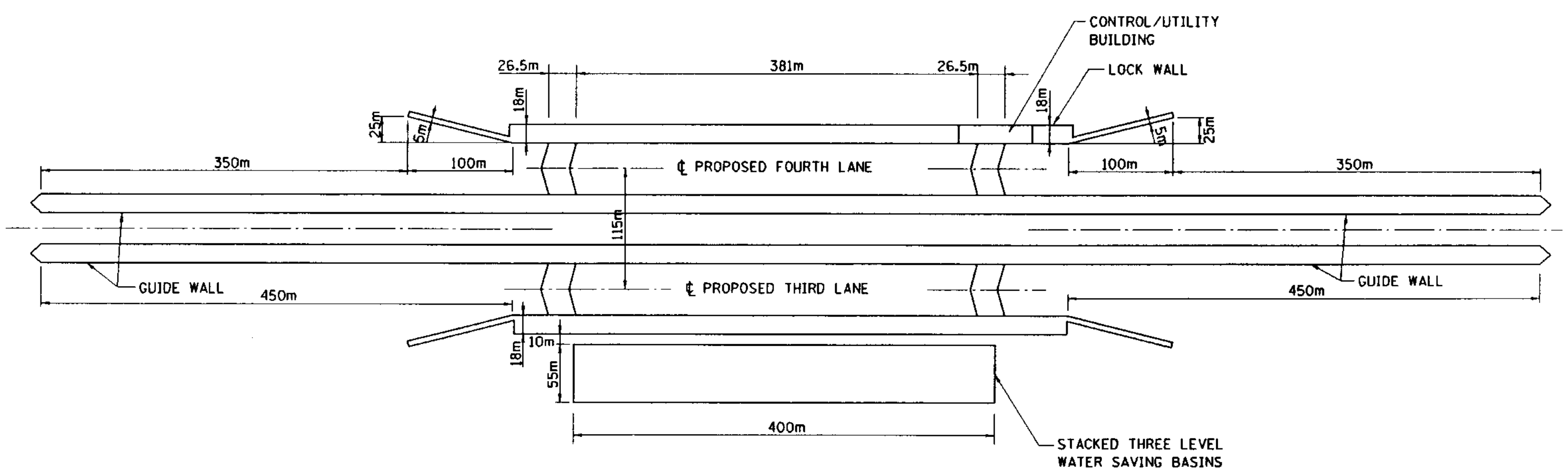
| | | |
|---|---|---|
| HARZA TAMS | August 2000 | Exhibit 3 |

8/7/00 10:40:11 AM  P:\PLOT\QUEUE\CHICAGO.qcf MEG170 r:\15593\d.canal alignments\cagxcp03.prl




TYPICAL EAST SIDE TWO-LIFT LOCK COMPLEX
WITH
THREE WATER SAVING BASINS PER LOCK

PACIFIC ENTRANCE




TYPICAL EAST SIDE ONE-LIFT LOCK COMPLEX
WITH
THREE WATER SAVING BASINS PER LOCK

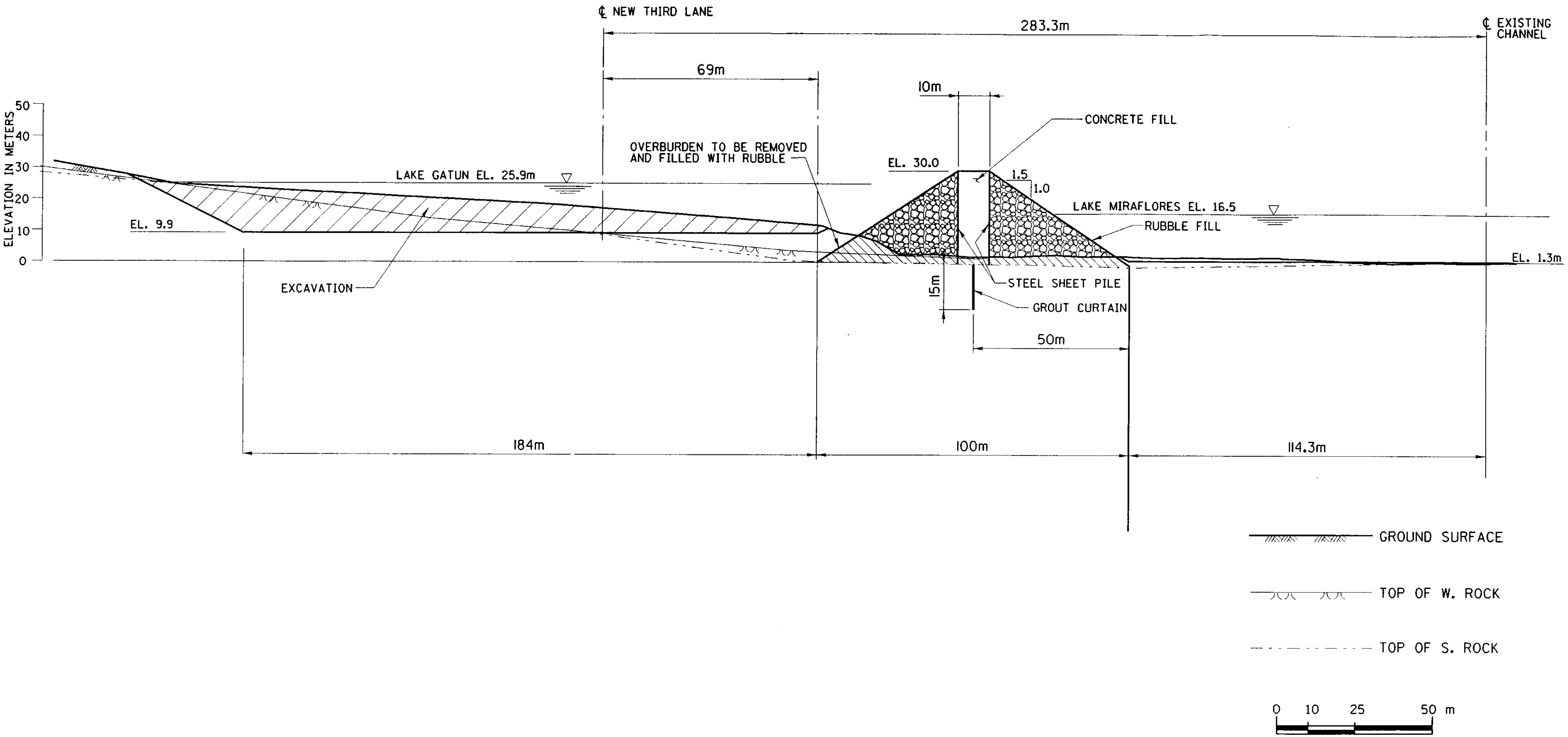
PACIFIC ENTRANCE

0 100 200
SCALE: 1: 6000

**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Typical East Side Two-Lift & One-Lift Complexes

| HARZA TAMS | August 2000 | Exhibit 4 |
|---|---|---|




**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC–5–536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Typical Cross Section Of Alignment P2

| HARZA TAMS | AUGUST 2000 | Exhibit 13 |
|---|---|---|

# Autoridad del Canal de Panama

## Oficina de Proyectos de Capacidad del Canal

## Final Evaluation of Lock Channel Alignments

## Summary of Navigation Times

| Alignment | Approach from Pacific | | | Miraflores Lock Passage | Transit Lake Miraflores | | | Pedro Miguel Lock Passage | Merge with Gaillard Cut | | | Total Time (min) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Speed (knots) | Distance (m) | Time (min) | Time (min) | Speed (knots) | Distance (m) | Sail Time (min) | Time (min) | Speed (knots) | Distance (m) | Time (min) | |
| P1 - Far West Bypass Alignment | 6 | 3,110 | 17 | 130 * | - | - | - | - | 6 | 6,150 | 33 | 180 |
| P2 - Near West Bypass Alignment | 6 | 3,400 | 18 | 130 * | - | - | - | - | 6 | 6,860 | 37 | 185 |
| P3 - Dual - Lock Alignment East of Existing | 6 | 4,900 | 26 | 95 ** | 2 | 1,210 | 20 | 70 *** | 6 | 3,610 | 19 | 231 |
| P4 - Dual - Lock Alignment West of Existing | 6 | 4,300 | 23 | 95 ** | 2 | 1,230 | 20 | 70 *** | 6 | 3,490 | 19 | 227 |
| P5 - Dual - Lock Alignment Using 1939 Excavation | 6 | 3,580 | 19 | 95 ** | 2 | 1,850 | 30 | 70 *** | 6 | 3,480 | 19 | 233 |

**Notes:**

All information provided by ACP Marine Traffic Control.

Total Time from ACP Sta 2400 (N889650, E657155) to ACP Sta 2000 (N998723, E649685)

* Lock passage time at Gatun Locks (3 lift)

** Lock passage time at Miraflores Locks (2 lift)

*** Lock passage time at Pedro Miguel Locks (1 lift)

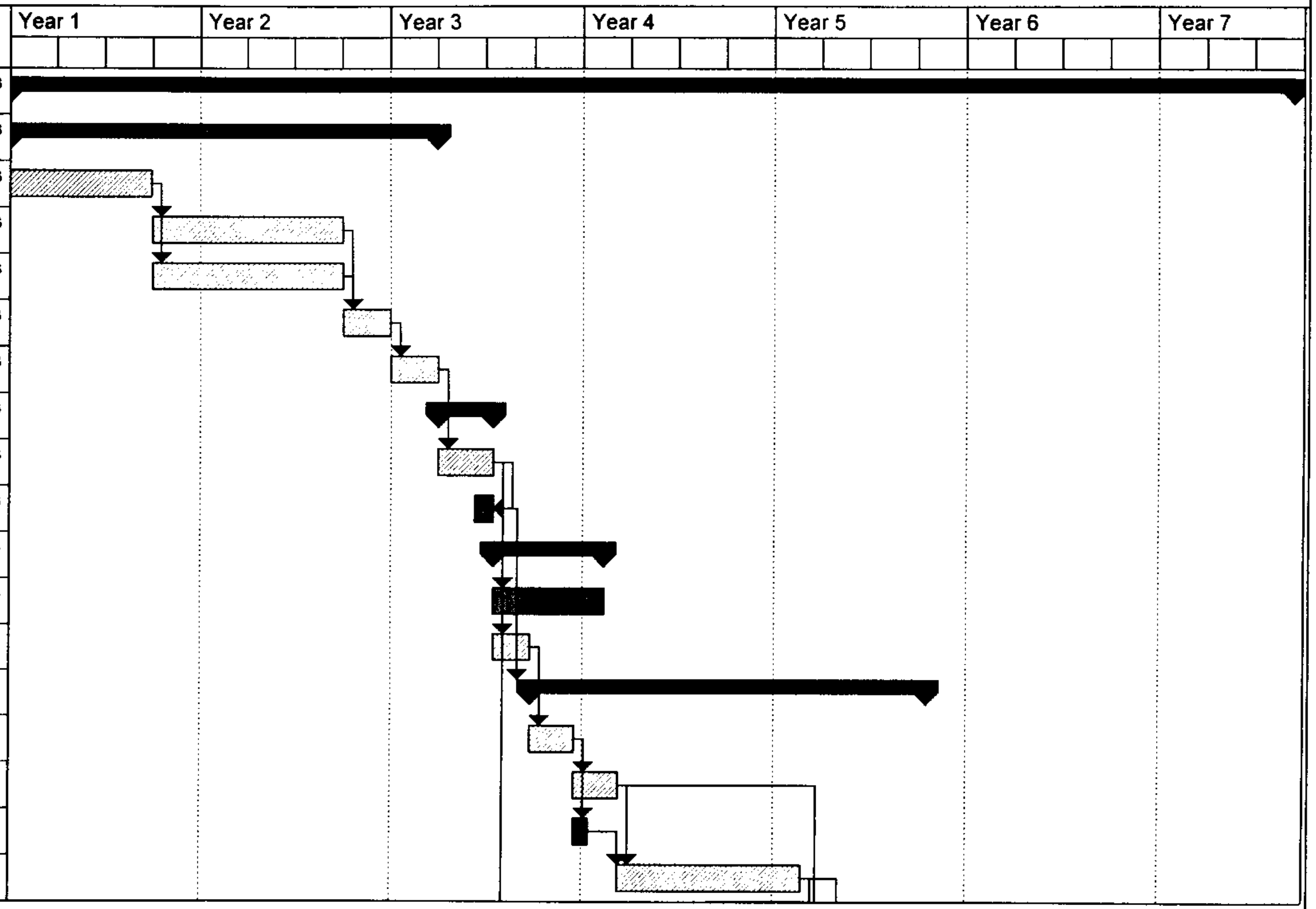
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Summary of Navigation Times

HARZA TAMS | August 2000 | Exhibit 15

## CONSTRUCTION SEQUENCE FOR ALIGNMENT A1

| ID | Task Name | Duration |
|---|---|---|
| 1 | **Project Summary** | **1748 days** |
| 2 | **Design and Preliminaries** | **586 days** |
| 3 | Feasability Study | 195 days |
| 4 | Secure Project Financing | 261 days |
| 5 | Prepare Design and Tender Documents | 261 days |
| 6 | Tender Construction Contracts | 65 days |
| 7 | Tender Evaluation | 65 days |
| 8 | **Mobilization** | **75 days** |
| 9 | Mobilization of Excavation Equipment | 75 days |
| 10 | Set up site offices | 25 days |
| 11 | **Relocations and Demolition** | **150 days** |
| 12 | Relocate Housing | 150 days |
| 13 | Site Clearing | 50 days |
| 14 | **Dry Excavation** | **540 days** |
| 15 | Build Access Roads | 60 days |
| 16 | Prep Disposal Areas | 60 days |
| 17 | Dewater 1939 Third Locks Excavation | 20 days |
| 18 | Excavate Station 2+400 to 4+900 | 250 days |




Task
Critical Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Critical Task

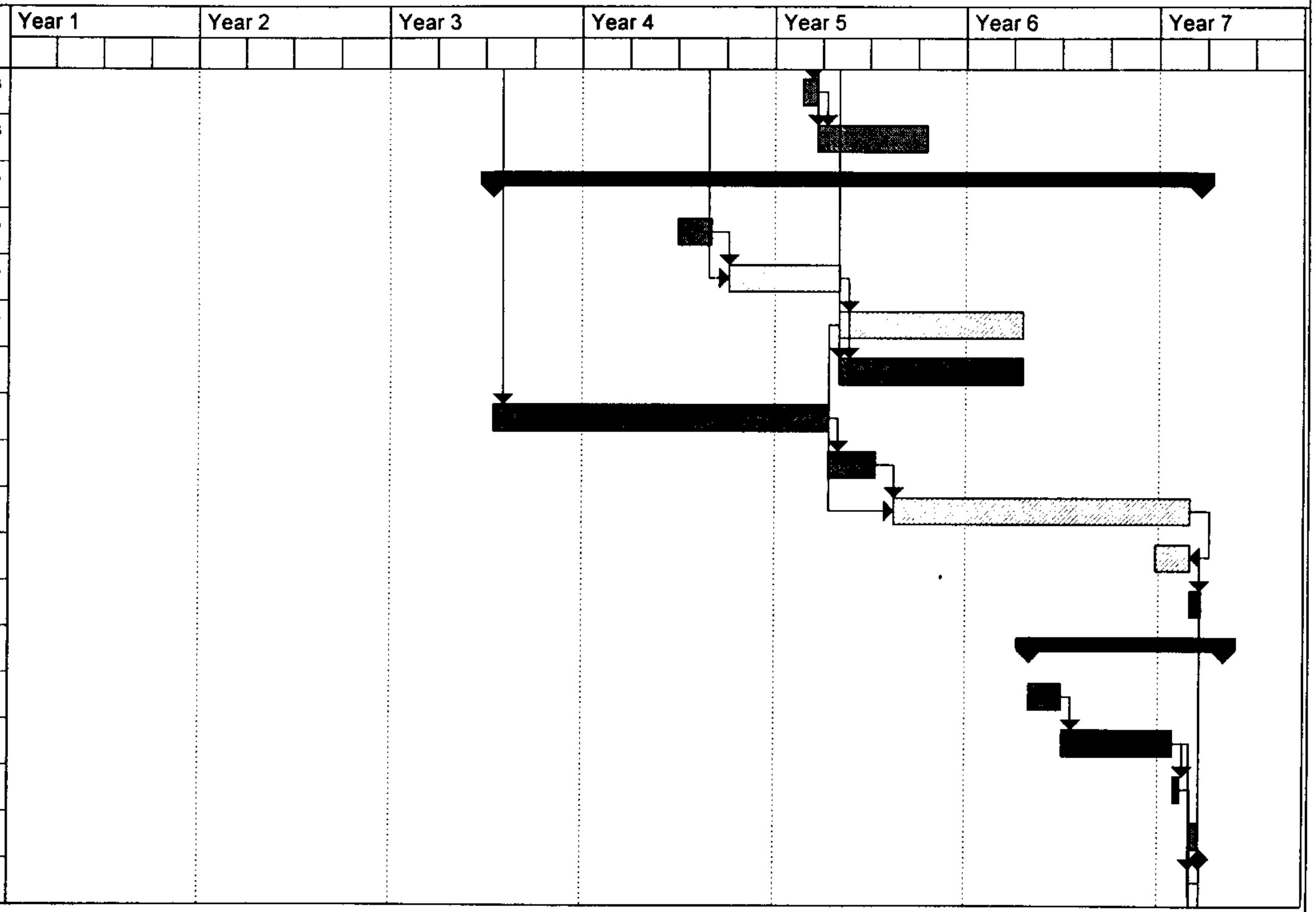
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

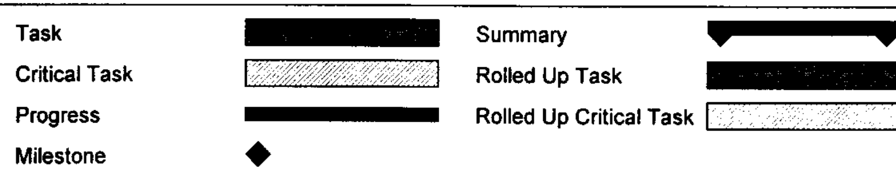
CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment A1

| HARZA TAMS | August 2000 | Exhibit 16 |
|---|---|---|

## CONSTRUCTION SEQUENCE FOR ALIGNMENT A1

| ID | Task Name | Duration |
|---|---|---|
| 19 | Construct Cofferdam at Sta 1+200 | 20 days |
| 20 | Excavate Station 1+200 to 2+400 | 150 days |
| 21 | **Locks Construction** | **960 days** |
| 22 | Mobilize Equipment to Site | 45 days |
| 23 | Pour Concrete Foundations | 150 days |
| 24 | Construct Lock Walls | 250 days |
| 25 | Construct Guidewalls | 250 days |
| 26 | Gate Fabrication | 455 days |
| 27 | Gate Shipping | 65 days |
| 28 | Install Gates and Mechanical | 400 days |
| 29 | Test Gates and Mechanical | 45 days |
| 30 | Demobilize Equipment | 15 days |
| 31 | **Wet Excavation** | **263 days** |
| 32 | Mobilize Dredging Plant | 45 days |
| 33 | Dredge Station 0+000 to Station 1+200 | 150 days |
| 34 | Transfer Dredging Equipment to Gatun Lake | 10 days |
| 35 | Remove Cofferdam at Station 1+200 | 10 days |
| 36 | Flood New Alignment | 2 days |



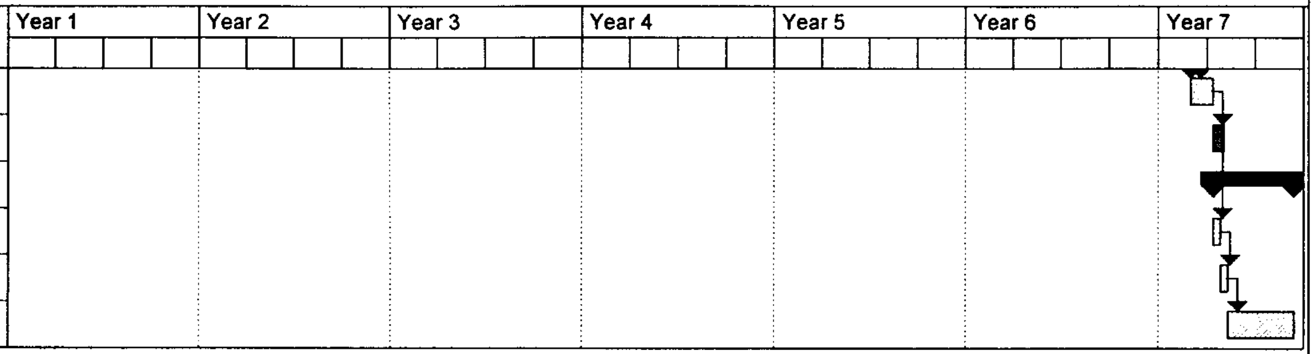

**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment A1

| HARZA TAMS | August 2000 | Exhibit 16 |
|---|---|---|

# CONSTRUCTION SEQUENCE FOR ALIGNMENT A1

| ID | Task Name | Duration |
|---|---|---|
| 37 | Remove Plug & Dredge Sta. 5+300 to 5+400 | 30 days |
| 38 | Demobilize Dredging Equipment | 15 days |
| 39 | **Operations Test and Demobilization** | **110 days** |
| 40 | Test Gates and Valves | 10 days |
| 41 | Test Run through locks | 10 days |
| 42 | Demobilize Equipment and Close Site Office | 90 days |




**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

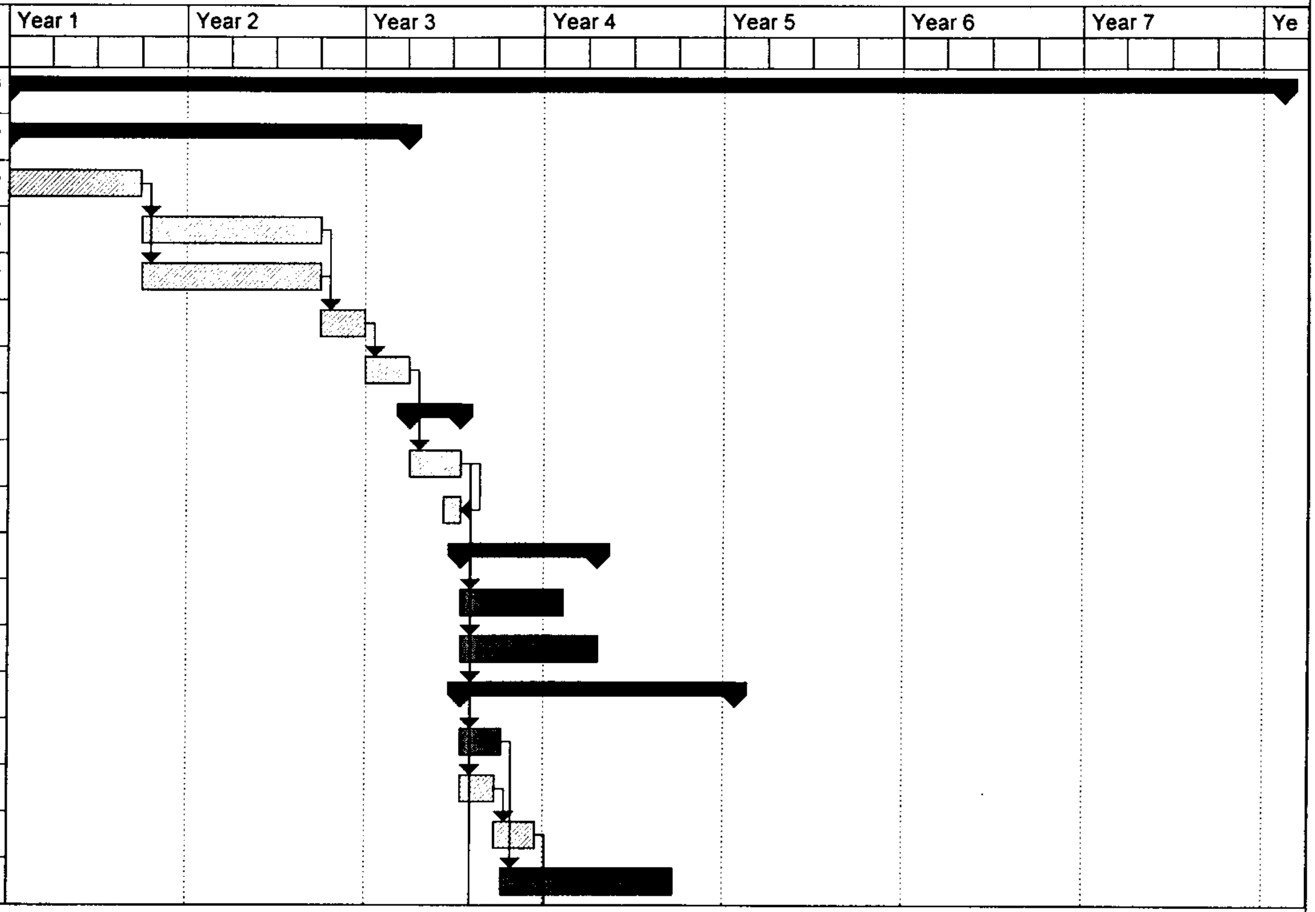
CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment A1

| HARZA TAMS | August 2000 | Exhibit 16 |
|---|---|---|

| | | | |
|---|---|---|---|
| Task | | Summary | |
| Critical Task | | Rolled Up Task | |
| Progress | | Rolled Up Critical Task | |
| Milestone | ◆ | | |

# CONSTRUCTION SEQUENCE FOR ALIGNMENT A2

| ID | Task Name | Duration |
|---|---|---|
| 1 | **Project Summary** | **1858 days** |
| 2 | **Design and Preliminaries** | **586 days** |
| 3 | Feasability Study | 195 days |
| 4 | Secure Project Financing | 261 days |
| 5 | Prepare Design and Tender Documents | 261 days |
| 6 | Tender Construction Contracts | 65 days |
| 7 | Tender Evaluation | 65 days |
| 8 | **Mobilization** | **75 days** |
| 9 | Mobilization of Excavation Equipment | 75 days |
| 10 | Set up site offices | 25 days |
| 11 | **Relocations and Demolition** | **200 days** |
| 12 | Relocate ACP Facilities | 150 days |
| 13 | Relocate Access to Existing Locks | 200 days |
| 14 | **Dry Excavation** | **400 days** |
| 15 | Build Access Roads | 60 days |
| 16 | Dewater 1939 Third Lane Excavation | 50 days |
| 17 | Prep Disposal Areas | 60 days |
| 18 | Build Cellulat Cofferdam in Gatun Lake | 250 days |




Task | Summary
Critical Task | Rolled Up Task
Progress | Rolled Up Critical Task
Milestone

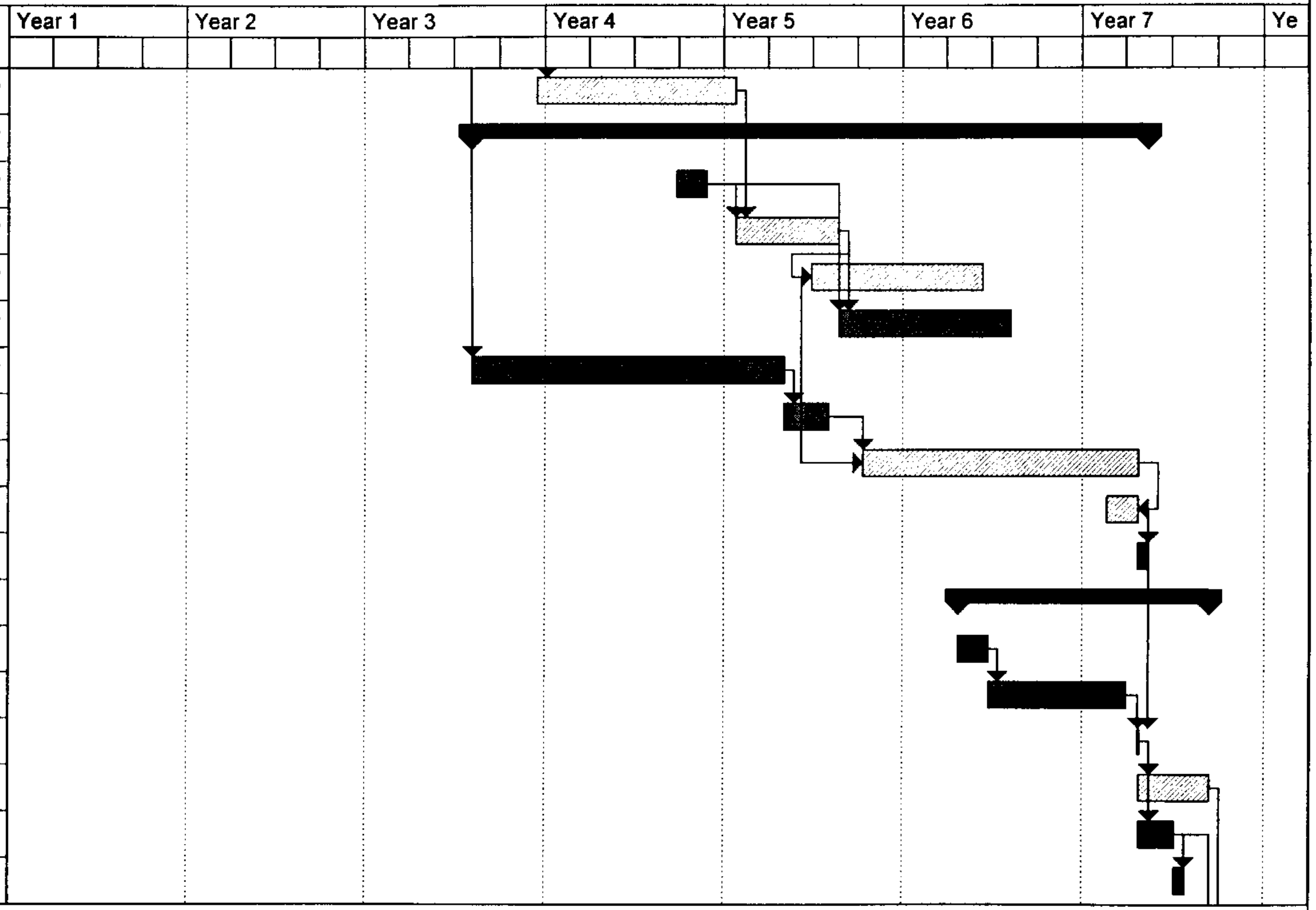
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment A2

HARZA TAMS | August 2000 | Exhibit 17

# CONSTRUCTION SEQUENCE FOR ALIGNMENT A2

| ID | Task Name | Duration |
|---|---|---|
| 19 | Excavate Station 1+500 to 4+500 | 290 days |
| 20 | **Locks Construction** | **985 days** |
| 21 | Mobilize Equipment to Site | 45 days |
| 22 | Pour Concrete Foundations | 150 days |
| 23 | Construct Lock Walls | 250 days |
| 24 | Construct Guidewalls | 250 days |
| 25 | Fabricate Gates | 455 days |
| 26 | Shipping Gates | 65 days |
| 27 | Install Gates and Mechanical | 400 days |
| 28 | Test Gates and Mechanical | 45 days |
| 29 | Demobilize Equipment | 15 days |
| 30 | **Wet Excavation** | **363 days** |
| 31 | Mobilize Dredging Plant | 45 days |
| 32 | Dredge Station 0+000 to 1+300 | 200 days |
| 33 | Flood New Alignment | 2 days |
| 34 | Remove Cellular Cofferdam | 100 days |
| 35 | Dredge Station 1+300 to 1+500 | 50 days |
| 36 | Demobilize Dredging Equipment | 15 days |




Task
Critical Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Critical Task

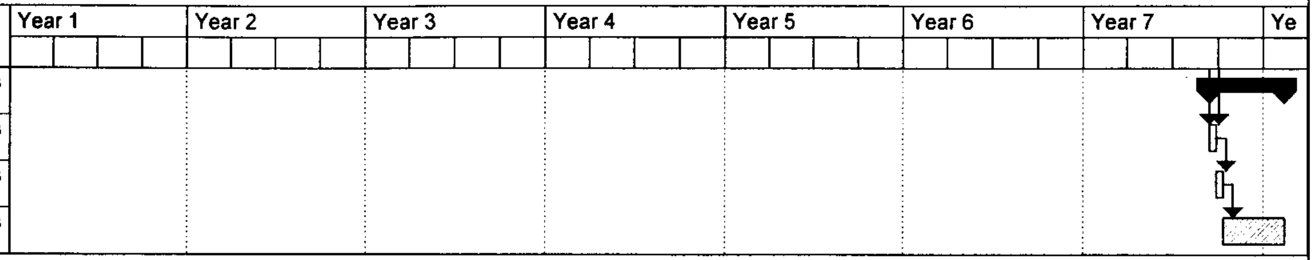
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment A2

| | | |
|---|---|---|
| HARZA TAMS | August 2000 | Exhibit 17 |

## CONSTRUCTION SEQUENCE FOR ALIGNMENT A2

| ID | Task Name | Duration |
|---|---|---|
| 37 | **Operations Test and Demobilization** | **110 days** |
| 38 | Test Gates and Valves | 10 days |
| 39 | Test Run through locks | 10 days |
| 40 | Demobilize Equipment and Close Site Office | 90 days |




| | | | |
|---|---|---|---|
| Task | | Summary | |
| Critical Task | | Rolled Up Task | |
| Progress | | Rolled Up Critical Task | |
| Milestone | ◆ | | |

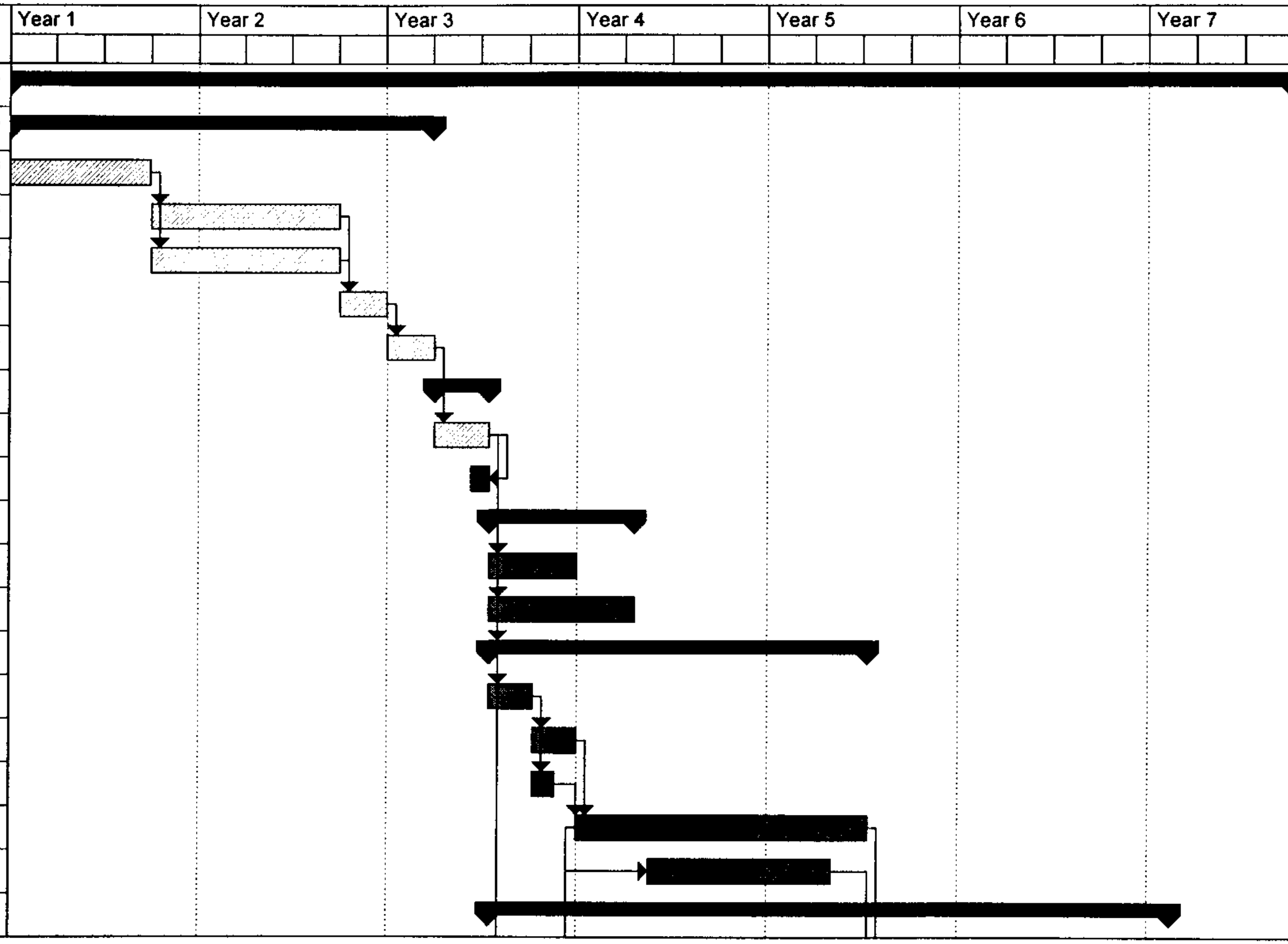
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment A2

HARZA TAMS | August 2000 | Exhibit 17

# CONSTRUCTION SEQUENCE FOR ALIGNMENT A3

| ID | Task Name | Duration |
|---|---|---|
| 1 | **Project Summary** | 1758 days |
| 2 | **Design and Preliminaries** | 586 days |
| 3 | Feasability Study | 195 days |
| 4 | Secure Project Financing | 261 days |
| 5 | Prepare Design and Tender Documents | 261 days |
| 6 | Tender Construction Contracts | 65 days |
| 7 | Tender Evaluation | 65 days |
| 8 | **Mobilization** | 75 days |
| 9 | Mobilization of Excavation Equipment | 75 days |
| 10 | Set up site offices | 25 days |
| 11 | **Relocations and Demolition** | 200 days |
| 12 | Relocate ACP Facilities | 120 days |
| 13 | Relocate Highway and Demolish Bridge | 200 days |
| 14 | **Dry Excavation** | 520 days |
| 15 | Build Access Roads | 60 days |
| 16 | Prep Disposal Areas | 60 days |
| 17 | Build Cofferdam at Sta 0+750 | 30 days |
| 18 | Excavate Station 0+750 to 3+600 | 400 days |
| 19 | Build Cellular Cofferdam on Gatun Dam | 250 days |
| 20 | **Locks Construction** | 935 days |





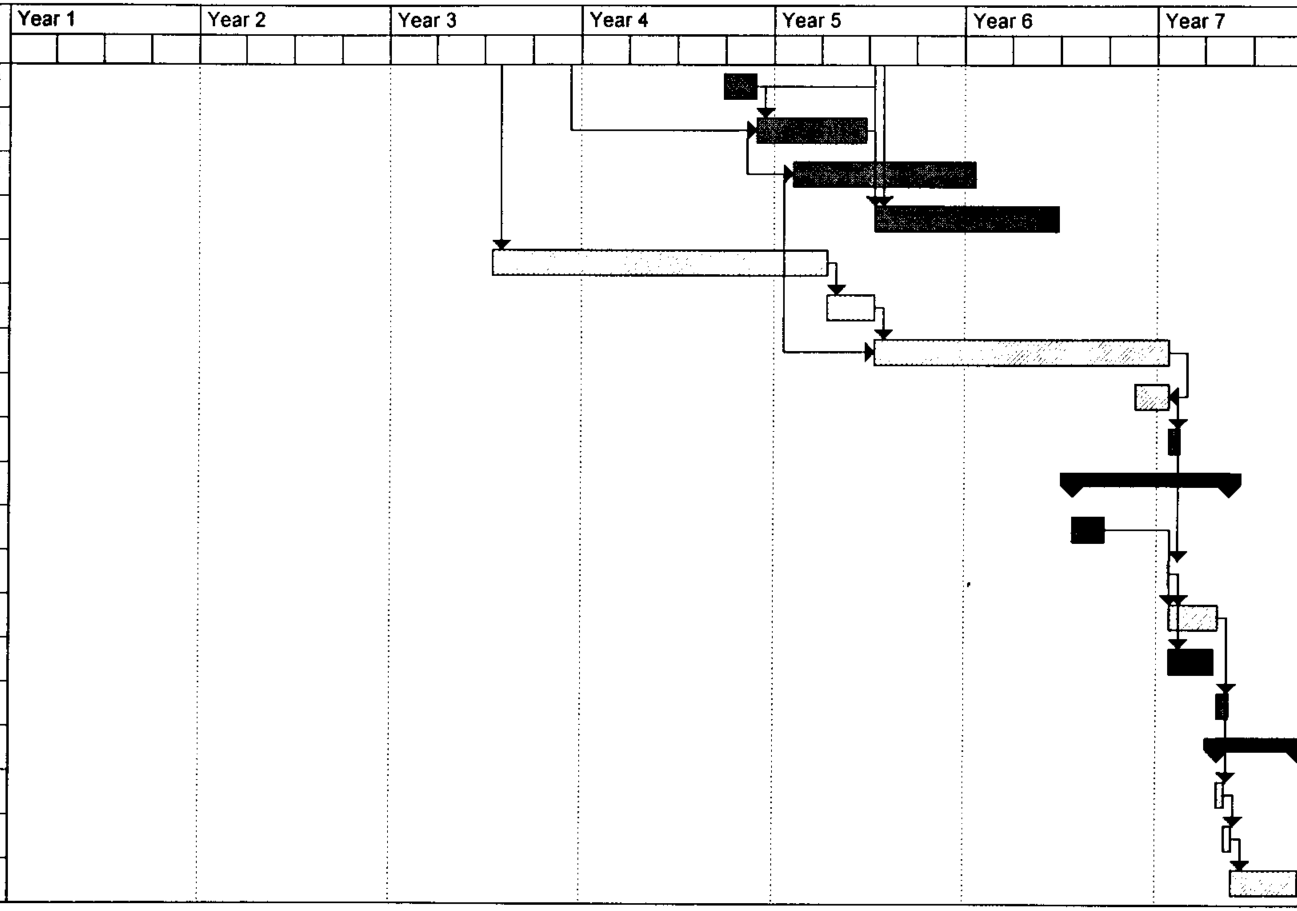
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment A3

| HARZA TAMS | August 2000 | Exhibit 18 |
|---|---|---|

## CONSTRUCTION SEQUENCE FOR ALIGNMENT A3

| ID | Task Name | Duration |
|---|---|---|
| 21 | Mobilize Equipment to Site | 45 days |
| 22 | Pour Concrete Foundations | 150 days |
| 23 | Construct Lock Walls | 250 days |
| 24 | Construct Guidewalls | 250 days |
| 25 | Fabricate Gate | 455 days |
| 26 | Shipping Gates | 65 days |
| 27 | Install Gates and Mechanical | 400 days |
| 28 | Test Gates and Mechanical | 45 days |
| 29 | Demobilize Equipment | 15 days |
| 30 | **Wet Excavation** | **213 days** |
| 31 | Mobilize Dredging Plant | 45 days |
| 32 | Flood New Alignment | 2 days |
| 33 | Remove Cofferdam & Dredge Atlantic Entran | 65 days |
| 34 | Remove (Partial) Cellular Cofferdam on Gatu | 60 days |
| 35 | Demobilize Dredging Equipment | 15 days |
| 36 | **Operations Test and Demobilization** | **110 days** |
| 37 | Test Gates and Valves | 10 days |
| 38 | Test Run through locks | 10 days |
| 39 | Demobilize Equipment and Close Site Offices | 90 days |




| | | | | | |
|---|---|---|---|---|---|
| Task | | Milestone | | Rolled Up Critical Task | |
| Critical Task | | Summary | | | |
| Progress | | Rolled Up Task | | | |

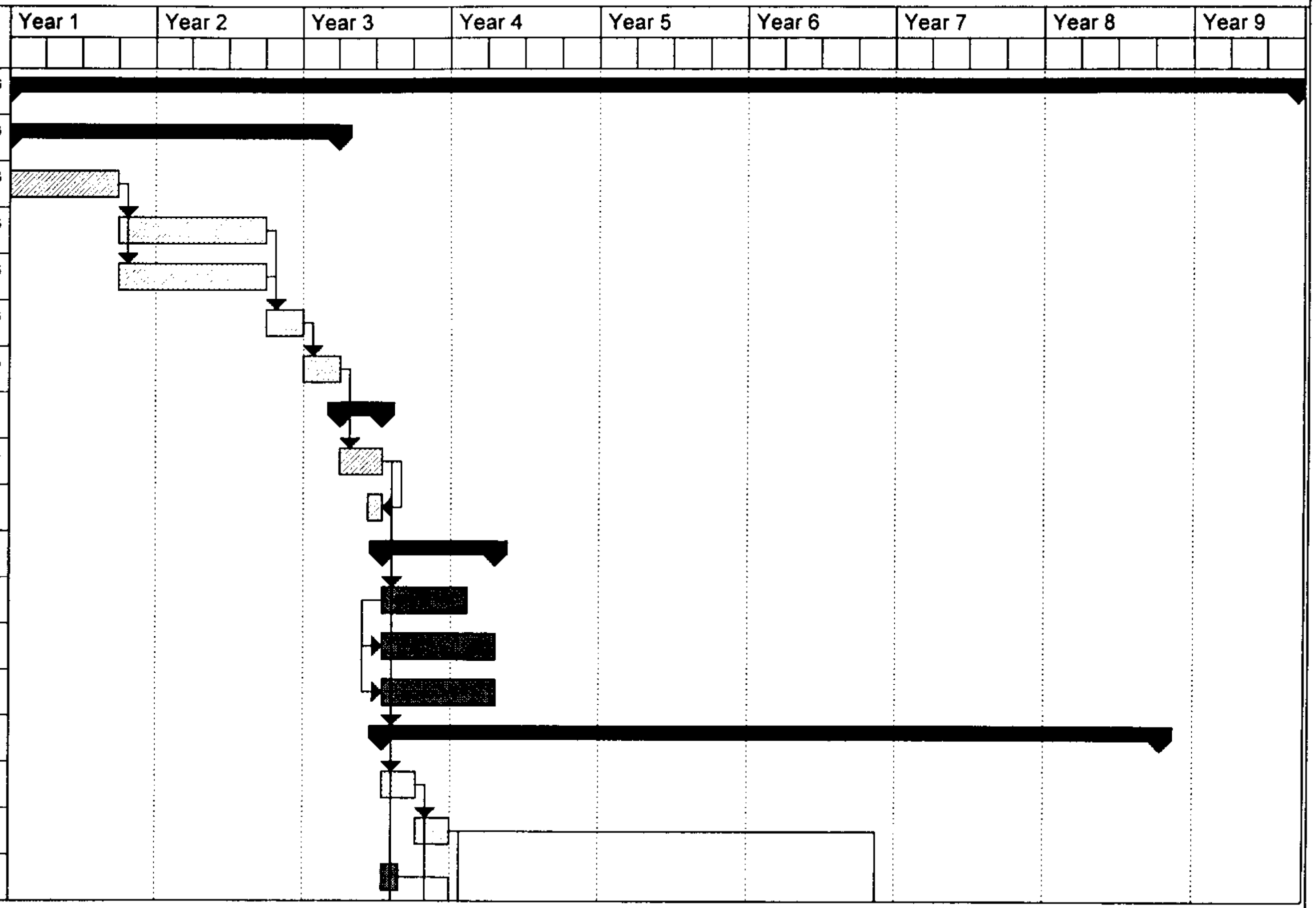
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment A3

HARZA TAMS | August 2000 | Exhibit 18

# CONSTRUCTION SEQUENCE FOR ALIGNMENT P1

| ID | Task Name | Duration |
|---|---|---|
| 1 | **Project Summary** | **2271 days** |
| 2 | **Design and Preliminaries** | **586 days** |
| 3 | Feasability Study | 195 days |
| 4 | Secure Project Financing | 261 days |
| 5 | Prepare Design and Tender Documents | 261 days |
| 6 | Tender Construction Contracts | 65 days |
| 7 | Tender Evaluation | 65 days |
| 8 | **Mobilization** | **75 days** |
| 9 | Mobilization of Excavation Equipment | 75 days |
| 10 | Set up site offices | 25 days |
| 11 | **Relocations and Demolition** | **200 days** |
| 12 | Relocate Cocoli Housing Complex | 150 days |
| 13 | Relocate Miraflores Electrical Substation | 200 days |
| 14 | Relocate Borindouen Highway | 200 days |
| 15 | **Dry Excavation** | **1370 days** |
| 16 | Build Access Roads | 60 days |
| 17 | Prep Disposal Areas | 60 days |
| 18 | Construct Temporary Diversion of Rio Cocoli | 30 days |




Task | Critical Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Critical Task

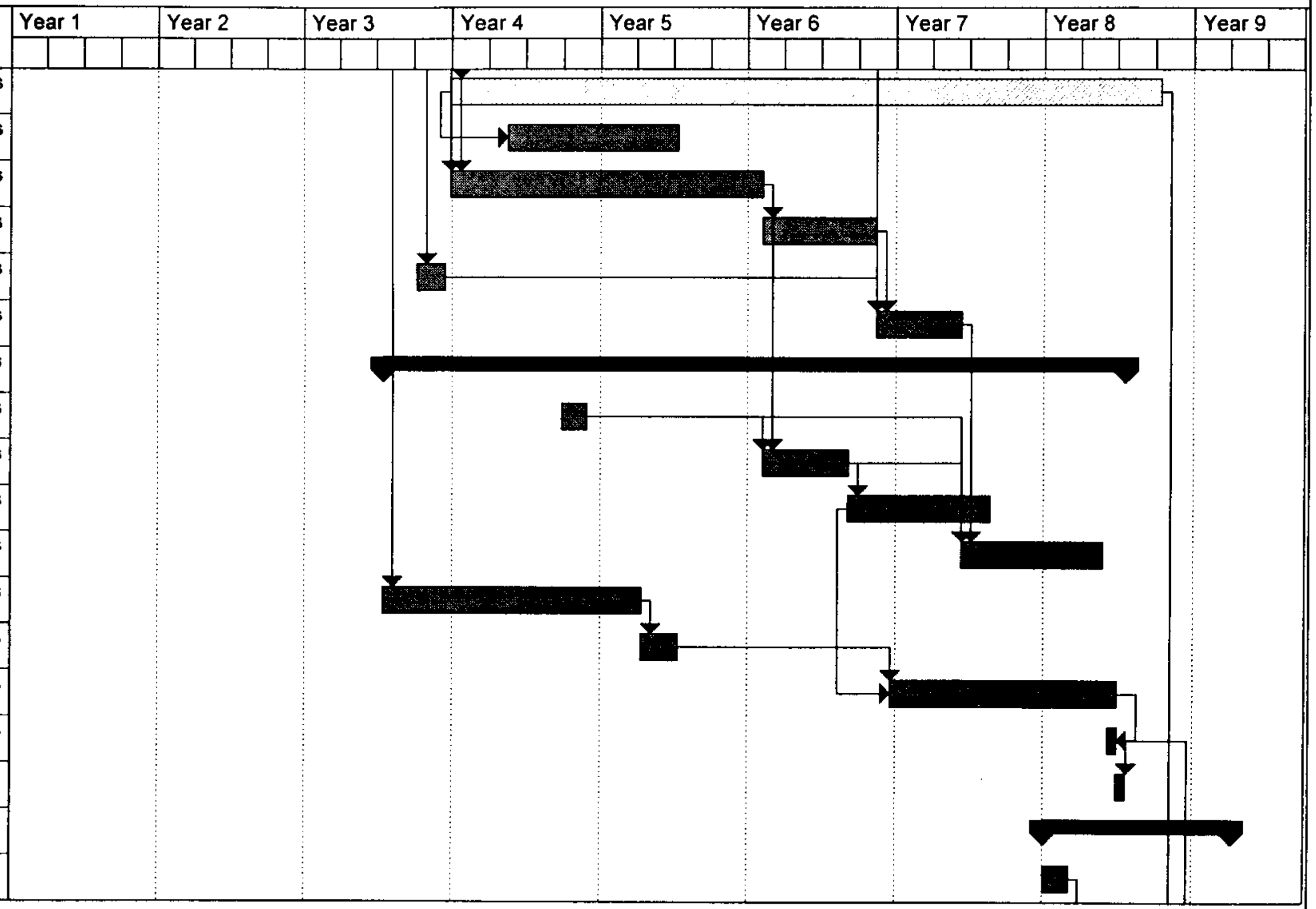
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P1

HARZA TAMS | August 2000 | Exhibit 19

# CONSTRUCTION SEQUENCE FOR ALIGNMENT P1

| ID | Task Name | Duration |
|---|---|---|
| 19 | Excavate Station 1+500 to 5+500 | 1250 days |
| 20 | Construct Levee from 2+900 to 3+800 | 300 days |
| 21 | Excavate Station 8+100 to 5+500 | 550 days |
| 22 | Construct Levee from 6+100 to 6+900 | 200 days |
| 23 | Dewater 1939 Third Locks Excavation | 50 days |
| 24 | Excavate Station 8+100 to 8+700 | 150 days |
| 25 | **Locks Construction** | **1310 days** |
| 26 | Mobilize Equipment to Site | 45 days |
| 27 | Pour Concrete Foundations | 150 days |
| 28 | Construct Lock Walls | 250 days |
| 29 | Construct Guidewalls | 250 days |
| 30 | Fabricate Gates | 455 days |
| 31 | Ship Gates | 65 days |
| 32 | Install Gates and Mechanical | 400 days |
| 33 | Test Gates and Mechanical | 15 days |
| 34 | Demobilize Equipment | 15 days |
| 35 | **Wet Excavation** | **330 days** |
| 36 | Mobilize Dredging Plant | 45 days |




Task
Critical Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Critical Task

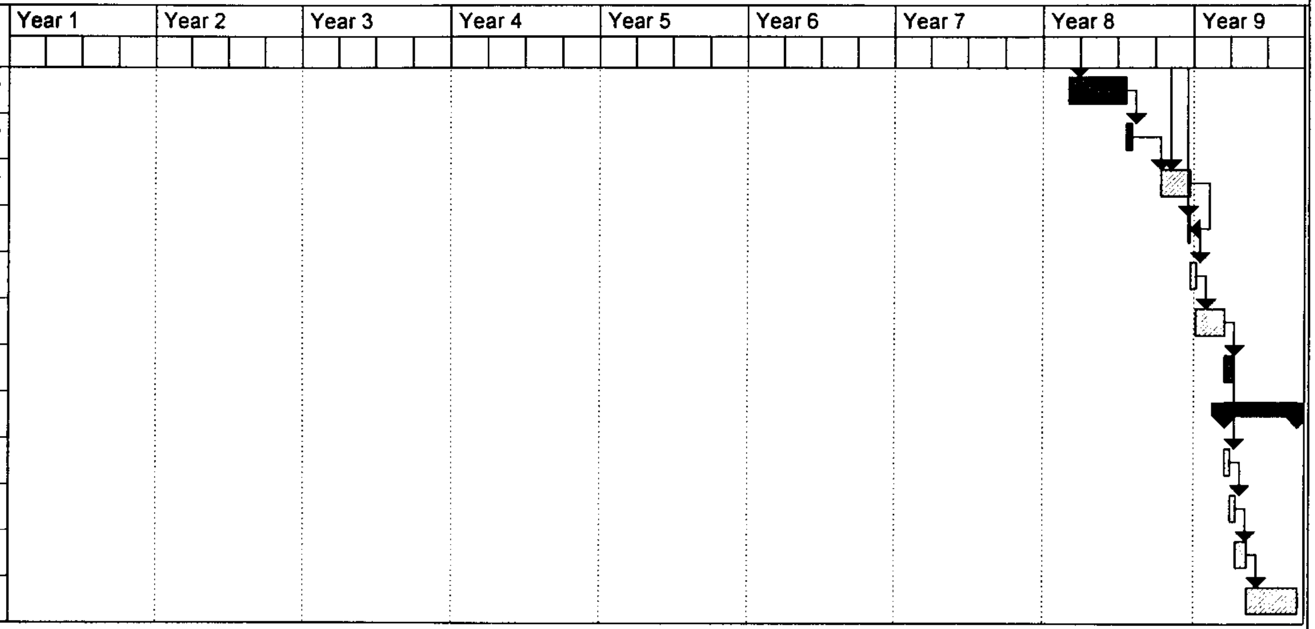
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P1

HARZA TAMS | August 2000 | Exhibit 19

## CONSTRUCTION SEQUENCE FOR ALIGNMENT P1

| ID | Task Name | Duration |
|---|---|---|
| 37 | Dredge Station 10+250 to Station 8+800 | 100 days |
| 38 | Mobilize Dredging Equipment to Gaillard Cut | 10 days |
| 39 | Dredge Station 1+000 to 1+500 | 50 days |
| 40 | Flood New Alignment | 2 days |
| 41 | Mobilize Back to Pacific Entrance | 10 days |
| 42 | Remove Plug & Dredge Sta. 8+800 to 8+600 | 50 days |
| 43 | Demobilize Dredging Equipment | 15 days |
| 44 | **Operations Test and Demobilization** | **130 days** |
| 45 | Test Gates and Valves | 10 days |
| 46 | Test Run through locks | 10 days |
| 47 | Install Bouys and Navigation Aids | 20 days |
| 48 | Demobilize Equipment and Close Site Office | 90 days |




Task
Critical Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Critical Task

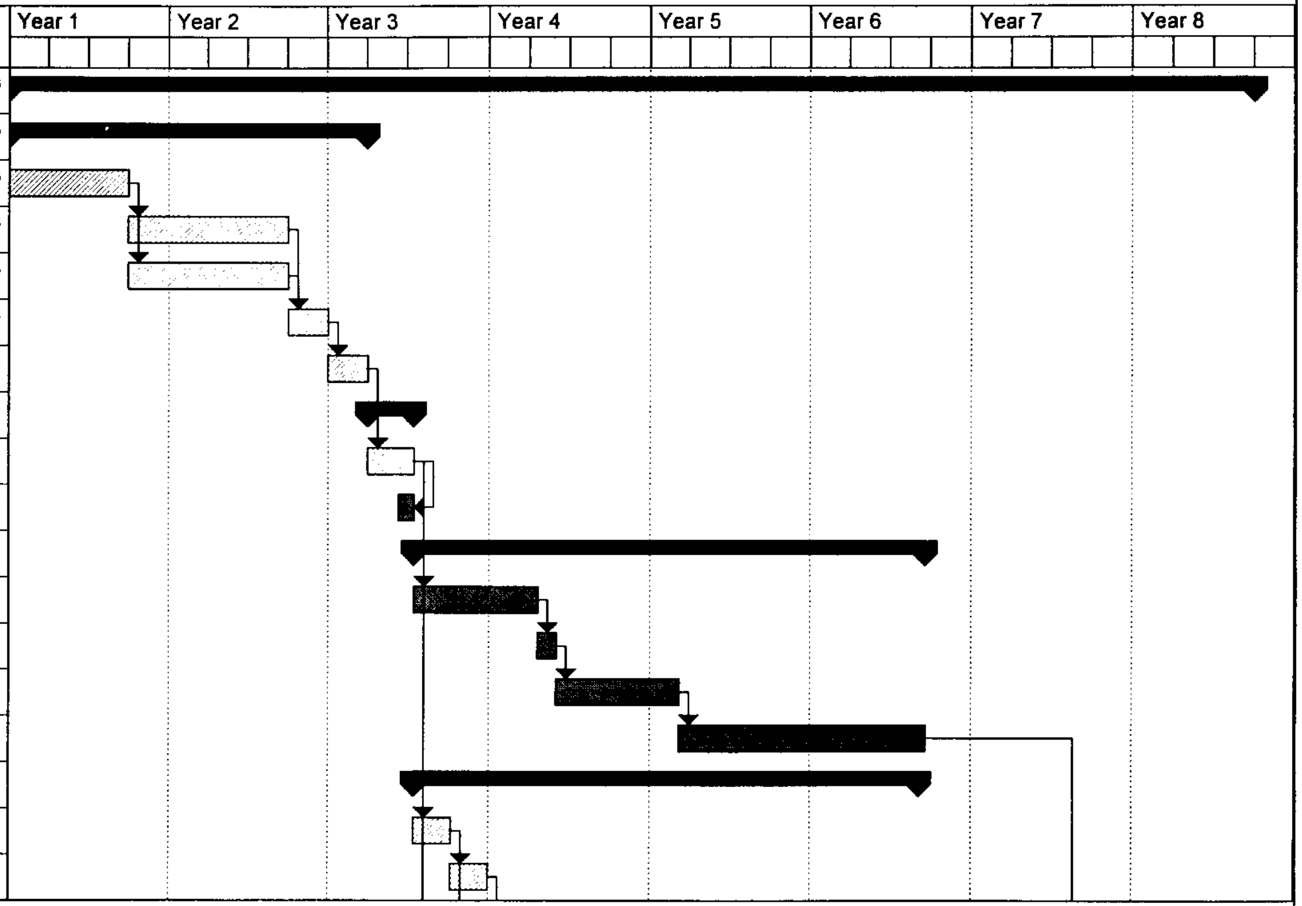
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

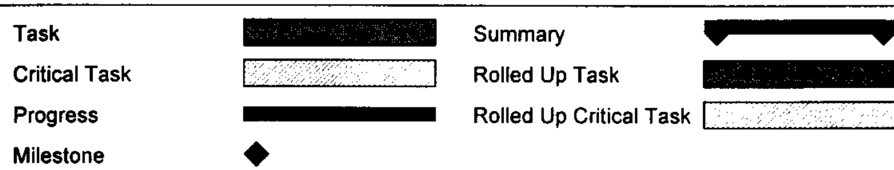
CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P1

HARZA TAMS | August 2000 | Exhibit 19

# CONSTRUCTION SEQUENCE FOR ALIGNMENT P2

| ID | Task Name | Duration |
|---|---|---|
| 1 | **Project Summary** | **2023 days** |
| 2 | **Design and Preliminaries** | **586 days** |
| 3 | Feasability Study | 195 days |
| 4 | Secure Project Financing | 261 days |
| 5 | Prepare Design and Tender Documents | 261 days |
| 6 | Tender Construction Contracts | 65 days |
| 7 | Tender Evaluation | 65 days |
| 8 | **Mobilization** | **75 days** |
| 9 | Mobilization of Excavation Equipment | 75 days |
| 10 | Set up site offices | 25 days |
| 11 | **Construct Barrier Dam** | **830 days** |
| 12 | Drive Sheet Piles and Install Bracing | 200 days |
| 13 | Dewater Area between Sheet Piles | 30 days |
| 14 | Strip and Prepare Foundation for Dam | 200 days |
| 15 | Construct Permanent Barrier Dam | 400 days |
| 16 | **Dry Excavation** | **820 days** |
| 17 | Build Access Roads | 60 days |
| 18 | Prep Disposal Areas | 60 days |



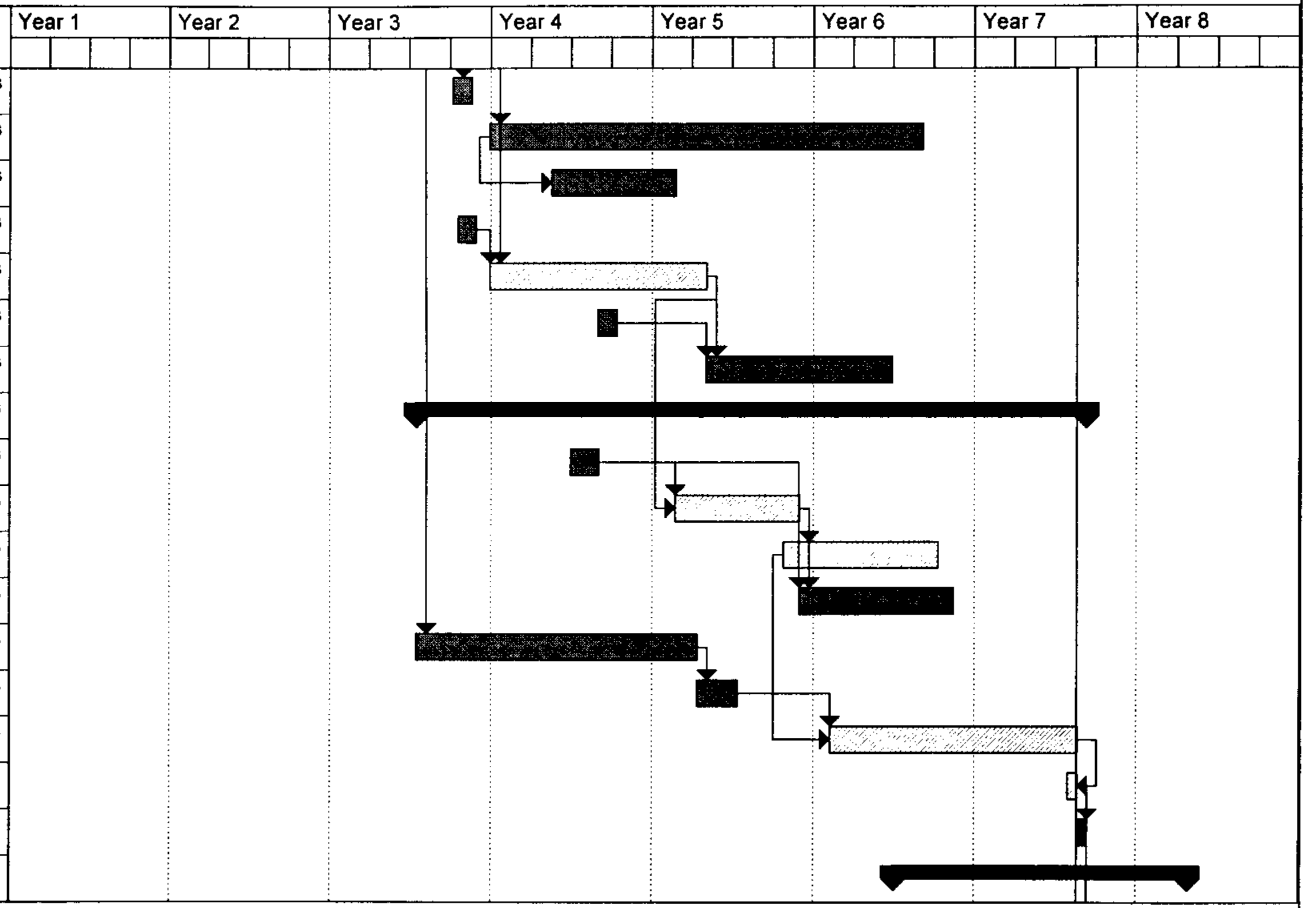

**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P2

| HARZA TAMS | August 2000 | Exhibit 20 |
|---|---|---|

## CONSTRUCTION SEQUENCE FOR ALIGNMENT P2

| ID | Task Name | Duration |
|---|---|---|
| 19 | Construct Temp. Diversion of Rio Cocoli | 30 days |
| 20 | Excavate 1+500 to 3+500 | 700 days |
| 21 | Construct Levee from 2+400 to 3+500 | 200 days |
| 22 | Dewater 1939 Third Locks Excavation | 30 days |
| 23 | Excavate 8+100 to 6+000 | 350 days |
| 24 | Dewater West of Barrier Dam | 30 days |
| 25 | Excavate 3+500 to 6+000 | 300 days |
| 26 | **Locks Construction** | **1085 days** |
| 27 | Mobilize Equipment to Site | 45 days |
| 28 | Pour Concrete Foundations | 200 days |
| 29 | Construct Lock Walls | 250 days |
| 30 | Construct Guidewalls | 250 days |
| 31 | Fabricate Gates | 455 days |
| 32 | Ship Gates | 65 days |
| 33 | Install Gates and Mechanical | 400 days |
| 34 | Test Gates and Mechanical | 15 days |
| 35 | Demobilize Equipment | 15 days |
| 36 | **Wet Excavation** | **474 days** |




Task
Critical Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Critical Task

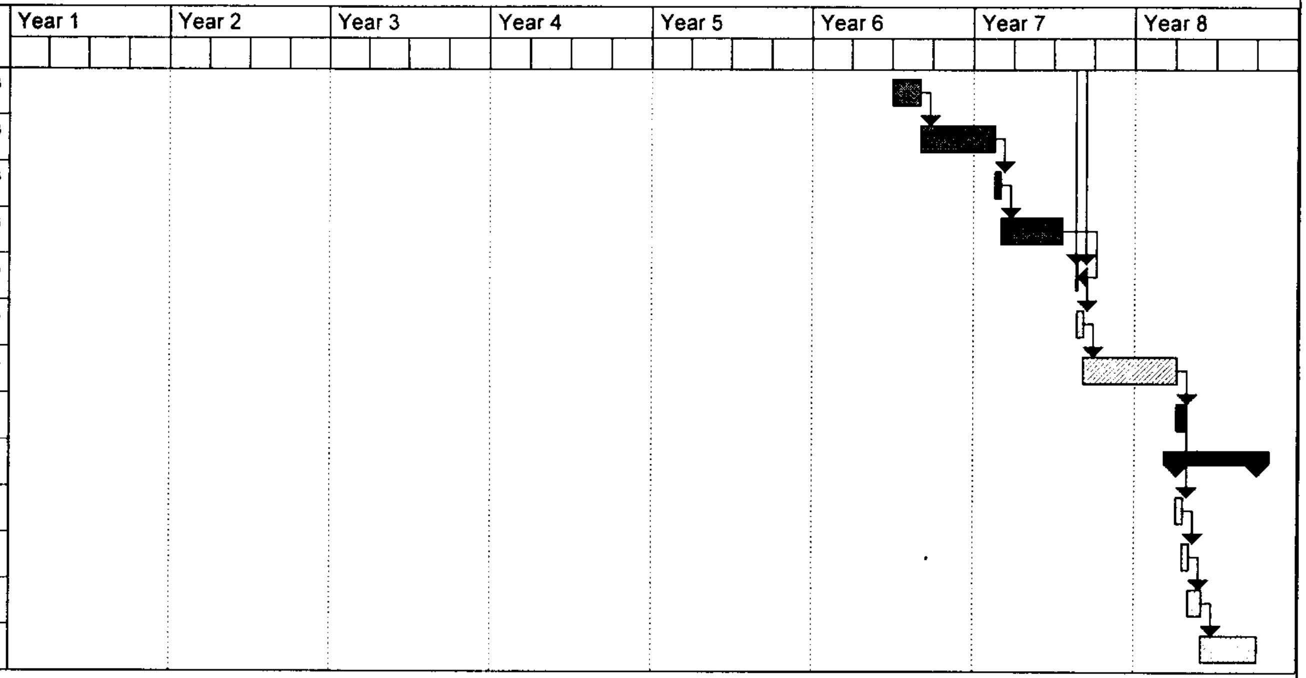
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P2

HARZA TAMS | August 2000 | Exhibit 20

# CONSTRUCTION SEQUENCE FOR ALIGNMENT P2

| ID | Task Name | Duration |
|---|---|---|
| 37 | Mobilize Dredging Plant | 45 days |
| 38 | Dredge 10+450 to 8+800 | 120 days |
| 39 | Mobilize Dredging Plant to Gaillard Cut | 10 days |
| 40 | Dredge 1+000 to 1+500 | 100 days |
| 41 | Flood New Alignment | 2 days |
| 42 | Mobilize Back to Pacific Entrance | 10 days |
| 43 | Remove Plug and Dredge 8+800 to 8+200 | 150 days |
| 44 | Demobilize Dredging Equipment | 15 days |
| 45 | **Operations Test and Demobilization** | **130 days** |
| 46 | Test Gates and Valves | 10 days |
| 47 | Test Run through locks | 10 days |
| 48 | Install Bouys and Navigation Aids | 20 days |
| 49 | Demobilize Equipment and Close Site Offices | 90 days |




**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

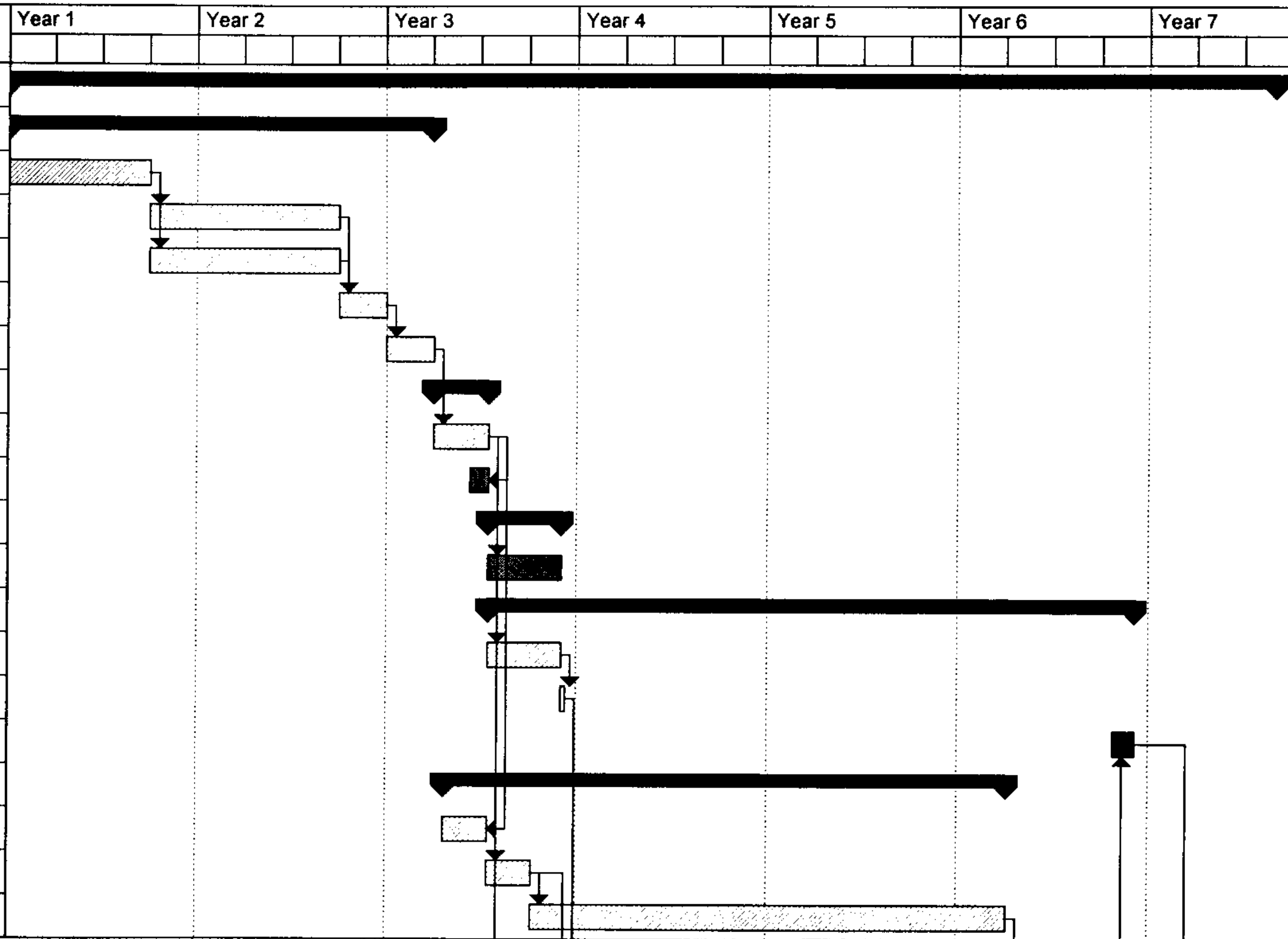
CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P2

HARZA TAMS | August 2000 | Exhibit 20

Task
Critical Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Critical Task

# CONSTRUCTION SEQUENCE FOR ALIGNMENT P3

| ID | Task Name | Duration |
|---|---|---|
| 1 | **Project Summary** | **1736 days** |
| 2 | **Design and Preliminaries** | **586 days** |
| 3 | Feasability Study | 195 days |
| 4 | Secure Project Financing | 261 days |
| 5 | Prepare Design and Tender Documents | 261 days |
| 6 | Tender Construction Contracts | 65 days |
| 7 | Tender Evaluation | 65 days |
| 8 | **Mobilization** | **75 days** |
| 9 | Mobilization of Excavation Equipment to site | 75 days |
| 10 | Set up site offices | 25 days |
| 11 | **Relocations** | **100 days** |
| 12 | Relocate buildings and equipment | 100 days |
| 13 | **Cofferdams** | **885 days** |
| 14 | Construct cofferdam at N bank of MF locks | 100 days |
| 15 | Dewater behind Cofferdam | 5 days |
| 16 | Remove Cofferdam | 30 days |
| 17 | **Dry Excavation** | **770 days** |
| 18 | Build Access Roads | 60 days |
| 19 | Prep Disposal Areas | 60 days |
| 20 | Excavate Station 1+100 to Station 3+600 | 650 days |




Task
Critical Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Critical Task

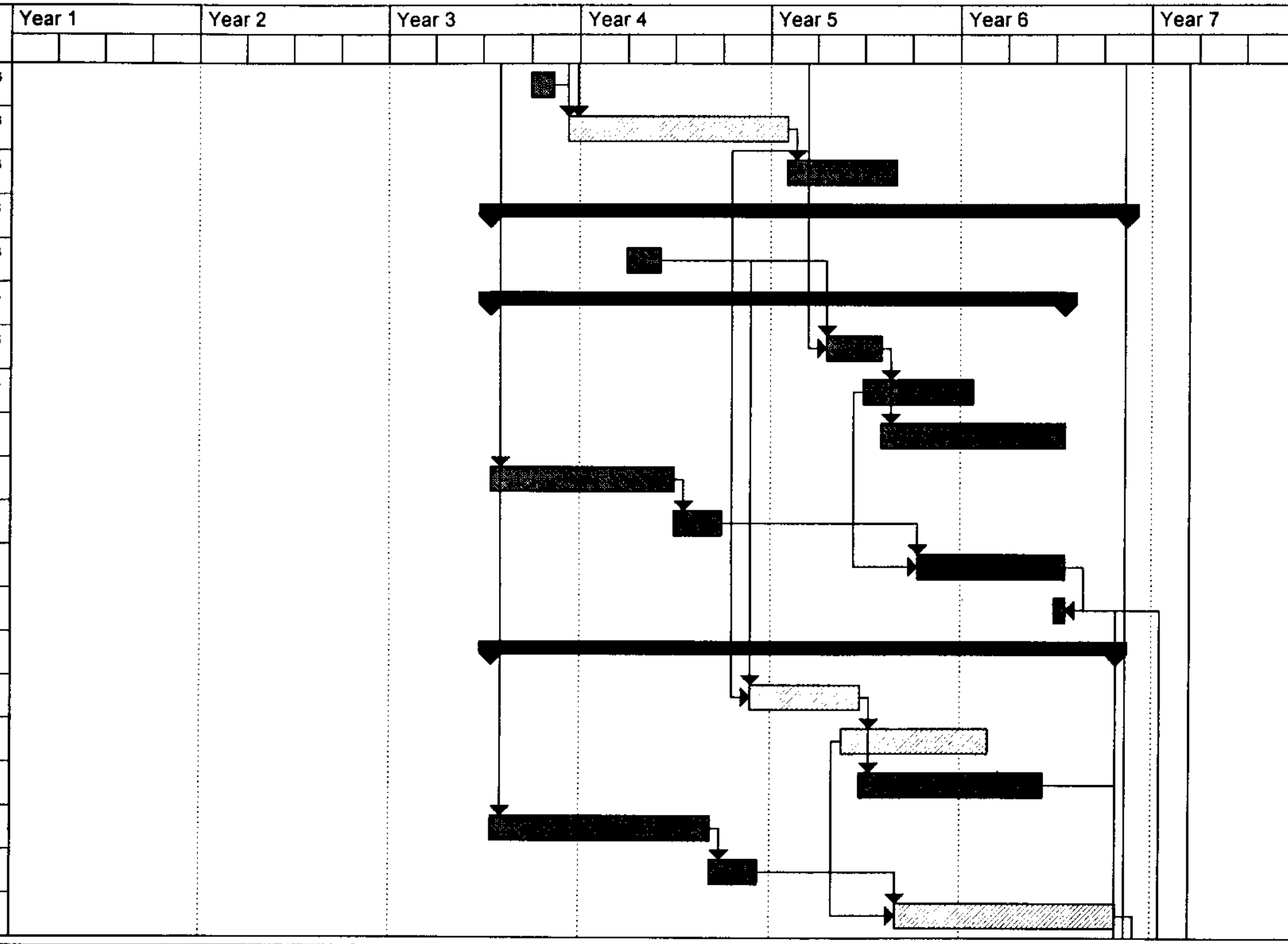
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P3

HARZA TAMS | August 2000 | Exhibit 21

## CONSTRUCTION SEQUENCE FOR ALIGNMENT P3

| ID | Task Name | Duration |
|---|---|---|
| 21 | Dewater 1939 Third Locks Excavation | 30 days |
| 22 | Excavate Station 7+500 to Station 5+800 | 300 days |
| 23 | Excavate Station 7+500 to Station 8+200 | 150 days |
| 24 | **Locks Construction** | 870 days |
| 25 | Mobilize Equipment to Site | 45 days |
| 26 | **Pedro Miguel Third Lane Locks** | 785 days |
| 27 | Pour Concrete Foundations | 75 days |
| 28 | Construct Lock Walls | 150 days |
| 29 | Construct Guidewalls | 250 days |
| 30 | Fabricate Gates | 250 days |
| 31 | Ship Gates | 65 days |
| 32 | Install Gates and Mechanical | 200 days |
| 33 | Test Gates and Mechanical | 15 days |
| 34 | **Miraflores Third Lane Locks** | 855 days |
| 35 | Pour Concrete Foundations | 150 days |
| 36 | Construct Lock Walls | 200 days |
| 37 | Construct Guidewalls | 250 days |
| 38 | Fabricate Gates | 300 days |
| 39 | Ship Gates | 65 days |
| 40 | Install Gates and Mechanical | 300 days |




Task | Critical Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Critical Task

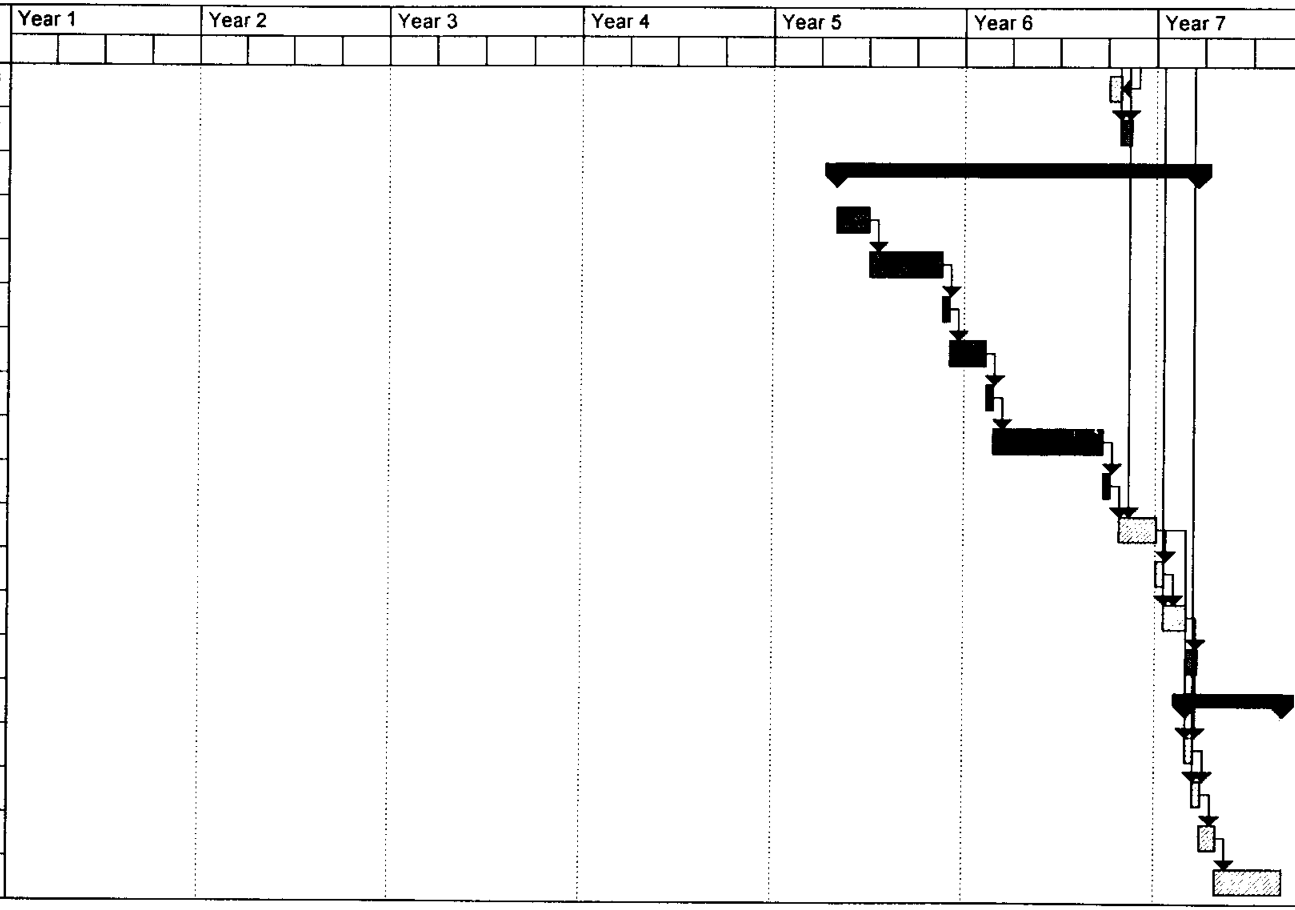
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P3

HARZA TAMS | August 2000 | Exhibit 21

## CONSTRUCTION SEQUENCE FOR ALIGNMENT P3

| ID | Task Name | Duration |
|---|---|---|
| 41 | Test Gates and Mechanical | 15 days |
| 42 | Demobilize Equipment | 15 days |
| 43 | **Wet Excavation** | **492 days** |
| 44 | Mobilize Dredging Plant | 45 days |
| 45 | Dredge Station 7+900 to Station 7+500 | 100 days |
| 46 | Mobilize Dredging Equipment to Gaillard Cut | 10 days |
| 47 | Dredge Station 1+000 to Station 1+300 | 50 days |
| 48 | Mobilize to Lake Miraflores | 10 days |
| 49 | Dredge Station 3+500 to Station 5+300 | 150 days |
| 50 | Mobilize to Pacific Entrance | 10 days |
| 51 | Remove Plug and Dredge 7+500 to 7+000 | 50 days |
| 52 | Mobilize Dredging Equipment to Gaillard Cut | 10 days |
| 53 | Remove Plug and Dredge 1+300 to 1+500 | 30 days |
| 54 | Demobilize Dredging Equipment | 15 days |
| 55 | **Operations Test and Demobilization** | **130 days** |
| 56 | Test Gates and Valves | 10 days |
| 57 | Test Run through locks | 10 days |
| 58 | Install Bouys and Navigation Aids | 20 days |
| 59 | Demobilize Equipment and Close Site Offices | 90 days |




Legend: Task; Critical Task; Progress; Milestone; Summary; Rolled Up Task; Rolled Up Critical Task

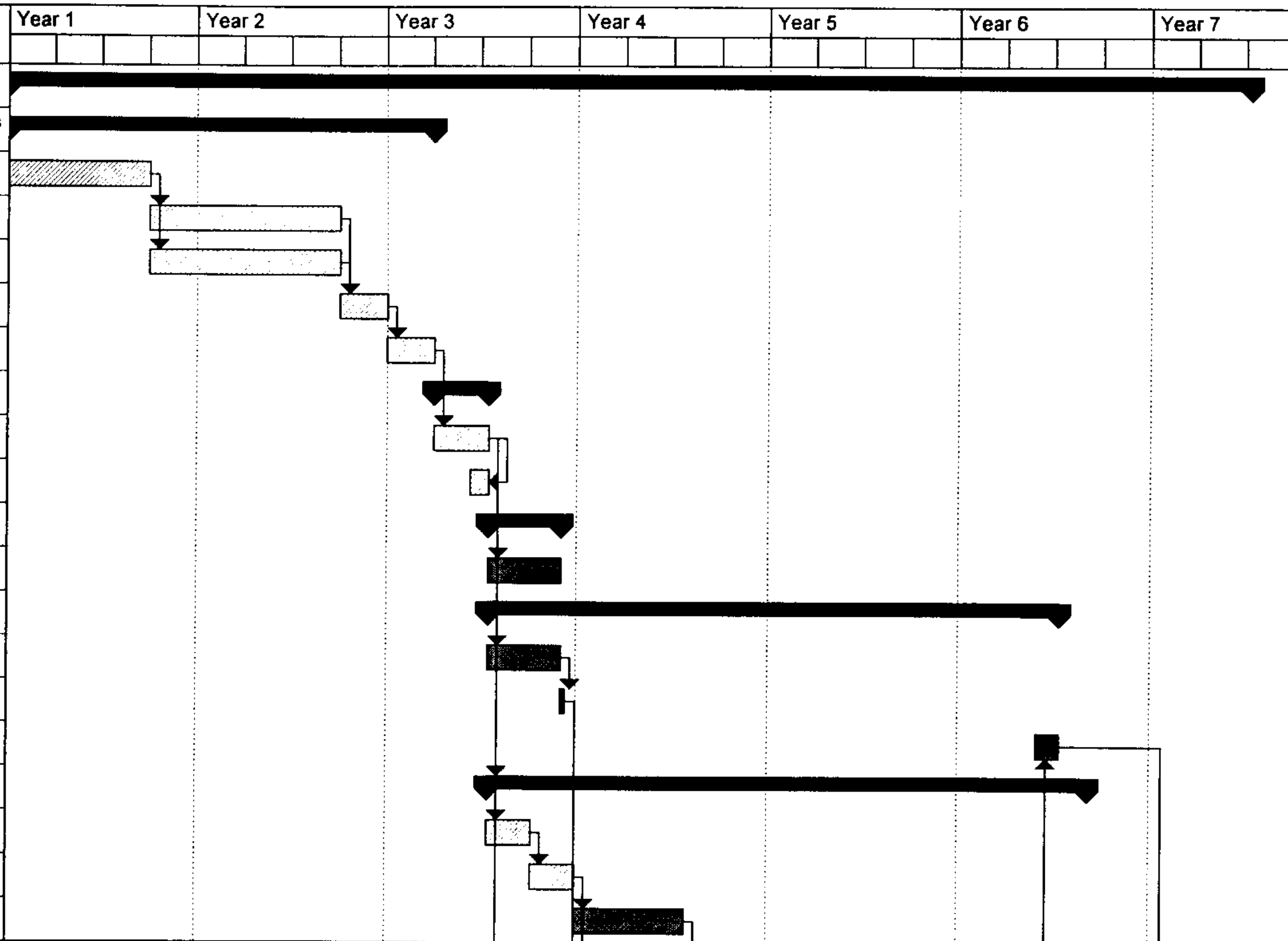
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P3

HARZA TAMS | August 2000 | Exhibit 21

## CONSTRUCTION SEQUENCE FOR ALIGNMENT P4

| ID | Task Name | Duration |
|---|---|---|
| 1 | **Project Summary** | **1701 days** |
| 2 | **Design and Preliminaries** | **586 days** |
| 3 | Feasability Study | 195 days |
| 4 | Secure Project Financing | 261 days |
| 5 | Prepare Design and Tender Documents | 261 days |
| 6 | Tender Construction Contracts | 65 days |
| 7 | Tender Evaluation | 65 days |
| 8 | **Mobilization** | **75 days** |
| 9 | Mobilization of Excavation Equipment | 75 days |
| 10 | Set up site offices | 25 days |
| 11 | **Relocations** | **100 days** |
| 12 | Relocate buildings and equipment | 100 days |
| 13 | **Cofferdams** | **780 days** |
| 14 | Construct cofferdam at N bank of MF locks | 100 days |
| 15 | Dewater behind Cofferdam | 5 days |
| 16 | Remove Cofferdam | 30 days |
| 17 | **Dry Excavation** | **820 days** |
| 18 | Build Access Roads | 60 days |
| 19 | Prep Disposal Areas | 60 days |
| 20 | Excavate Station 2+500 to Station 3+500 | 150 days |




Task | Critical Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Critical Task

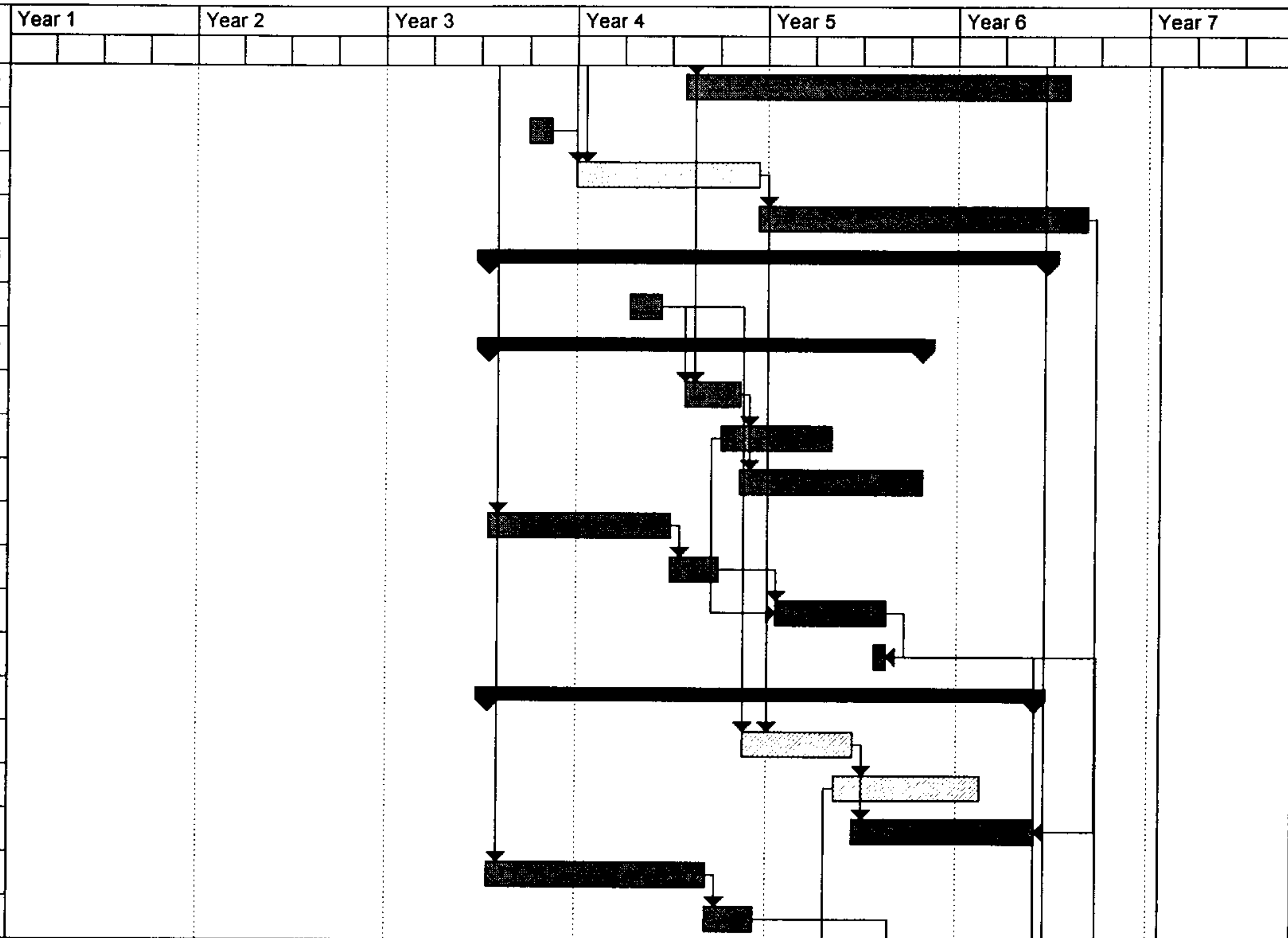
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P4

HARZA TAMS | August 2000 | Exhibit 22

# CONSTRUCTION SEQUENCE FOR ALIGNMENT P4

| ID | Task Name | Duration |
|---|---|---|
| 21 | Excavate Station 1+400 to Station 2+500 | 525 days |
| 22 | Dewater 1939 Third Locks Excavation | 30 days |
| 23 | Excavate Station 6+500 to Station 5+500 | 250 days |
| 24 | Excavate Station 6+500 to Station 7+000 | 450 days |
| 25 | **Locks Construction** | **765 days** |
| 26 | Mobilize Equipment to Site | 45 days |
| 27 | **Pedro Miguel Third Lane Locks** | **595 days** |
| 28 | Pour Concrete Foundations | 75 days |
| 29 | Construct Lock Walls | 150 days |
| 30 | Construct Guidewalls | 250 days |
| 31 | Fabricate Gates | 250 days |
| 32 | Ship Gates | 65 days |
| 33 | Install Gates and Mechanical | 150 days |
| 34 | Test Gates and Mechanical | 15 days |
| 35 | **Miraflores Third Lane Locks** | **750 days** |
| 36 | Pour Concrete Foundations | 150 days |
| 37 | Construct Lock Walls | 200 days |
| 38 | Construct Guidewalls | 250 days |
| 39 | Fabricate Gates | 300 days |
| 40 | Ship Gates | 65 days |




Task | Critical Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Critical Task

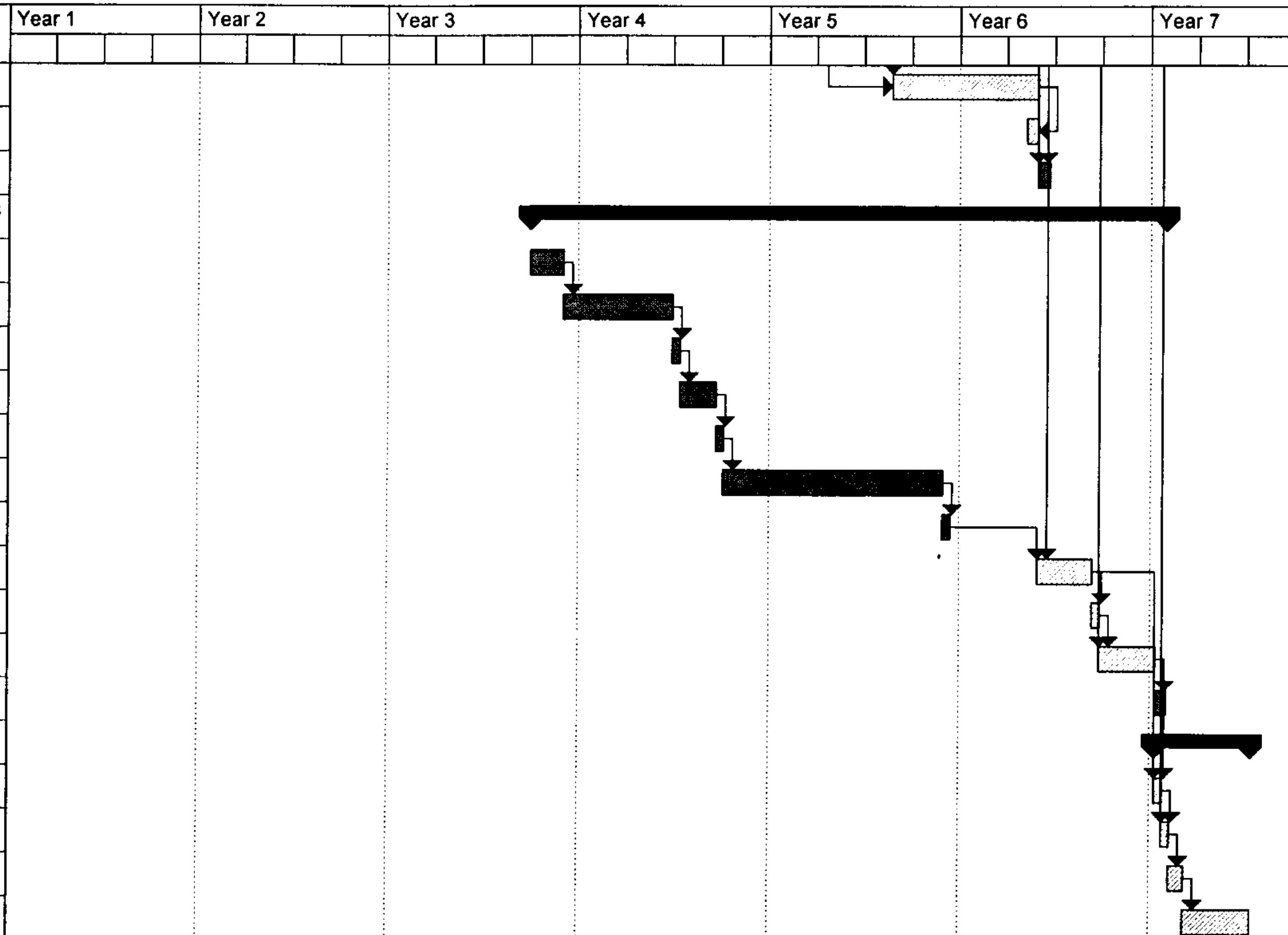
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P4

HARZA TAMS | August 2000 | Exhibit 22

# CONSTRUCTION SEQUENCE FOR ALIGNMENT P4

| ID | Task Name | Duration |
|---|---|---|
| 41 | Install Gates and Mechanical | 200 days |
| 42 | Test Gates and Mechanical | 15 days |
| 43 | Demobilize Equipment | 15 days |
| 44 | **Wet Excavation** | **870 days** |
| 45 | Mobilize Dredging Plant | 45 days |
| 46 | Dredge Station 7+900 to Station 7+500 | 150 days |
| 47 | Mobilize Dredging Equipment to Gaillard Cut | 10 days |
| 48 | Dredge Station 1+000 to Station 1+300 | 50 days |
| 49 | Mobilize to Lake Miraflores | 10 days |
| 50 | Dredge Station 3+500 to Station 5+300 | 300 days |
| 51 | Mobilize to Pacific Entrance | 10 days |
| 52 | Remove Plug and Dredge Station 7+500 to 7+0 | 75 days |
| 53 | Mobilize Dredging Equipment to Gaillard Cut | 10 days |
| 54 | Remove Plug and Dredge 1+300 to 1+500 | 75 days |
| 55 | Demobilize Dredging Equipment | 15 days |
| 56 | **Operations Test and Demobilization** | **130 days** |
| 57 | Test Gates and Valves | 10 days |
| 58 | Test Run through locks | 10 days |
| 59 | Install Bouys and Navigation Aids | 20 days |
| 60 | Demobilize Equipment and Close Site Offices | 90 days |




Task | Milestone | Rolled Up Critical Task
Critical Task | Summary
Progress | Rolled Up Task

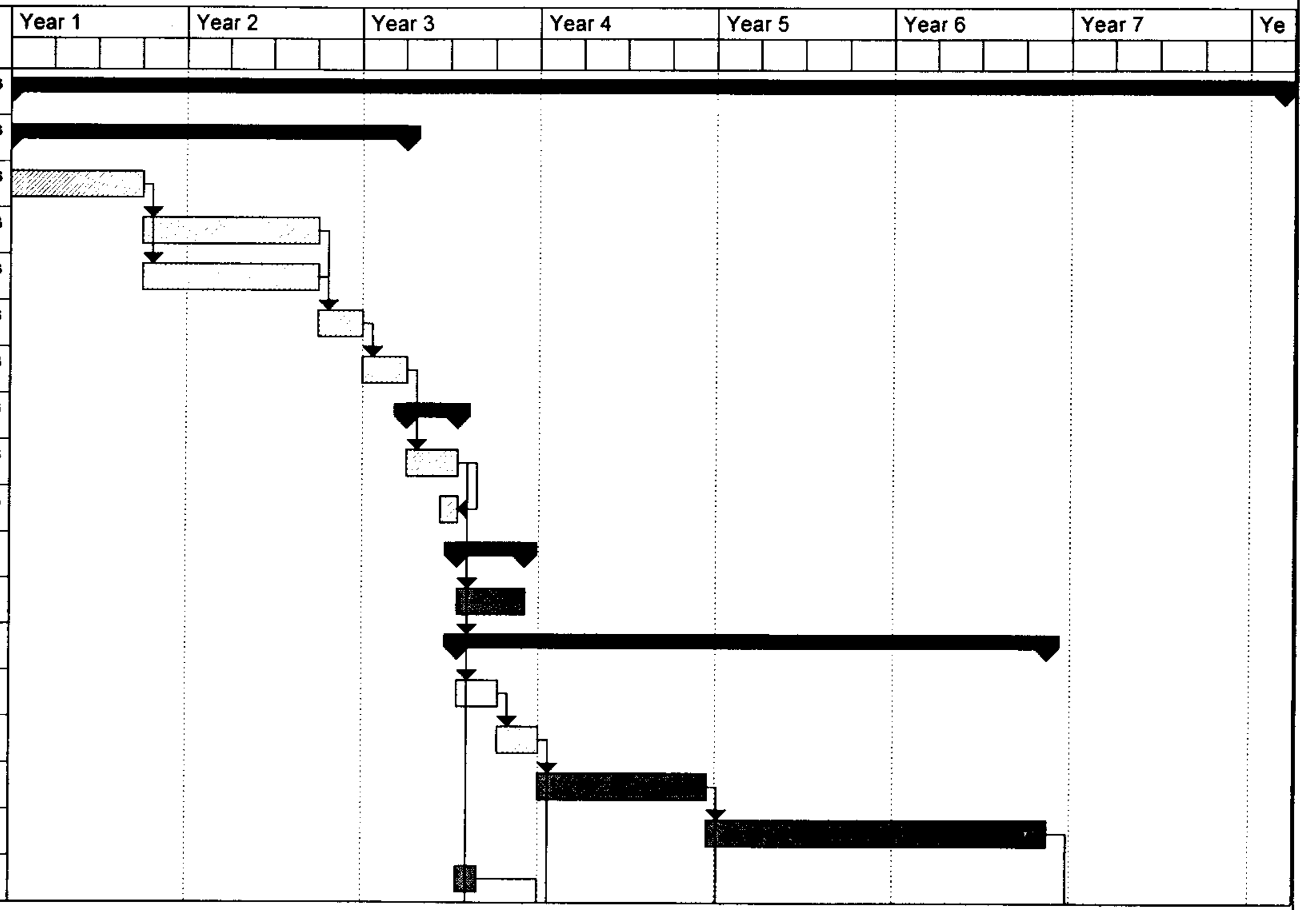
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P4

HARZA TAMS | August 2000 | Exhibit 22

# CONSTRUCTION SEQUENCE FOR ALIGNMENT P5

| ID | Task Name | Duration |
|---|---|---|
| 1 | **Project Summary** | **1876 days** |
| 2 | **Design and Preliminaries** | **586 days** |
| 3 | Feasability Study | 195 days |
| 4 | Secure Project Financing | 261 days |
| 5 | Prepare Design and Tender Documents | 261 days |
| 6 | Tender Construction Contracts | 65 days |
| 7 | Tender Evaluation | 65 days |
| 8 | **Mobilization** | **75 days** |
| 9 | Mobilization of Excavation Equipment | 75 days |
| 10 | Set up site offices | 25 days |
| 11 | **Relocations** | **100 days** |
| 12 | Relocate Borindouen Highway | 100 days |
| 13 | **Dry Excavation** | **870 days** |
| 14 | Build Access Roads | 60 days |
| 15 | Prep Disposal Areas | 60 days |
| 16 | Excavate Station 2+200 to Station 3+500 | 250 days |
| 17 | Excavate Station 1+400 to Station 2+200 | 500 days |
| 18 | Dewater 1939 Third Locks Excavation | 30 days |




| | |
|---|---|
| Task | Summary |
| Critical Task | Rolled Up Task |
| Progress | Rolled Up Critical Task |
| Milestone | |

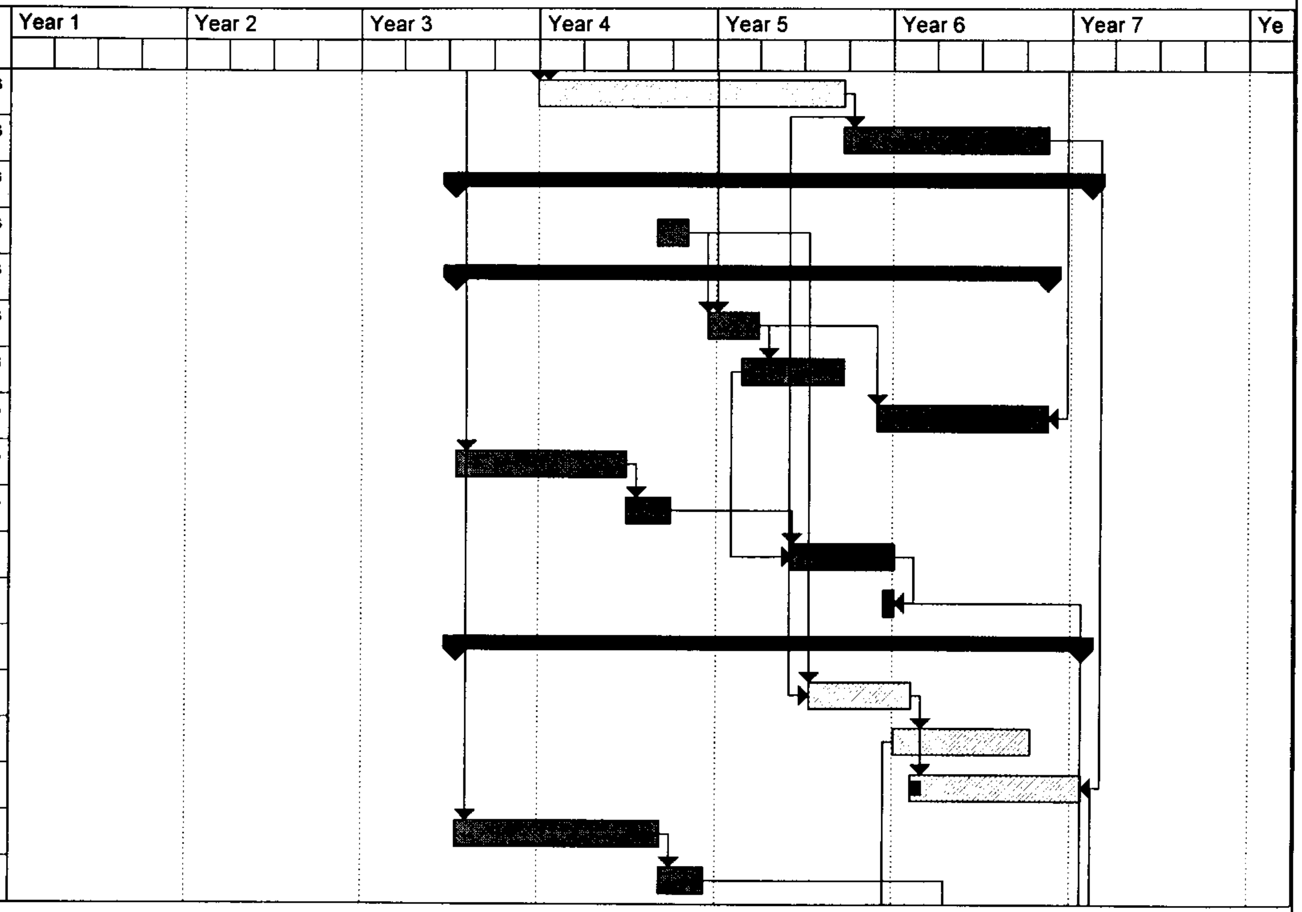
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P5

HARZA TAMS | August 2000 | Exhibit 23

# CONSTRUCTION SEQUENCE FOR ALIGNMENT P5

| ID | Task Name | Duration |
|---|---|---|
| 19 | Excavate Station 8+100 to 5+800 | 450 days |
| 20 | Excavate Station 3+500 to Station 5+800 | 300 days |
| 21 | **Locks Construction** | **935 days** |
| 22 | Mobilize Equipment to Site | 45 days |
| 23 | **Pedro Miguel Third Lane Locks** | **870 days** |
| 24 | Pour Concrete Foundations | 75 days |
| 25 | Construct Lock Walls | 150 days |
| 26 | Construct Guidewalls | 250 days |
| 27 | Fabricate Gates | 250 days |
| 28 | Ship Gates | 65 days |
| 29 | Install Gates and Mechanical | 150 days |
| 30 | Test Gates and Mechanical | 15 days |
| 31 | **Miraflores Third Lane Locks** | **920 days** |
| 32 | Pour Concrete Foundations | 150 days |
| 33 | Construct Lock Walls | 200 days |
| 34 | Construct Guidewalls | 250 days |
| 35 | Fabricate Gates | 300 days |
| 36 | Ship Gates | 65 days |




Task
Critical Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Critical Task

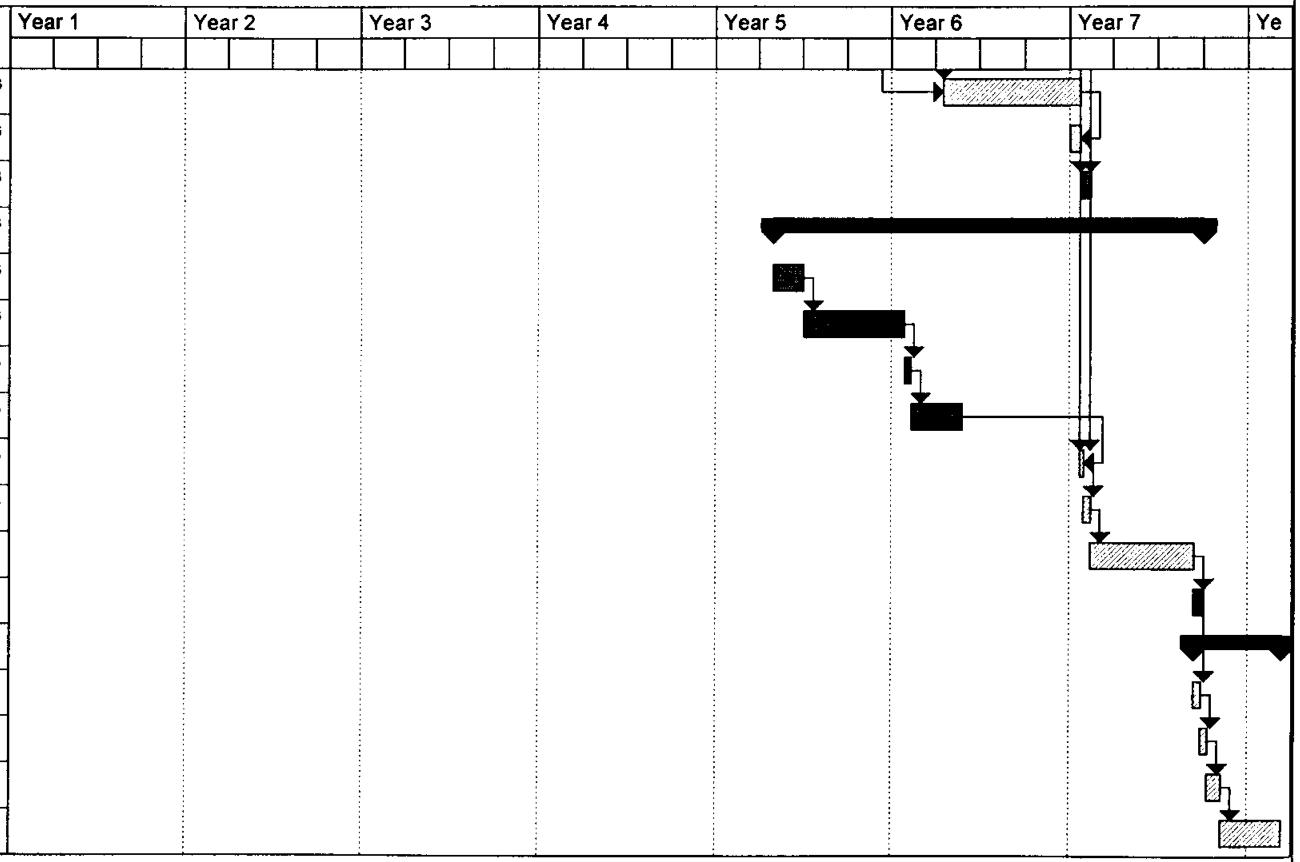
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P5

| HARZA TAMS | August 2000 | Exhibit 23 |
|---|---|---|

# CONSTRUCTION SEQUENCE FOR ALIGNMENT P5

| ID | Task Name | Duration |
|---|---|---|
| 37 | Install Gates and Mechanical | 200 days |
| 38 | Test Gates and Mechanical | 15 days |
| 39 | Demobilize Equipment | 15 days |
| 40 | **Wet Excavation** | **632 days** |
| 41 | Mobilize Dredging Plant | 45 days |
| 42 | Dredge Station 10+450 to Station 8+800 | 150 days |
| 43 | Mobilize Dredging Equipment to Gaillard Cut | 10 days |
| 44 | Dredge Station 1+000 to Station 1+500 | 75 days |
| 45 | Flood New Alignment | 5 days |
| 46 | Mobilize Back to Pacific Entrance | 10 days |
| 47 | Remove Plug and Dredge 8+800 to 8+200 | 150 days |
| 48 | Demobilize Dredging Equipment | 15 days |
| 49 | **Operations Test and Demobilization** | **130 days** |
| 50 | Test Gates and Valves | 10 days |
| 51 | Test Run through locks | 10 days |
| 52 | Install Bouys and Navigation Aids | 20 days |
| 53 | Demobilize Equipment and Close Site Offices | 90 days |

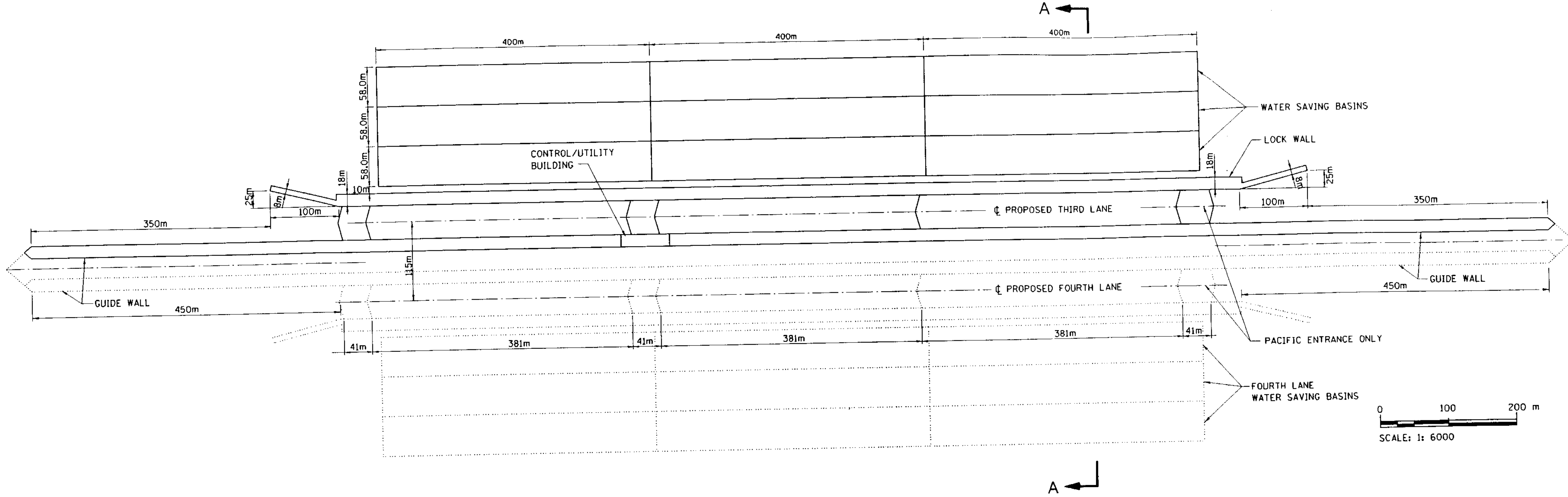


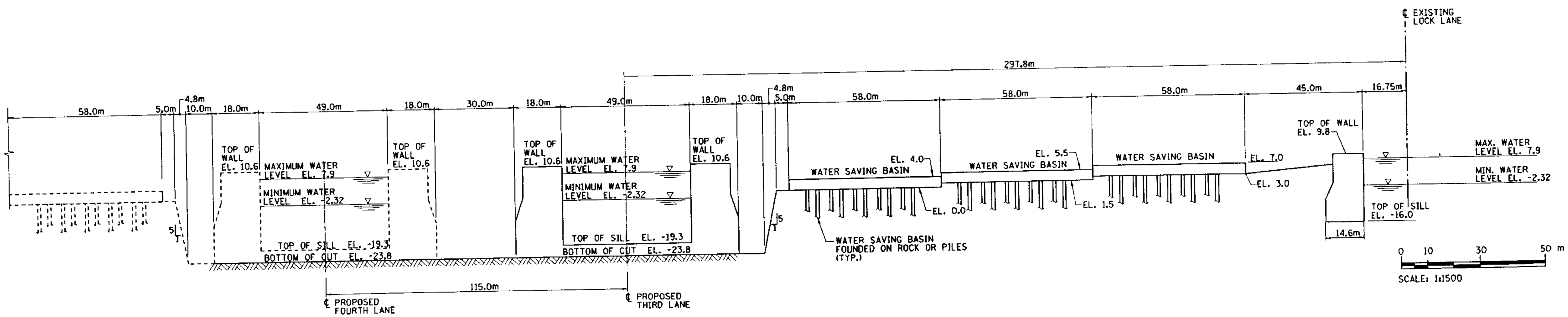

Task | Critical Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Critical Task

**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Final Evaluation
Construction Sequence for Alignment P5

HARZA TAMS | August 2000 | Exhibit 23




**NOTE:**
ATLANTIC ENTRANCE
TOP OF SILL EL. -17.4
BOTTOM OF CUT EL. -21.6

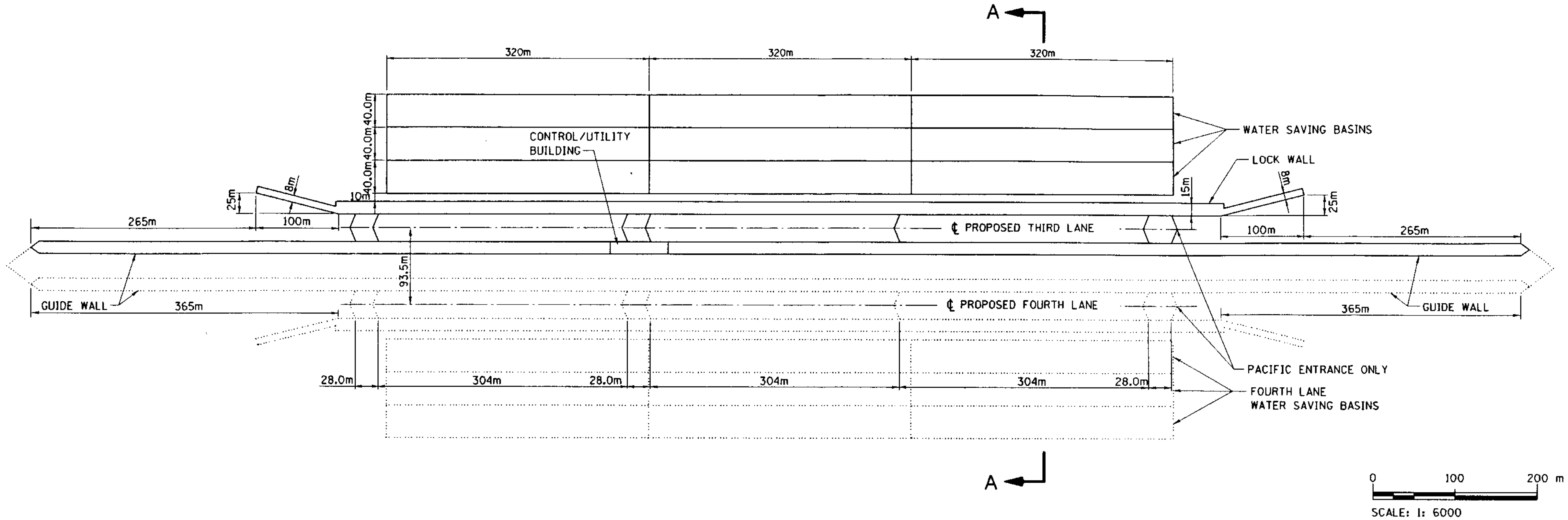
SECTION A – A

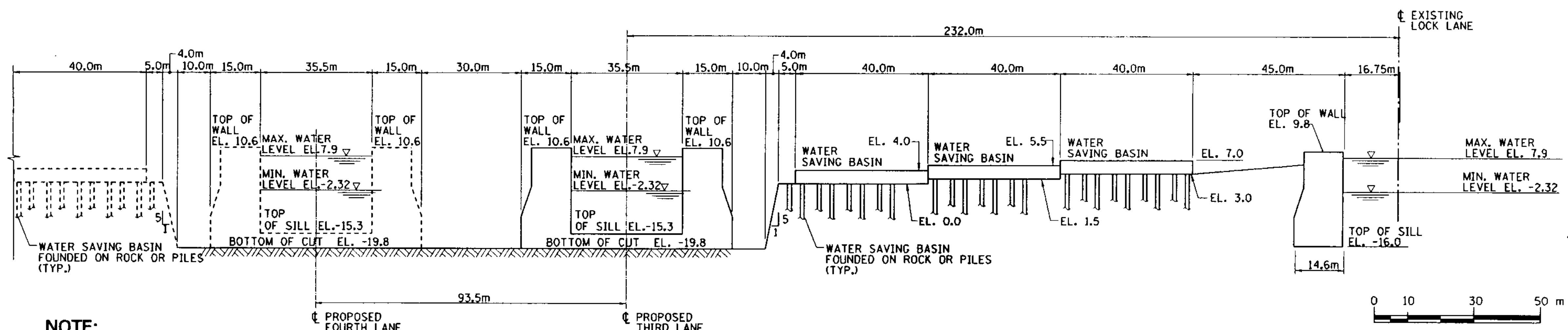
POST – PANAMAX LOCK COMPLEX WITH
THREE WATER SAVING BASINS PER LOCK
ATLANTIC AND PACIFIC ENTRANCES
PHASED CONSTRUCTION OF THIRD AND FOURTH LANES

AUTORIDAD DEL CANAL DE PANAMA
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Post – Panamax Lock Complex

| | | |
|---|---|---|
| HARZA TAMS | August 2000 | Exhibit 24 |




**NOTE:**
ATLANTIC ENTRANCE
TOP OF SILL EL. -13.1
BOTTOM OF CUT EL. -17.6

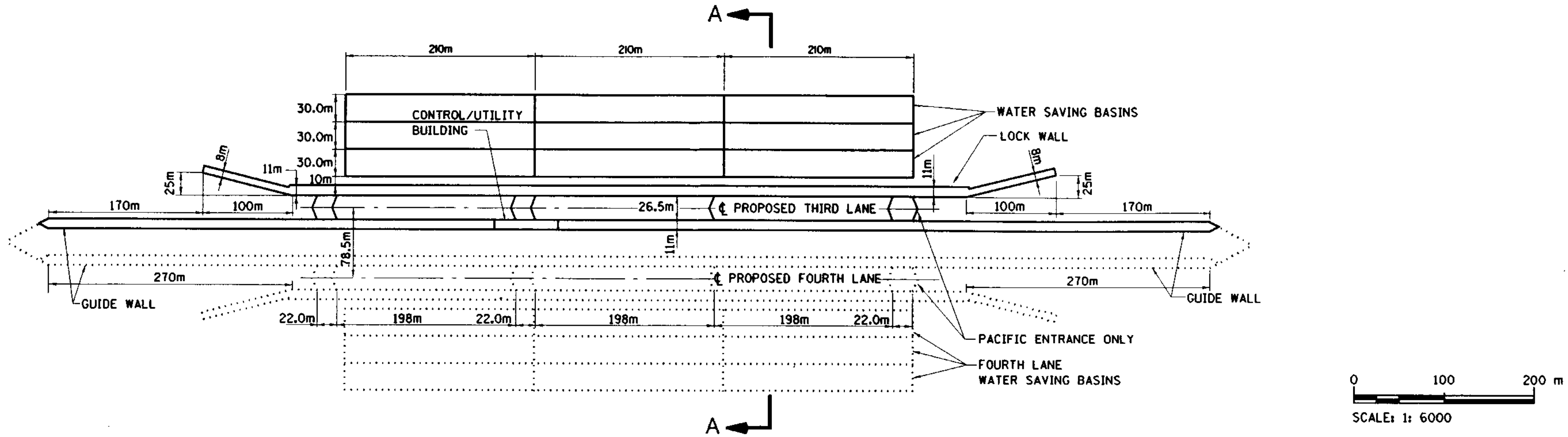
SECTION A – A

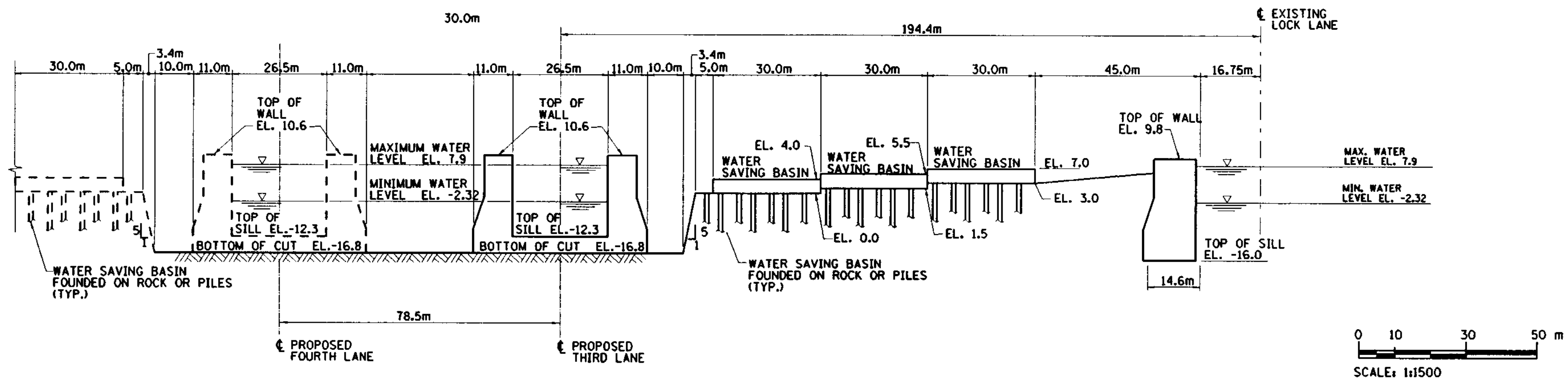
PANAMAX LOCK COMPLEX WITH
THREE WATER SAVING BASINS PER LOCK
ATLANTIC AND PACIFIC ENTRANCES
PHASED CONSTRUCTION OF THIRD AND FOURTH LANES

**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Panamax Lock Complex

| | | |
|---|---|---|
| HARZA TAMS | August 2000 | Exhibit 25 |




SECTION A - A

NOTE:

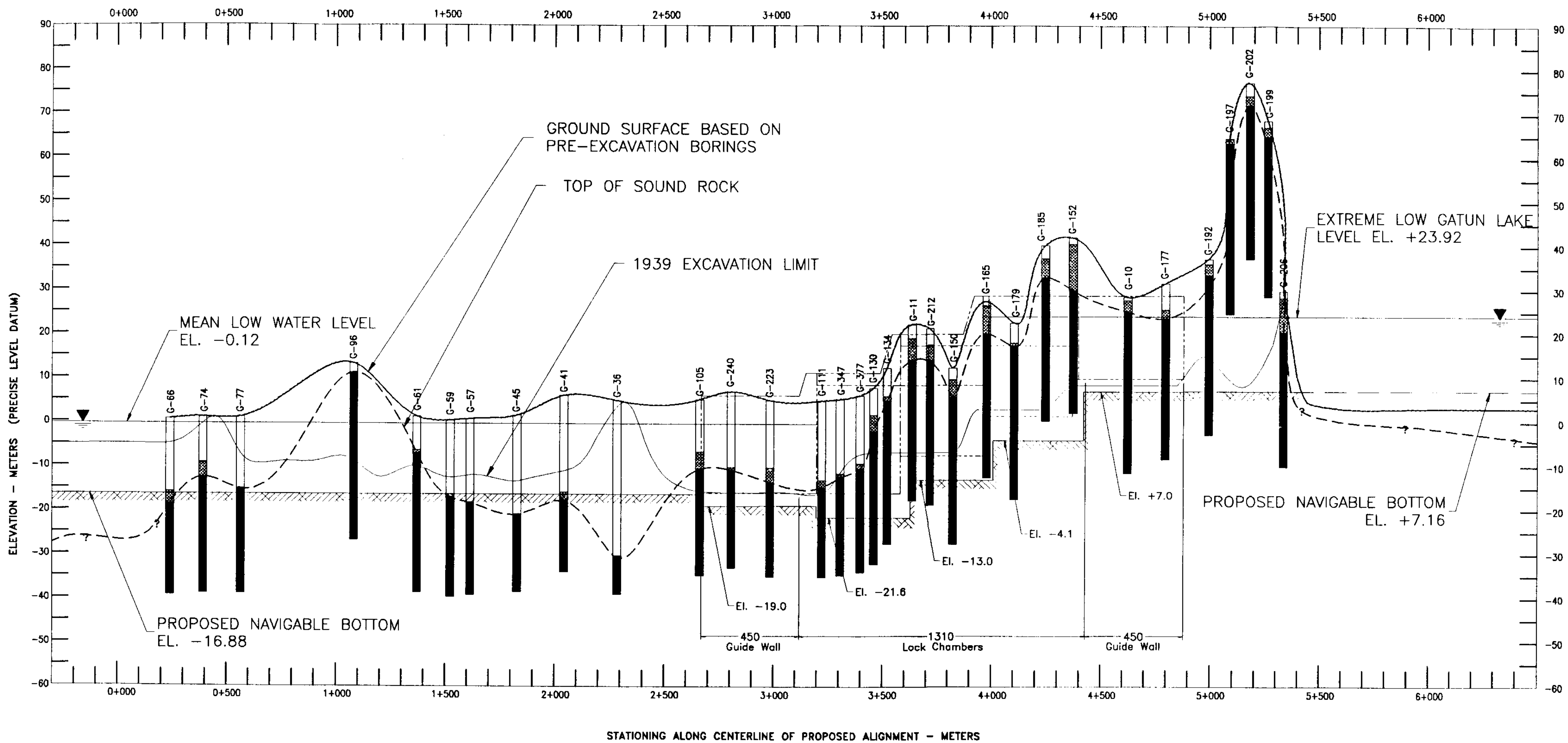
ATLANTIC ENTRANCE
TOP OF SILL EL. -10.1
BOTTOM OF CUT EL. -14.6

SMALL LOCK COMPLEX WITH
THREE WATER SAVING BASINS PER LOCK
ATLANTIC AND PACIFIC ENTRANCES
PHASED CONSTRUCTION OF THIRD AND FOURTH LANES

AUTORIDAD DEL CANAL DE PANAMA
Oficina de Proyectos de Capacidad del Canal

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Smaller - Than - Panamax Lock Complex

HARZA TAMS | August 2000 | Exhibit 26




**LEGEND**

ORIGINAL GROUND SURFACE
TOP OF SOUND ROCK
1939 EXCAVATION LIMIT
PROPOSED EXCAVATION LIMIT

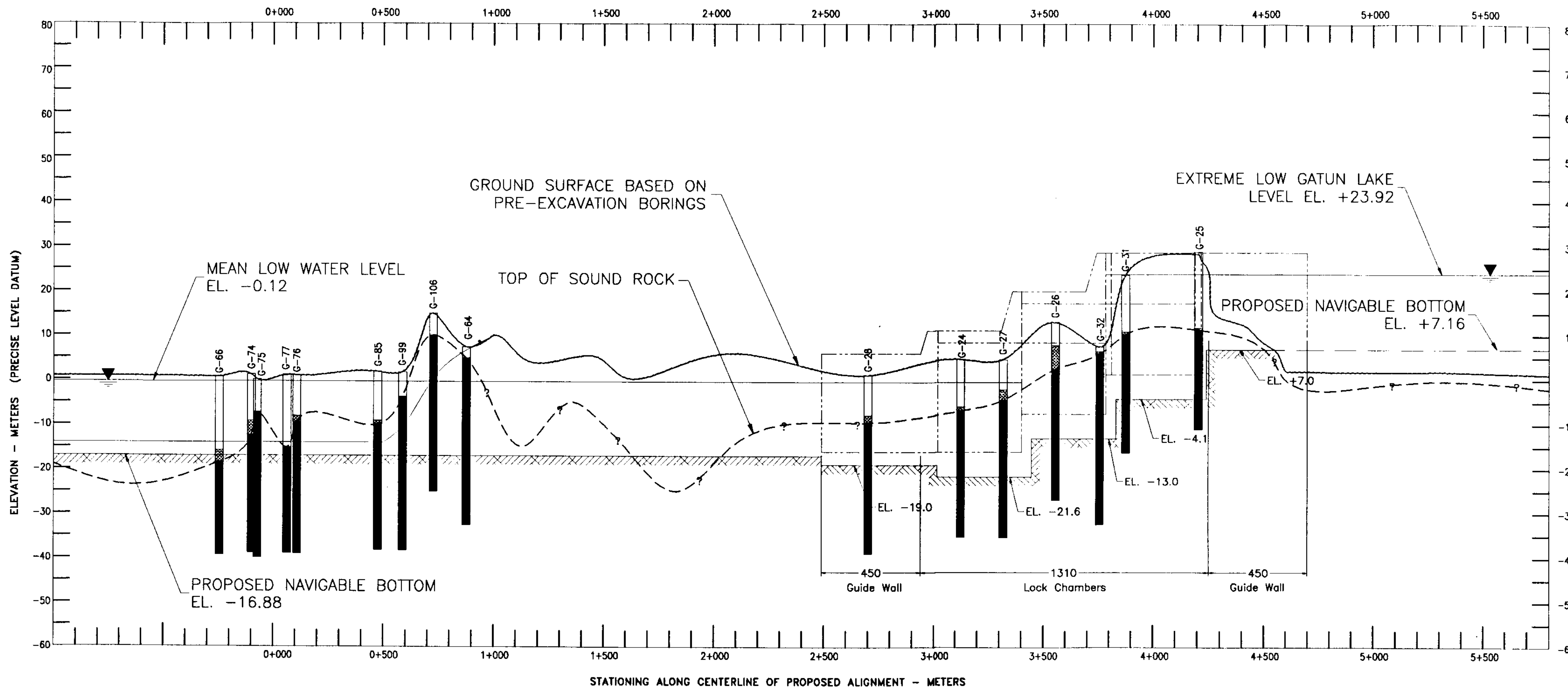
BOREHOLE
G–57 ← BOREHOLE NUMBER
OVERBURDEN
WEATHERED ROCK
SOUND ROCK

HORIZONTAL 250 0 500 1000 SCALE 1:20000
VERTICAL 10 0 25 50 SCALE 1:1000
SCALE IN METERS

**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC–5–536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Geology of Alignment A1

HARZA TAMS | August 2000 | Exhibit 27




HORIZONTAL SCALE 1:20000

VERTICAL SCALE 1:1000

SCALE IN METERS

LEGEND

- ORIGINAL GROUND SURFACE
- TOP OF SOUND ROCK
- 1939 EXCAVATION LIMIT
- PROPOSED EXCAVATION LIMIT

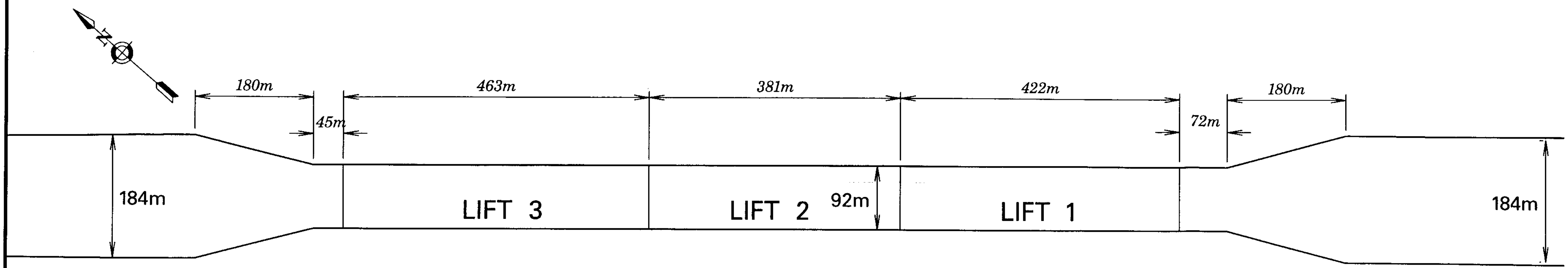
BOREHOLE

- G-57 — BOREHOLE NUMBER
- OVERBURDEN
- WEATHERED ROCK
- SOUND ROCK

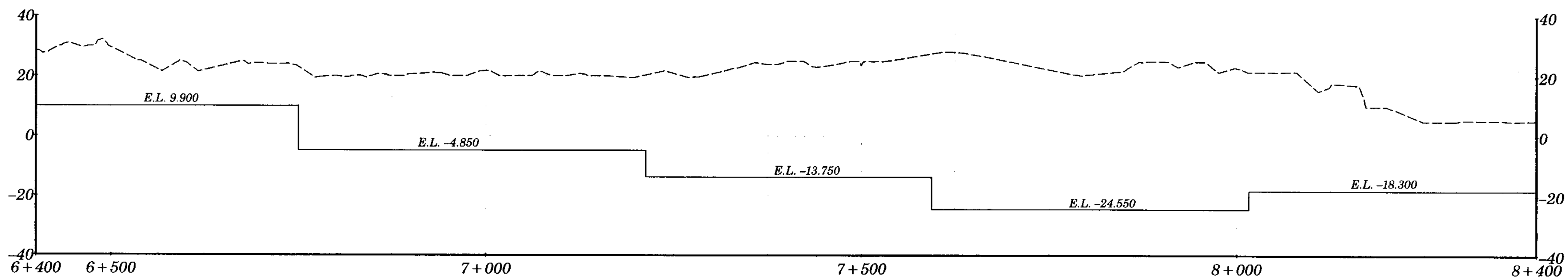
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Geology of Alignment A2

| HARZA TAMS | August 2000 | Exhibit 28 |
|---|---|---|



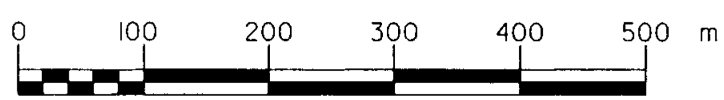

PROPOSED LOCK EXCAVATION




PROPOSED LOCK EXCAVATION

| LINE | SURFACE |
|---|---|
| ----------- | Existing Ground |

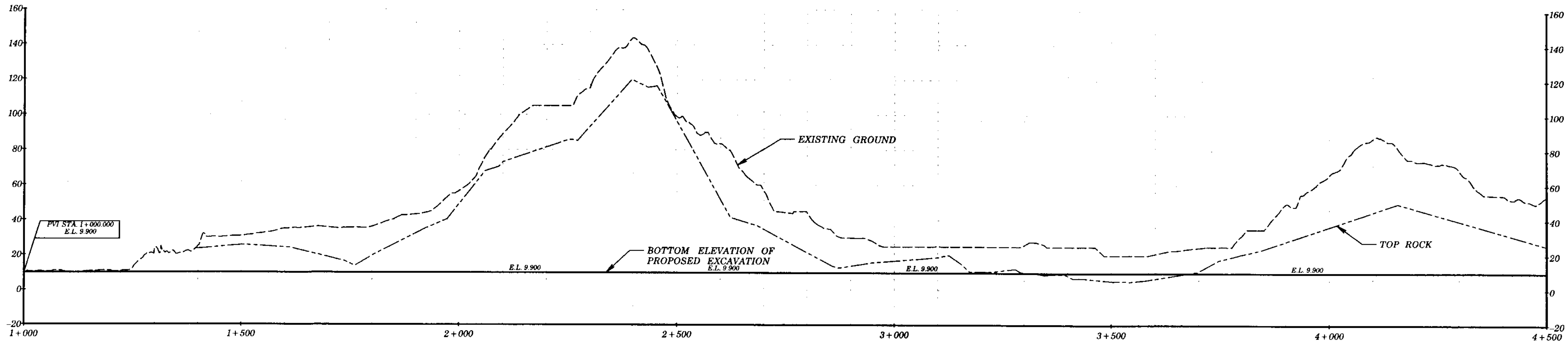
Scale 1:1500 Ver.
Scale 1:6000 Hor.

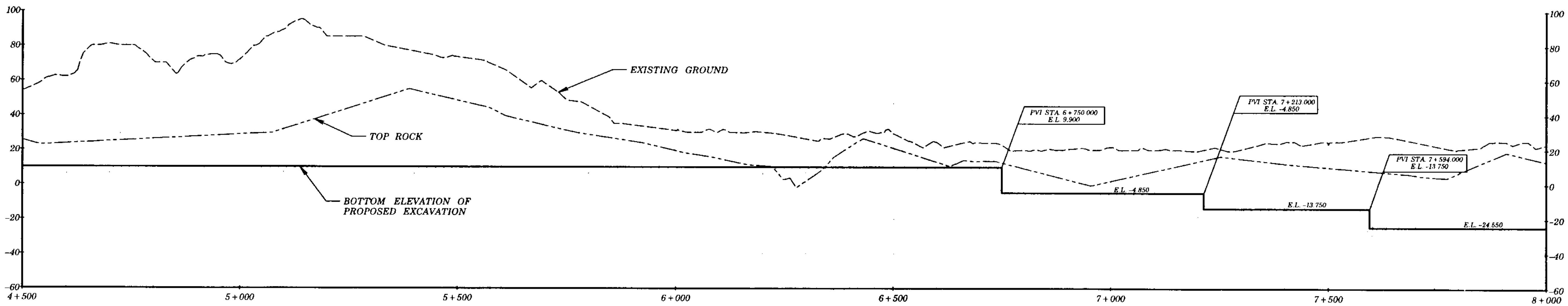


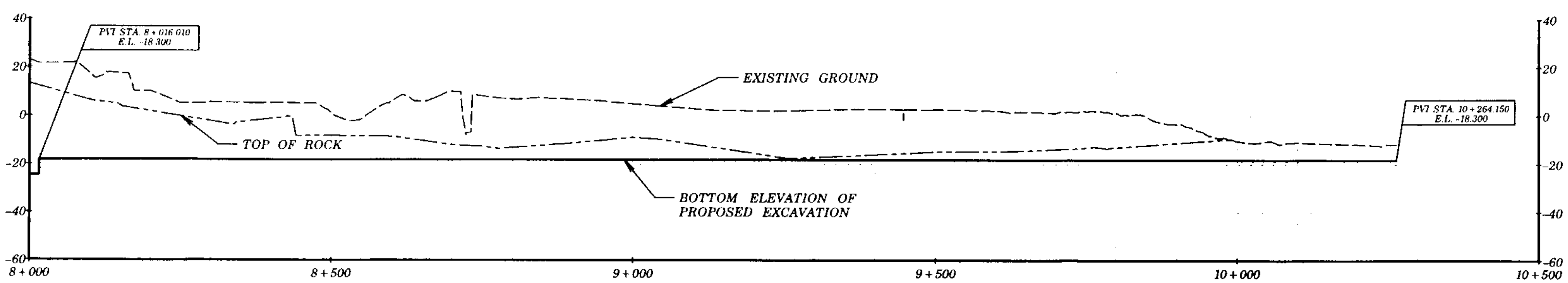

AUTORIDAD DEL CANAL DE PANAMA
Oficina de Proyectos de Capacidad del Canal

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Pacific Entrance Proposed Lock Excavation Plan/Profile

| HARZA TAMS | August 2000 | Exhibit 33 |
|---|---|---|




LEGEND

- – – – – Existing Ground Surface
- ——— Proposed Excavation
- – · – · – Top of Rock

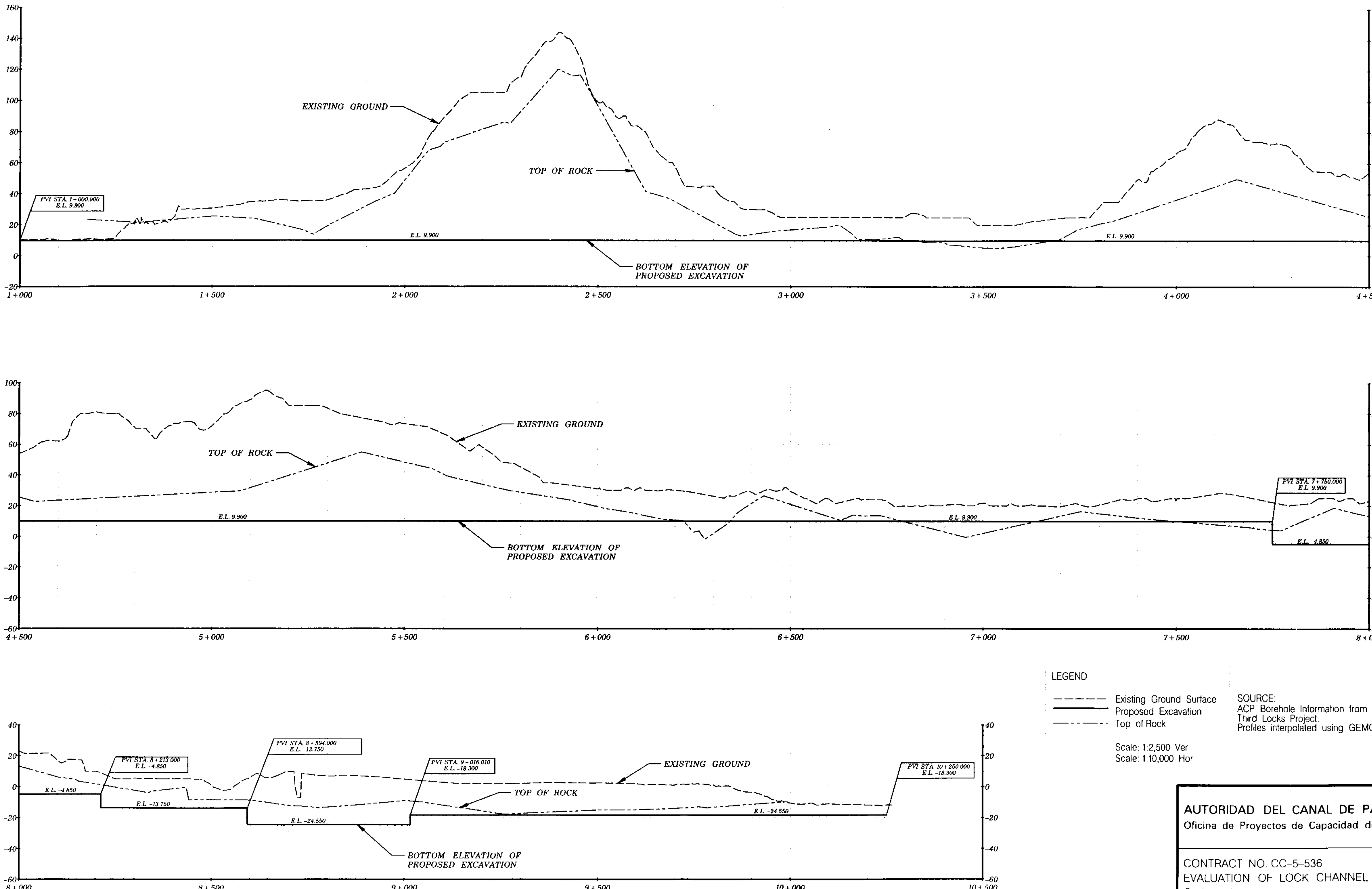
SOURCE:
ACP Borehole Information from 1939 Third Locks Project.
Profiles interpolated using GEMCOM.

Scale: 1:2,500 Ver
Scale: 1:10,000 Hor

AUTORIDAD DEL CANAL DE PANAMA
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Geological Profile of Align. P1 with Lock at STA 6+750

| HARZA TAMS | August 2000 | Exhibit 34 |
|---|---|---|




LEGEND

- Existing Ground Surface
- Proposed Excavation
- Top of Rock

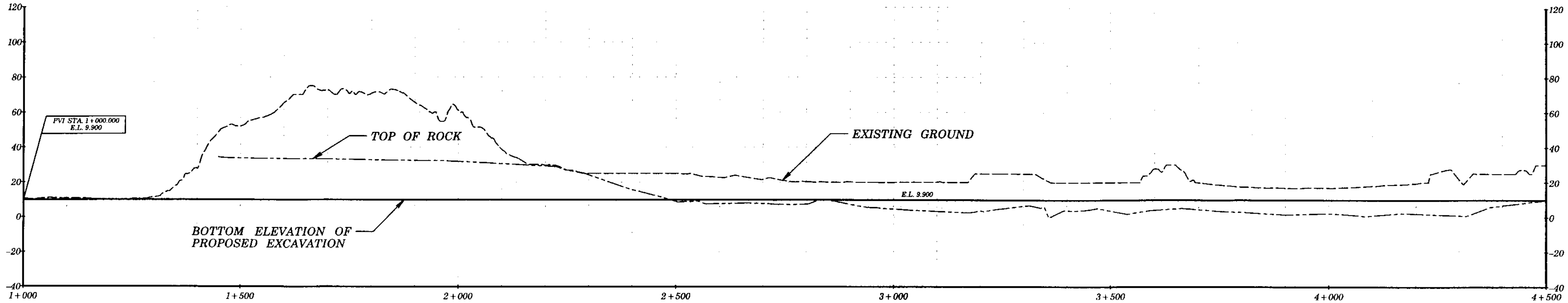
SOURCE:
ACP Borehole Information from 1939 Third Locks Project.
Profiles interpolated using GEMCOM.

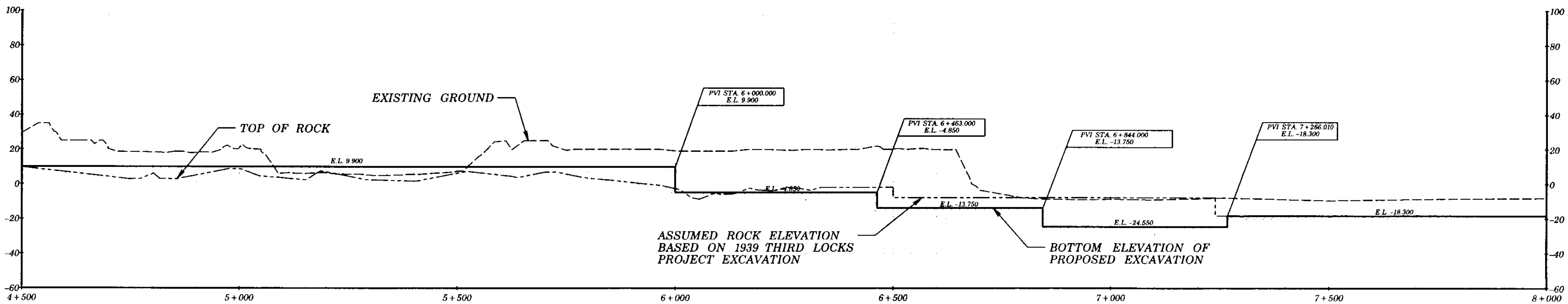
Scale: 1:2,500 Ver
Scale: 1:10,000 Hor

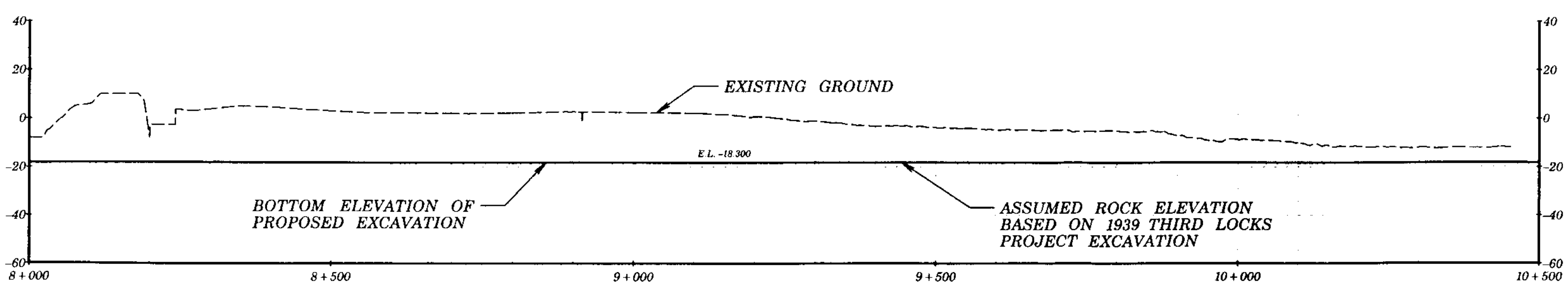
**AUTORIDAD DEL CANAL DE PANAMA**
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Geological Profile of Align. P1 with Lock at STA 7+750

| HARZA TAMS | August 2000 | Exhibit 35 |
|---|---|---|




LEGEND

- - - - Existing Ground Surface
—— Proposed Excavation
-·-·-· Top of Rock

SOURCE:
ACP Borehole Information from 1939 Third Locks Project.
Profiles interpolated using GEMCOM.

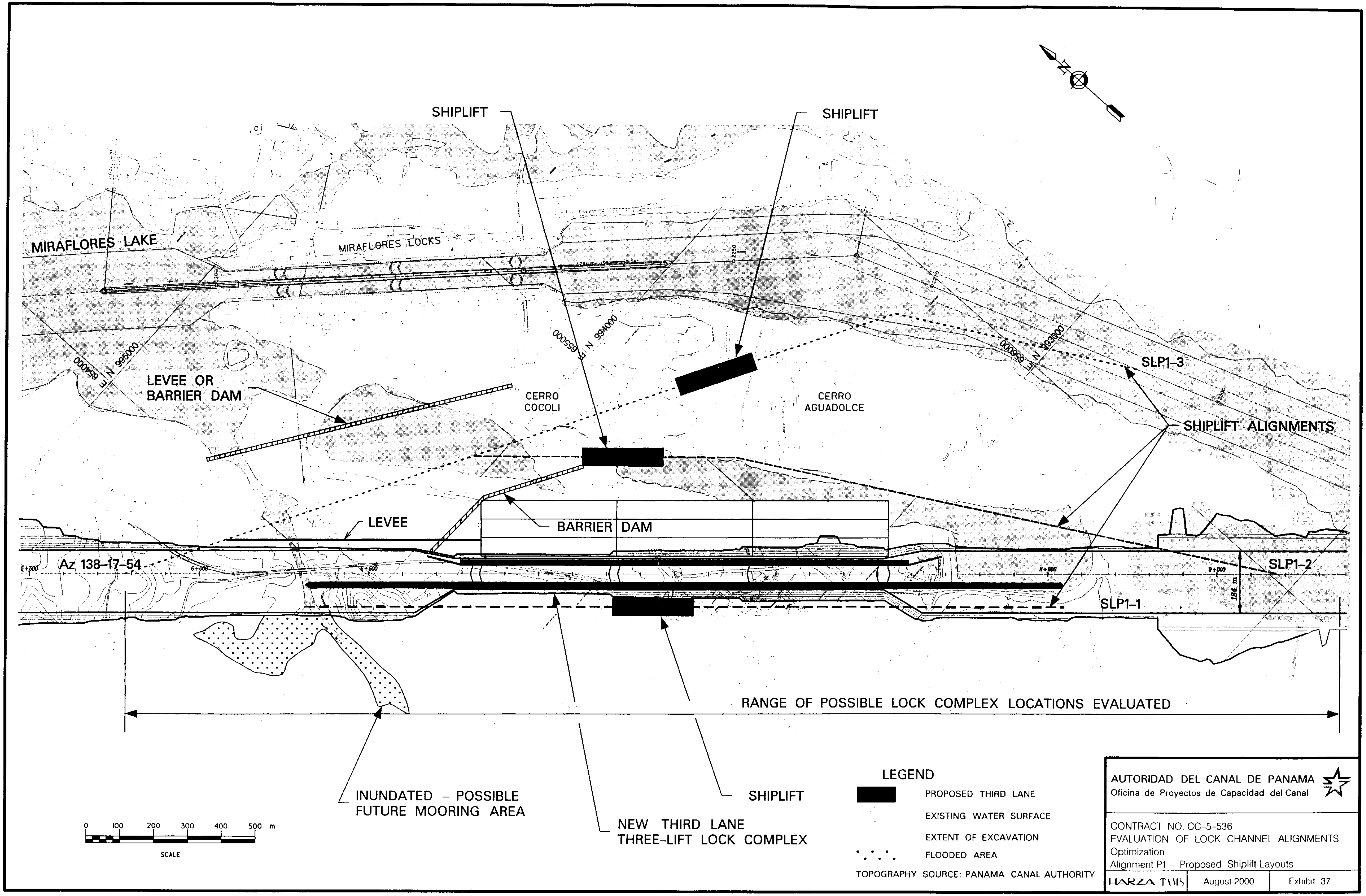
Scale: 1:2,500 Ver
Scale: 1:10,000 Hor

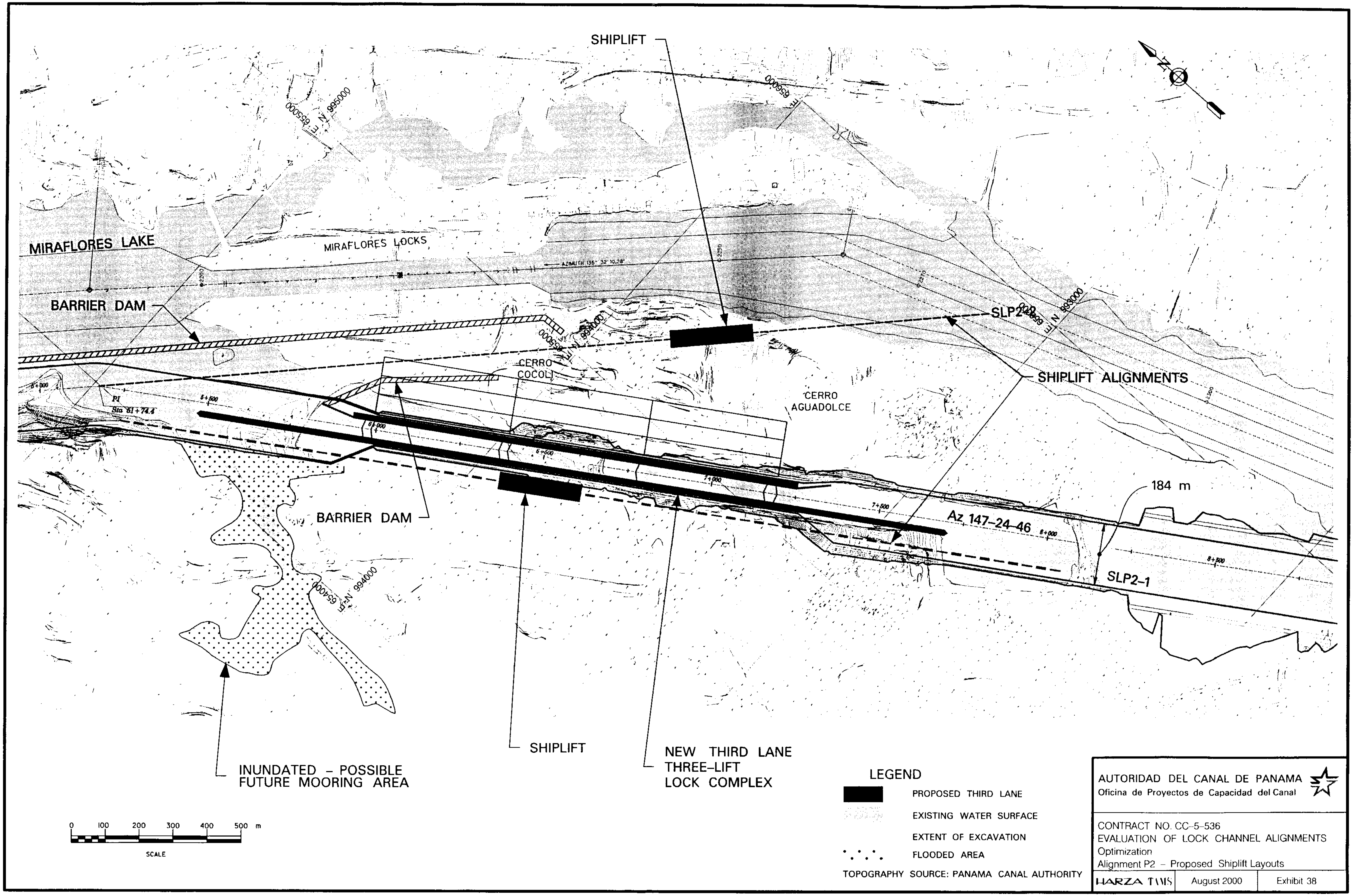
AUTORIDAD DEL CANAL DE PANAMA
Oficina de Proyectos de Capacidad del Canal

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Geological Profile of Align. P2 with Lock at STA 6+000

| HARZA TAMS | August 2000 | Exhibit 36 |
|---|---|---|

\volume3\geology_p2_6000.dgn Aug. 14, 2000 11:41:19


SHIPLIFT
SHIPLIFT
MIRAFLORES LAKE
MIRAFLORES LOCKS
N 995000
E 654000
N 994000
E 655000
N 993000
E 656000
LEVEE OR
BARRIER DAM
CERRO
COCOLI
CERRO
AGUADOLCE
SLP1-3
SHIPLIFT ALIGNMENTS
LEVEE
BARRIER DAM
Az 138-17-54
SLP1-2
SLP1-1
184 m
RANGE OF POSSIBLE LOCK COMPLEX LOCATIONS EVALUATED
INUNDATED - POSSIBLE
FUTURE MOORING AREA
NEW THIRD LANE
THREE-LIFT LOCK COMPLEX
SHIPLIFT
0 100 200 300 400 500 m
SCALE
LEGEND
PROPOSED THIRD LANE
EXISTING WATER SURFACE
EXTENT OF EXCAVATION
FLOODED AREA
TOPOGRAPHY SOURCE: PANAMA CANAL AUTHORITY
AUTORIDAD DEL CANAL DE PANAMA
Oficina de Proyectos de Capacidad del Canal
CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Alignment P1 - Proposed Shiplift Layouts
HARZA TAMS
August 2000
Exhibit 37


SHIPLIFT
MIRAFLORES LAKE
MIRAFLORES LOCKS
BARRIER DAM
SLP2-2
CERRO COCOLI
SHIPLIFT ALIGNMENTS
CERRO AGUADOLCE
BARRIER DAM
184 m
Az 147-24-46
SLP2-1
SHIPLIFT
NEW THIRD LANE
THREE-LIFT
LOCK COMPLEX
INUNDATED - POSSIBLE
FUTURE MOORING AREA
0 100 200 300 400 500 m
SCALE
LEGEND
PROPOSED THIRD LANE
EXISTING WATER SURFACE
EXTENT OF EXCAVATION
FLOODED AREA
TOPOGRAPHY SOURCE: PANAMA CANAL AUTHORITY
AUTORIDAD DEL CANAL DE PANAMA
Oficina de Proyectos de Capacidad del Canal
CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Optimization
Alignment P2 - Proposed Shiplift Layouts
HARZA TAMS
August 2000
Exhibit 38

# THE PANAMA CANAL
# EVALUATION OF LOCK CHANNEL ALIGNMENTS
# PART 3 - FINAL EVALUATION AND OPTIMIZATION

# APPENDIX A

# PRELIMINARY EXCAVATION COST ESTIMATES

# THE PANAMA CANAL
# EVALUATION OF LOCK CHANNEL ALIGNMENTS
# PART 3 - FINAL EVALUATION AND OPTIMIZATION

## APPENDIX A
## PRELIMINARY EXCAVATION COST ESTIMATES

## TABLE OF CONTENTS

# TABLES



# ATTACHMENTS

# 1.0 INTRODUCTION

This section provides preliminary cost estimates for the excavation of the preferred alignments. The estimated costs cover both wet and dry excavation for the new access channels as well as the excavation required for the locks and water saving basins. In accordance with the Scope of Services, cost estimates for construction of locks, shiplifts, water saving basins and other ancillary structures are not provided at this time.

Section 2.0 provides the criteria used in evaluating the various unit rates and where those unit rates were applied to the eight preferred alignments. The quantities used in determining the overall excavation cost were calculated as part of the Final Evaluation. The cost estimates presented assume that three techniques are used for excavation of the alignments. First, dry excavation is accomplished using a large hydraulic excavator and a fleet of off-highway trucks for disposal. Second, mechanical dredging is performed by a large capacity backhoe dredge filling dump scows. Finally, a heavy-duty cutter-suction dredge pumping spoil to an upland disposal accomplishes hydraulic dredging.

Section 3.0 provides the unit rates that were derived for the excavations. Section 4.0 details the application of these unit rates to the proposed alignments. This includes where dry or wet excavation is applied. A discussion of disposal assumptions is presented in section 5.0. Section 6.0 details the features that have and have not been considered in the cost of the alignment excavations.

The excavation costs provided on Attachment 1 and the barrier dam cost on Attachment 2 are of pre-feasibility level and are thus limited. The accuracy of the excavation quantities was limited by both the available IFSAR data and the excavation side slope assumptions that were taken from the 1993 Canal Alternatives Study. The barrier dam cost was derived from similar but much smaller structures designed for construction in the United States. Thus, the estimate provides a comparison among alignment alternative costs as well as an order of magnitude for the overall excavation contract cost.

## 2.0 DETERMINATION OF UNIT RATES

Overall excavation costs have been developed from excavation unit rates. The unit rates were then applied to various situations. Spreadsheets were developed to calculate and present excavation costs per cubic meter. The rates are derived from the overall daily cost of excavation divided by the estimated daily production. The rates reflect variations in quantity of equipment and production rates associated with excavating different material types and the distance of the excavation site from the spoil disposal site. Thus, for each of the three types of excavation studied (in the dry, in the wet – mechanical, and in the wet – hydraulic), six unit costs are presented. In each case, three material types are considered: overburden, weathered rock and blasted rock. Each of these three is further broken down according to the haul or pump distance to the disposal site. The haul/pump distance is categorized as either short or long. Attachment 1, page 5 summarizes the unit costs for each of the three excavation types for all six categories.

In each case, the estimate assumes that sufficient excavation volume is required on each contract to justify the mobilization of efficient heavy-duty equipment. In general this means that contracts for dry excavation and cutter-suction dredging will total at least 10,000,000 $m^3$ each. The assumed minimum quantity for backhoe dredging is 5,000,000 $m^3$. If contract quantities are lower, unit rates may be significantly higher.

### 2.1 Mobilization and Demobilization Costs

The cost of mobilization and demobilization has not been included in the unit rates. This cost may vary widely according to the position of the world's excavation fleet at the time that the contracts are bid. However, for budget purposes, lump sum prices may be applied for indicated mobilizations. Table A-1 below summarizes estimated lump sum mobilization costs. All prices are given in US dollars for comparison purposes only.

**Table A-1**

**Budget Mobilization Costs for Excavation Equipment**

| Equipment | Lump Sum Cost |
|---|---|
| Heavy-duty Cutter-suction Dredge | $5,000,000 |
| Heavy-duty Backhoe Dredge and 4000 $M^3$ Dump Barges | $5,000,000 |
| Two Heavy-duty Hydraulic Crawler Excavators and 200 Ton Dump Trucks | $5,000,000 |

## 2.2 General Daily Cost Assumptions

In order to arrive at the daily unit cost for each type of excavation, assumptions were made about the general cost items: ownership, maintenance, insurance, operating and labor costs. For each equipment unit, several assumptions were made about each cost category to simplify and unify comparative cost calculations.

- The hourly ownership rates are derived from an assumed purchase price and a 10 to 20 percent salvage value at the end of an appropriate useful life.
- A number of project revenue hours per year is assigned to each unit.
- An interest rate of eight percent is used to calculate the hourly depreciation.
- Annual fixed maintenance is equal to the unit first cost divided by the useful life in years.
- Annual insurance is assigned at one percent of the first cost.
- Fuel consumption and hourly labor were assigned to each equipment unit based on the function and rated power of the unit.
- Hourly lubricants cost is assumed as 15 percent of the hourly fuel cost.
- Variable maintenance includes wear items that are most closely linked with operating hours. It is generally assigned 50 percent of the fixed maintenance hourly cost.
- The supplies category includes other consumables such as blasting powder.

Hourly rates are derived from annual costs. Hourly rates are calculated by dividing the annual cost by the number of revenue (on-the-job) hours per year.

## 2.3 General Daily Production Assumptions

For each equipment unit a production rate was assumed. Rates are based on historical data for similar equipment in similar conditions. They were adjusted according to the equipment power and the material type. Similarly, time efficiencies were allotted to each unit. In general, time efficiency for rock excavation is lower than for common excavation because of more frequent equipment breakdowns associated with rock excavation.

## 2.4 Wet Excavation Unit Rate

### 2.4.1 Mechanical Dredging

The assumed excavation equipment spread is given below in Table A-2.

**Table A-2**

**Equipment List for Mechanical Dredging**

| Number of Units | Description |
|---|---|
| 1 | 19 $m^3$ Backhoe Dredge |
| 2-3 | 4000 $m^3$ bottom-dump hopper barges (scows) |
| 1 | 3000 Hp Towing Tug |
| 1 | 250 Hp Survey Launch |
| 1 | Drillboat |
| 1 or 2 (for blasting) | 800 Hp Workboat |

The dredging equipment is modeled on a large backhoe shovel similar to that of the Liebherr 996 series. It was chosen for its ability to efficiently excavate overburden as well as weathered and blasted rock. The dredge fills 4000 $m^3$ scows that are towed by a 3000 Hp tug to disposal sites either at the Atlantic and Pacific entrances or in Gatun Lake. The high-capacity barges were chosen because they are generally more efficient for long haul disposal.

The main equipment is accompanied by a survey launch that is also used to transport crew and supplies to and from the dredge. A drillboat and 800 Hp workboat are added to the spread for the blasted rock categories. Ownership and operation costs, fuel consumption and production data was estimated based on historical information for similar equipment.

### 2.4.2 Hydraulic Dredging

The assumed excavation equipment spread is given below in Table A-3.

**Table A-3**

**Equipment List for Hydraulic Dredging**

| Number of Units | Description |
|---|---|
| 1 | 15,000 kW Cutter-suction Dredge |
| 1 | 1500 Hp Tug |
| 1 | Derrick Barge |
| 1 or 2 (for blasting) | 800 Hp Workboat |
| 1 | Anchor Barge |
| 1 | Survey Launch |
| 3 | High Capacity Bulldozers |
| 1 | Drillboat |

This dredging unit was chosen because of its high production in both common and rock excavation. The cutter head should be powered with a minimum of 2,000 kW in order to cut unblasted weathered rock efficiently. The 1500 Hp tugboat would help position the dredge and assist with moving anchors and the derrick barge. The workboat would assist the larger tug with lighter duties and assist the survey launch as a crew and supply shuttle. A second workboat is assigned to the drilling platform during blasting operations. Three bulldozers would be required for leveling the fill area.

As with mechanical information, ownership and operation costs, fuel consumption and production data was estimated based on historical information for similar equipment.

## 2.5 Dry Excavation Unit Rates

Table A-4 provides a possible fleet of equipment for large-scale excavation.

**Table A-4**

**Equipment List for Dry Excavation**

| Number of Units | Description |
|---|---|
| 1 | 22 $m^3$ Hydraulic Front Shovel |
| 3-5 | 200 Ton Off-Road Dump Trucks |
| 1 | 425 kW Tractor with Ripper |
| 1 | 300 kW Bulldozer |
| 1 | 200 kW Grader |
| 1 | 60 Ton Water Truck |
| 1 | Auxiliary Equipment (Light Plants, Generators, etc.) |
| 1 | Drilling and Blasting Equipment |

As with the wet excavation equipment, the dry excavation equipment was chosen for its high capacity and flexibility in working in a variety of material types. The crawler hydraulic shovel was assumed for excavation of both rock and overburden because it works efficiently in both. The 200 Ton trucks are a suitable match for the excavator. If a smaller excavator were used, smaller trucks would also be appropriate. The tractor equipped with a ripper is used to loosen weathered rock in the excavation area. The bulldozer is necessary for leveling the fill area. The grader and water trucks are used to maintain the haul roads.

Ownership and operation costs, fuel consumption and production data was taken from the Caterpillar Performance Handbook. These rates are theoretical costs and production provided by the equipment manufacturer. Actual costs and production rates will vary according to work conditions. Because of the heavy rainfall and other severe climactic conditions often experienced in the work area, the most severe conditions for usage and wear were taken as a baseline. Operator ability was assumed as moderate.

Scrapers and belt loaders may prove more efficient excavating soft overburden than the proposed equipment. However, in order to simplify the estimate and plan for a more conservative scenario (i.e., overburden too stiff for scrapers), they were not considered at this time. The ultimate decision whether to employ scrapers or belt loaders will be governed by the final breakdown and character of materials for the selected alignments. If the overburden quantity is low, it may be more cost effective to use the same equipment for overburden and rock excavation instead of paying ownership and mobilization costs for extra equipment.

# 3.0 EXCAVATION UNIT RATES

Using the methodologies and assumptions developed in section 2.0, unit rates were assigned to each type of excavation in each material type. Table A-5 provides a summary of those rates. They include contractor profit, but do not include a pre-feasibility contingency. See Attachment 1 for a breakdown of the costs and productions used to arrive at these rates.

**Table A-5**

**Summary of Excavation Unit Rates ($/m$^3$)**

| Excavation Type | Mechanical Dredge | Hydraulic Dredge | Dry Excavation |
|---|---|---|---|
| Overburden - Short Haul | $ 5.00 | $ 3.00 | $ 3.00 |
| Overburden - Long Haul | $ 6.00 | $ 6.00 | $ 4.00 |
| 2000 PSI Weathered Rock - Short Haul | $ 21.00 | $ 24.00 | $ 4.00 |
| 2000 PSI Weathered Rock - Long Haul | $ 26.00 | $ 32.00 | $ 5.00 |
| Blasted Rock - Short Haul | $ 28.00 | $ 24.00 | $ 6.00 |
| Blasted Rock - Long Haul | $ 32.00 | $ 40.00 | $ 8.00 |

# 4.0 APPLICATION OF UNIT RATES

The plan layout of each alignment was utilized to determine where to apply the unit rates. The quantities for each alignment were calculated and are tabulated in Appendix B of Part 3. The percentage of wet and dry excavation was determined at each 100 m station. This percentage was applied to the volume calculated for that station by the average end area method.

For the Atlantic entrance the percentages of overburden, weathered rock and sound rock were determined using the 1939 Third Locks Project Boring data along each alignment. For the Pacific Entrance the 1939 borings did not sufficiently cover the area of all five alignments to perform detailed takeoffs by material type. Instead percentages of overburden, weathered rock and sound rock were determined along Alignments P1 and P2, which had the best boring data. From these alignments' profiles, it was determined that the breakdown of material along the alignment was approximately 20% overburden, 15% weathered rock and 65% sound rock. These percentages were applied to all five Pacific alignments to determine the gross volumes of overburden, weathered rock and sound rock in each alignment.

# 5.0 DISPOSAL OF EXCAVATED MATERIAL

Attachments 3 and 4 provide the proposed disposal areas and capacities for Atlantic entrance Alignments A1 through A3. Attachments 5 and 6 give the same information for the Pacific Entrance. The theoretical disposals shown on the attachments are all within short haul or short pump range of the excavation areas. It is assumed that any quantity in excess of these capacities will require long haul or long pump. Thus the quantities were broken out according to haul or pump distance for each alignment. This breakdown is reflected for the Pacific Entrance on Attachment 1, page 2 and for the Atlantic Entrance on Attachment 1, page 3. For the Pacific Entrance, all mechanically dredged spoil requires long haul, either to Disposal 14 in Gatun Lake or to the Pacific dumping grounds centered approximately 1 km southwest of buoy no. 1.

The haul distances were divided between short and long. A-6 below provides the breakdown.

**Table A-6**

**Haul/Pump Distance Breakdown**

| Excavation Type | Mechanical Dredge | Hydraulic Dredge | Dry Excavation |
|---|---|---|---|
| Short Haul/Pump | 0 – 25 Km | 0-2000 m | 0 – 3.5 Km |
| Long Haul/Pump | 25-50 Km | 2000-4000 m | 3.5 – 7 Km |

The haul/pump distance is a critical component of the cost. Hydraulic dredging costs are particularly sensitive to small changes in pumping distance. Should the disposal areas or capacities change significantly, the excavation costs would also change significantly.

# 6.0 BARRIER DAM AND OTHER FEATURES

The cost estimate for the proposed barrier dam is provided on Attachment A-2. For the Pacific Entrance, only Alignment P2 utilizes a dam to dewater a significant area. For the other alignments, excavation of small areas in the wet was considered more desirable than building temporary structures to excavate them in the dry. Should cofferdams be necessary to construct the locks, they would be covered as part of the locks construction cost, not the excavation cost.

## 6.1 Barrier Dam

A cross section of Alignment P2, including the proposed barrier dam cross section, is shown on Volume 3, Exhibit 13. The cost estimate for the barrier dam is provided on Attachment A-2. The barrier dam structure will consist of a 10 m diameter sheetpile cellular structure filled with concrete. Rip rap (approximately 4 ton stones) will be placed on both sides of the structure. The stone will add to the factory of safety against overturning or sliding and will protect the dam from potential collisions with vessels in both traffic lanes. A grout curtain will also be drilled and filled to prevent seepage under the dam. A proposed construction sequence is provided below:

1. Strip Overburden underlying both the new concrete-filled cellular sheetpile dam and the rubble fill protection. Average depth of overburden is approximately 5 m. The over-burden will be cast by a dragline dredge into the new alignment to be removed later in the dry.

2. Prepare and set sheetpile and construct cells.

3. Remove remaining soft material inside of the cells hydraulically. Prepare foundation.

4. Fill cells up to elevation +16.4 m PLD with tremie concrete. Cells will be constructed and filled from the north to the south.

5. Install grout curtain. Grout holes will be drilled through the tremie concrete, prior to placing normal concrete.

6. Fill cells up to elevation +30.0 PLD with normal concrete.

7. As concrete cures and assembles sufficient strength, begin quarrying stone from local excavation (Cerro Paraiso). Place rubble fill along the west side of the dam using rail mounted hopper cars and hydraulic cranes. Ten hydraulic cranes on the barrier dam will unload a train of ten gondola cars towed by a single locomotive. Dual tracks will be used on the dam to reduce waiting time between trains. After placing all rubble fill on the dam's west side, dewater the area west of the dam and begin excavation of Alignment P2 in the dry.

8. Place rubble on the east side of the barrier dam as described above.

Notes:

1. Rubble fill will be quarried from excavation on site. The excavation cost is not included in this section.

2. Low strength (~2000 psi) concrete will be used to fill the sheetpile cells.

### 6.2 Other Features

Other features included in the excavation cost include the cost of constructing rock and earth-filled levees and dikes. It was assumed that any additional cost to place fill and shape levees would be offset by the shorter haul distance since the levee structures generally occur adjacent to channel excavation limits. The cost of temporary diversions of rivers and of de-watering excavations are covered in the mobilization cost for dry excavation and the 20% pre-feasibility contingency. The cost of excavation design and construction management are not included in this cost estimate. Project financing cost are not part of the estimate scope either.

The cost of locks, including leveling and backfilling to create platforms for concrete structures are not included in these costs. It is assumed that those activities would be part of the locks' construction contract.

## 7.0 OVERALL EXCAVATION COSTS

Table A-7 below provides the overall excavation cost for the Atlantic and Pacific Entrance alignments.

**Table A-7**

**Summary of Overall Excavation Costs**

| Alignment No. | Overall Cost (millions) | Remarks |
|---|---|---|
| A1 | $120 | |
| A2 | $180 | |
| A3 | $70 | Least Costly Atlantic Entrance Alternative |
| P1 | $660 | Least Costly Bypass Alternative. |
| P2 | $830 | |
| P3 | $540 | |
| P4 | $370 | Least Costly Dual-Lock Complex Alternative. |
| P5 | $630 | |

These costs include the blasting (where appropriate), excavation, hauling and disposal of the soil and rock inside the proposed 184 m wide channel prism. They also include mobilization and demobilization of excavation equipment and the construction of barrier dams and cofferdams as indicated. Finally, a 20% pre-feasibility contingency was added in accordance with USACE guidelines specified in ER 1110-2-1302, Appendix D.

These comparative excavation cost offer a sense of which alternatives will be less expensive than the others and provide an order of magnitude of the overall excavation cost. However, they do not provide the entire project cost and should not be represented as such. The excavation volume is subject to change based on further study of the temporary and permanent excavation slopes and the results of a more accurate survey of the ground condition. More boreholes will be required to more accurately determine the quantity and character of the insitu soil and rock to accurately reflect its excavation cost. Finally, the cost of constructing locks and auxiliary structures has not been considered in this cost estimate.

# SUMMARY OF PRELIMINARY EXCAVATION COST ESTIMATES*

## Pacific Entrance Alignments

| Description | | Alignment P1 | | Alignment P2 | | Alignment P3 | | Alignment P4 | | Alignment P5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Quantity | Total Cost | Quantity | Total Cost | Quantity | Total Cost | Quantity | Total Cost | Quantity | Total Cost |
| Mobilization and Demobilization | | | $10,000,000 | | $10,000,000 | | $15,000,000 | | $15,000,000 | | $15,000,000 |
| Excavation Estimate | | 69,600,000 | $ 539,560,265 | 36,900,000 | $402,642,736 | 36,400,000 | $433,730,530 | 38,100,000 | $295,740,102 | 46,800,000 | $513,332,829 |
| Cofferdam/Barrier Dam Estimate | | | | | $280,682,767 | | | | | | |
| Contingency | 20% | | $ 109,912,053 | | $ 138,665,101 | | $ 89,746,106 | | $ 62,148,020 | | $105,666,566 |
| Estimate with Contingency | | | **$ 660,000,000** | | **$ 830,000,000** | | **$ 540,000,000** | | **$ 370,000,000** | | **$ 630,000,000** |

## Atlantic Entrance Alignments

| Description | | Alignment A1 | | Alignment A2 | | Alignment A3 | |
|---|---|---|---|---|---|---|---|
| | | Quantity | Total Cost | Quantity | Total Cost | Quantity | Total Cost |
| Mobilization and Demobilization | | | $10,000,000 | | $10,000,000 | | $10,000,000 |
| Preliminary Estimate | | 12,280,000 | $ 87,983,310 | 12,140,000 | $ 139,437,506 | 13,960,000 | $ 50,666,025 |
| Cofferdam/Barrier Dam Estimate | | | | | | | |
| Contingency | 20% | | $ 19,596,662 | | $ 29,887,501 | | $ 12,133,205 |
| Estimate with Contingency | | | **$ 120,000,000** | | **$ 180,000,000** | | **$ 70,000,000** |

*Channel Bottom Elevations

| | |
|---|---|
| Gatun Lake = | 9.9 m PLD |
| Atlantic Entrance = | -16.88 m PLD |
| Pacific Entrance = | -19.08 m PLD |

## SUMMARY OF OVERALL EXCAVATION COSTS FOR PACIFIC ENTRANCE ALIGNMENTS

| | | | Unit Price | Alignment P1 | | Alignment P2 | | Alignment P3 | | Alignment P4 | | Alignment P5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Quantity | Total Cost | Quantity | Total Cost | Quantity | Total Cost | Quantity | Total Cost | Quantity | Total Cost |
| Wet Excavation | Backhoe Dredge | Overburden - Short Haul | $ 4.86 | - | $ - | - | $ - | - | $ - | - | $ - | - | $ - |
| | | Overburden - Long Haul | $ 6.00 | 1,458,621 | $ 8,754,461 | 2,023,367 | $ 12,143,997 | 663,250 | $ 3,980,744 | 328,265 | $ 1,970,207 | 2,075,722 | $ 12,458,227 |
| | | 2000 PSI Weathered Rock - Short Haul | $ 21.12 | - | $ - | - | $ - | - | $ - | - | $ - | - | $ - |
| | | 2000 PSI Weathered Rock - Long Haul | $ 26.10 | 1,093,965 | $ 28,547,154 | 1,517,525 | $ 39,599,990 | 497,437 | $ 12,980,688 | 246,199 | $ 6,424,589 | 1,556,791 | $ 40,624,654 |
| | | Blasted Rock - Short Haul | $ 27.95 | - | $ - | - | $ - | - | $ - | - | $ - | - | $ - |
| | | Blasted Rock - Long Haul | $ 32.22 | 4,740,517 | $ 152,724,013 | 6,575,941 | $ 211,855,421 | 2,155,562 | $ 69,445,199 | 1,066,862 | $ 34,370,814 | 6,746,096 | $ 217,337,257 |
| | Cutter Suction Dredge | Overburden - Short Pump | $ 3.21 | - | $ - | - | $ - | 1,100,000 | $ 3,534,910 | 859,468 | $ 2,761,947 | 730,368 | $ 2,347,077 |
| | | Overburden - Long Pump | $ 5.97 | - | $ - | - | $ - | 515,967 | $ 3,079,303 | - | $ - | - | $ - |
| | | 2000 PSI Weathered Rock - Short Pump | $ 24.26 | - | $ - | - | $ - | 825,000 | $ 20,011,123 | 644,601 | $ 15,635,381 | 547,776 | $ 13,286,803 |
| | | 2000 PSI Weathered Rock - Long Pump | $ 32.34 | - | $ - | - | $ - | 386,975 | $ 12,515,235 | - | $ - | - | $ - |
| | | Blasted Rock - Short Pump | $ 24.17 | - | $ - | - | $ - | 3,575,000 | $ 86,395,204 | 2,793,271 | $ 67,503,558 | 2,373,696 | $ 57,363,901 |
| | | Blasted Rock - Long Pump | $ 40.28 | - | $ - | - | $ - | 1,676,891 | $ 67,540,956 | - | $ - | - | $ - |
| Dry Excavation | ME 5320 Excavator & 150 ton Dump Trucks | Overburden - Short Haul | $ 2.98 | 8,400,000 | $ 25,061,090 | 5,361,384 | $ 15,995,492 | 1,290,000 | $ 3,848,667 | 6,442,206 | $ 19,220,085 | 6,551,764 | $ 19,546,947 |
| | | Overburden - Long Haul | $ 4.16 | 4,055,813 | $ 16,857,286 | - | $ - | 3,720,255 | $ 15,462,596 | - | $ - | - | $ - |
| | | 2000 PSI Weathered Rock - Short Haul | $ 3.79 | 6,300,000 | $ 23,848,357 | 4,021,038 | $ 15,221,453 | 967,500 | $ 3,662,426 | 4,831,655 | $ 18,290,004 | 4,913,823 | $ 18,601,049 |
| | | 2000 PSI Weathered Rock - Long Haul | $ 5.13 | 3,041,860 | $ 15,592,176 | - | $ - | 2,790,191 | $ 14,302,156 | - | $ - | - | $ - |
| | | Blasted Rock - Short Haul | $ 6.19 | 27,300,000 | $ 168,938,014 | 17,424,499 | $ 107,826,383 | 4,192,500 | $ 25,944,052 | 20,937,171 | $ 129,563,517 | 21,293,234 | $ 131,766,913 |
| | | Blasted Rock - Long Haul | $ 7.53 | 13,181,392 | $ 99,237,715 | - | $ - | 12,090,827 | $ 91,027,270 | - | $ - | - | $ - |
| | | Totals | | **69,572,166** | **$ 539,560,265** | **36,923,754** | **$ 402,642,736** | **36,447,355** | **$ 433,730,530** | **38,149,698** | **$ 295,740,102** | **46,789,272** | **$ 513,332,829** |

# SUMMARY OF OVERALL EXCAVATION COSTS FOR ATLANTIC ENTRANCE ALIGNMENTS

| | | | Unit Price | Alignment A1 | | Alignment A2 | | Alignment A3 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Quantity | Total Cost | Quantity | Total Cost | Quantity | Total Cost |
| Wet Excavation | Backhoe Dredge | Overburden - Short Haul | $ 4.86 | 1,520,000 | $ 7,381,820 | 1,810,000 | $ 8,790,194 | 2,440,000 | $ 11,849,764 |
| | | Overburden - Long Haul | $ 6.00 | | $ - | | $ - | | $ - |
| | | 2000 PSI Weathered Rock - Short Haul | $ 21.12 | 350,000 | $ 7,390,266 | 520,000 | $ 10,979,824 | | $ - |
| | | 2000 PSI Weathered Rock - Long Haul | $ 26.10 | | $ - | | $ - | | $ - |
| | | Blasted Rock - Short Haul | $ 27.95 | 1,020,000 | $ 28,507,076 | 3,270,000 | $ 91,390,330 | | $ - |
| | | Blasted Rock - Long Haul | $ 32.22 | | $ - | | $ - | | $ - |
| | Cutter Suction Dredge | Overburden - Short Pump | $ 3.21 | | $ - | | $ - | | $ - |
| | | Overburden - Long Pump | $ 5.97 | | $ - | | $ - | | $ - |
| | | 2000 PSI Weathered Rock - Short Pump | $ 24.26 | | $ - | | $ - | | $ - |
| | | 2000 PSI Weathered Rock - Long Pump | $ 32.34 | | $ - | | $ - | | $ - |
| | | Blasted Rock - Short Pump | $ 24.17 | | $ - | | $ - | | $ - |
| | | Blasted Rock - Long Pump | $ 40.28 | | $ - | | $ - | | $ - |
| Dry Excavation | ME 5320 Excavator & 150 ton Dump Trucks | Overburden - Short Haul | $ 2.98 | 3,500,000 | $ 10,442,121 | 3,490,000 | $ 10,412,286 | 9,960,000 | $ 29,715,293 |
| | | Overburden - Long Haul | $ 4.16 | | $ - | | $ - | | $ - |
| | | 2000 PSI Weathered Rock - Short Haul | $ 3.79 | 910,000 | $ 3,444,763 | 420,000 | $ 1,589,890 | 230,000 | $ 870,654 |
| | | 2000 PSI Weathered Rock - Long Haul | $ 5.13 | | $ - | | $ - | | $ - |
| | | Blasted Rock - Short Haul | $ 6.19 | 4,980,000 | $ 30,817,264 | 2,630,000 | $ 16,274,981 | 1,330,000 | $ 8,230,313 |
| | | Blasted Rock - Long Haul | $ 7.53 | | $ - | | $ - | | $ - |
| | | Totals | | **12,280,000** | **$ 87,983,310** | **12,140,000** | **$ 139,437,506** | **13,960,000** | **$ 50,666,025** |

# PRODUCTION SUMMARY

## MECHANICAL WET EXCAVATION

| Excavation Type | Round Trip Haul Distance | Production ($M^3$ Dig/WH) | Dig/Pay Ratio | Time Efficiency | Hours/ Day | $M^3$ Pay/Day |
|---|---|---|---|---|---|---|
| Overburden - Short Haul | 0-20 KM | 1,000 | 1.15 | 75% | 24 | 15,652 |
| Overburden - Long Haul | 20-40 KM | 1,000 | 1.15 | 75% | 24 | 15,652 |
| 2000 PSI Weathered Rock - Short Haul | 0-20 KM | 300 | 1.30 | 65% | 24 | 3,600 |
| 2000 PSI Weathered Rock - Long Haul | 20-40 KM | 300 | 1.30 | 65% | 24 | 3,600 |
| Blasted Rock - Short Haul | 0-20 KM | 350 | 1.30 | 65% | 24 | 4,200 |
| Blasted Rock - Long Haul | 20-40 KM | 350 | 1.30 | 65% | 24 | 4,200 |

## HYDRAULIC WET EXCAVATION

| Excavation Type | Pump Distance | Production ($M^3$ Dig/WH) | Dig/Pay Ratio | Time Efficiency | Hours/ Day | $M^3$ Pay/Day |
|---|---|---|---|---|---|---|
| Overburden - Short Pump | 0-2000 m | 3,250 | 1.15 | 70% | 24 | 47,478 |
| Overburden - Long Pump | 2000-4000 m | 1,750 | 1.15 | 70% | 24 | 25,565 |
| 2000 PSI Weathered Rock - Short Pump | 0-2000 m | 600 | 1.25 | 60% | 24 | 6,912 |
| 2000 PSI Weathered Rock - Long Pump | 2000-4000 m | 450 | 1.25 | 60% | 24 | 5,184 |
| Blasted Rock - Short Pump | 0-2000 m | 750 | 1.25 | 60% | 24 | 8,640 |
| Blasted Rock - Long Pump | 2000-4000 m | 450 | 1.25 | 60% | 24 | 5,184 |

## DRY EXCAVATION

| Excavation Type | Round Trip Haul Distance | Production ($M^3$ Dig/WH) | Dig/Pay Ratio | Time Efficiency | Hours/ Day | $M^3$ Pay/Day |
|---|---|---|---|---|---|---|
| Overburden - Short Haul | 0-3.5 KM | 1,200 | 1.00 | 75% | 20 | 18,000 |
| Overburden - Long Haul | 3.5 - 7.0 KM | 1,200 | 1.00 | 75% | 20 | 18,000 |
| 2000 PSI Weathered Rock - Short Haul | 0-3.5 KM | 1,050 | 1.00 | 75% | 20 | 15,750 |
| 2000 PSI Weathered Rock - Long Haul | 3.5 - 7.0 KM | 1,050 | 1.00 | 75% | 20 | 15,750 |
| Blasted Rock - Short Haul | 0-3.5 KM | 1,050 | 1.00 | 75% | 20 | 15,750 |
| Blasted Rock - Long Haul | 3.5 - 7.0 KM | 1,050 | 1.00 | 75% | 20 | 15,750 |

# UNIT COST SUMMARY

## MECHANICAL WET EXCAVATION

| Excavation Type | Daily Production ($M^3$ Pay) | Daily Cost | Unit Cost |
|---|---|---|---|
| Overburden - Short Haul | 15,652 | $ 76,014 | $ 4.86 |
| Overburden - Long Haul | 15,652 | $ 93,942 | $ 6.00 |
| 2000 PSI Weathered Rock - Short Haul | 3,600 | $ 76,014 | $ 21.12 |
| 2000 PSI Weathered Rock - Long Haul | 3,600 | $ 93,942 | $ 26.10 |
| Blasted Rock - Short Haul | 4,200 | $ 117,382 | $ 27.95 |
| Blasted Rock - Long Haul | 4,200 | $ 135,310 | $ 32.22 |

## HYDRAULIC WET EXCAVATION

| Excavation Type | Daily Production ($M^3$ Pay) | Daily Cost | Unit Cost |
|---|---|---|---|
| Overburden - Short Pump | 47,478 | $ 152,574 | $ 3.21 |
| Overburden - Long Pump | 25,565 | $ 152,574 | $ 5.97 |
| 2000 PSI Weathered Rock - Short Pump | 6,912 | $ 167,657 | $ 24.26 |
| 2000 PSI Weathered Rock - Long Pump | 5,184 | $ 167,657 | $ 32.34 |
| Blasted Rock - Short Pump | 8,640 | $ 208,798 | $ 24.17 |
| Blasted Rock - Long Pump | 5,184 | $ 208,798 | $ 40.28 |

## DRY EXCAVATION

| Excavation Type | Daily Production ($M^3$ Pay) | Daily Cost | Unit Cost |
|---|---|---|---|
| Overburden - Short Haul | 18,000 | $ 53,702 | $ 2.98 |
| Overburden - Long Haul | 18,000 | $ 74,814 | $ 4.16 |
| 2000 PSI Weathered Rock - Short Haul | 15,750 | $ 59,621 | $ 3.79 |
| 2000 PSI Weathered Rock - Long Haul | 15,750 | $ 80,732 | $ 5.13 |
| Blasted Rock - Short Haul | 15,750 | $ 97,464 | $ 6.19 |
| Blasted Rock - Long Haul | 15,750 | $ 118,576 | $ 7.53 |

# BASIC FACTORS FOR COST CALCULATION

| Cost Type | Description | Unit | Remarks |
|---|---|---|---|
| Fuel | Fuel Price per US Gallon | $ 1.25 | Off-Highway/Marine Price. |
| Indirect Costs | Interest Rate | 8% | |
| | Site Overhead | 15% | |
| | Home Office | 10% | |
| | Bonds, Taxes and Fees | 8% | |
| | Profit | 15% | |
| Labor Costs | General Superintendent | $ 45.00 | Hourly rate - Expatriate |
| | Shift Foreman | $ 33.00 | Hourly rate - Expatriate |
| | Tug Master | $ 30.00 | Hourly rate - Local |
| | Launch Operator | $ 10.00 | Hourly rate - Local |
| | Equipment Operator 1 | $ 30.00 | Hourly rate - Expatriate |
| | Equipment Operator 2 | $ 15.00 | Hourly rate - Local |
| | Engineer 1 | $ 30.00 | Hourly rate - Expatriate |
| | Engineer 2 | $ 15.00 | Hourly rate - Local |
| | Laborer 1 | $ 10.00 | Hourly rate - Local |
| | Laborer 2 | $ 5.00 | Hourly rate - Local |
| Other Costs | Annual Fixed Maintenance | | Equals the purchase price divided by the useful life in years. |
| | Annual Insurance | 1% | of Purchase Price |
| | Lubricant Cost | 15% | of Fuel Cost |
| | Variable Maintenance | 50% | of Fixed Maintenance |

# DAILY COST FOR DRY EXCAVATION

| | |
|---|---|
| Fuel Price | $ 1.25 |
| Hours per Day | 20 |

ANNUAL COST

| Equipment | CAT 5230 Front Shovel | CAT 789 Off-Road Trucks | CAT D10 Ripper | CAT D9 Bull Dozer | CAT 16 H Grader | CAT 773 Water Truck | Auxillary Equipment | Rock Drills with Compressor | Blasting Truck |
|---|---|---|---|---|---|---|---|---|---|
| Quantity - Short Haul | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 3 | 1 |
| Quantity - Long Haul | 1 | 7 | 1 | 1 | 1 | 1 | 1 | 3 | 1 |
| Purchase Price | $3,210,000 | $1,550,000 | $850,000 | $635,000 | $450,000 | $715,000 | $100,000 | $500,000 | $80,000 |
| Salvage Value | $642,000 | $310,000 | $170,000 | $127,000 | $90,000 | $143,000 | $20,000 | $50,000 | $16,000 |
| Useful life (Years) | 10 | 10 | 5 | 5 | 10 | 10 | 10 | 4 | 10 |
| Revenue Hours per Year | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 |
| Interest Rate | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% |
| Annual Fixed Maintenance | $ 321,000 | $ 155,000 | $ 170,000 | $ 127,000 | $ 45,000 | $ 71,500 | $ 10,000 | $ 125,000 | $ 8,000 |
| Annual Depreciation | $ 382,708 | $ 184,797 | $ 170,310 | $ 127,232 | $ 53,651 | $ 85,245 | $ 11,922 | $ 135,864 | $ 9,538 |
| Annual Insurance | $ 32,100 | $ 15,500 | $ 8,500 | $ 6,350 | $ 4,500 | $ 7,150 | $ 1,000 | $ 5,000 | $ 800 |
| Fuel per Hour (gal) | 50 | 45 | 20 | 15 | 8 | 15 | 5 | 20 | 10 |

HOURLY COST

| Cost Type | CAT 5230 Front Shovel | CAT 789 Off-Road Trucks | CAT D10 Ripper | CAT D9 Bull Dozer | CAT 16 H Grader | CAT 773 Water Truck | Auxillary Equipment | Rock Drills with Compressor | Blasting Truck |
|---|---|---|---|---|---|---|---|---|---|
| Maintenance | $ 107.00 | $ 51.67 | $ 56.67 | $ 42.33 | $ 15.00 | $ 23.83 | $ 3.33 | $ 41.67 | $ 2.67 |
| Ownership | $ 127.57 | $ 61.60 | $ 56.77 | $ 42.41 | $ 17.88 | $ 28.41 | $ 3.97 | $ 45.29 | $ 3.18 |
| Insurance | $ 10.70 | $ 5.17 | $ 2.83 | $ 2.12 | $ 1.50 | $ 2.38 | $ 0.33 | $ 1.67 | $ 0.27 |
| Fuel | $ 62.50 | $ 56.25 | $ 25.00 | $ 18.75 | $ 10.00 | $ 18.75 | $ 6.25 | $ 25.00 | $ 12.50 |
| Lubricants | $ 9.38 | $ 8.44 | $ 3.75 | $ 2.81 | $ 1.50 | $ 2.81 | $ 0.94 | $ 3.75 | $ 1.88 |
| Variable Maint. | $ 53.50 | $ 25.83 | $ 28.33 | $ 21.17 | $ 7.50 | $ 11.92 | $ 1.67 | $ 20.83 | $ 1.33 |
| Labor (see Attachment 8) | $ 30.00 | $ 15.00 | $ 15.00 | $ 15.00 | $ 15.00 | $ 15.00 | $ 80.00 | $ 18.30 | $ 63.00 |
| Powder and Drill Bits | | | | | | | | $ 50.00 | $ 500.00 |
| Hourly Total | $ 400.64 | $ 223.95 | $ 188.35 | $ 144.59 | $ 68.38 | $ 103.11 | $ 96.49 | $ 206.50 | $ 584.82 |
| Daily Rates | $ 8,013 | $ 4,479 | $ 3,767 | $ 2,892 | $ 1,368 | $ 2,062 | $ 1,930 | $ 4,130 | $ 11,696 |
| Daily Total - Short Haul | $ 8,013 | $ 17,916 | $ 3,767 | $ 2,892 | $ 1,368 | $ 2,062 | $ 1,930 | $ 12,390 | $ 11,696 |
| Daily Total - Long Haul | $ 8,013 | $ 31,353 | $ 3,767 | $ 2,892 | $ 1,368 | $ 2,062 | $ 1,930 | $ 12,390 | $ 11,696 |

| | | Short Haul | | | Long Haul | | |
|---|---|---|---|---|---|---|---|
| | | Overburden | Unblasted Rock | Blasted Rock | Overburden | Unblasted Rock | Blasted Rock |
| Total Daily Package | | $ 34,181 | $ 37,948 | $ 62,034 | 47,618 | 51,385 | $ 75,472 |
| Site Overhead | 15% | $ 5,127 | $ 5,692 | $ 9,305 | $ 7,143 | $ 7,708 | $ 11,321 |
| Home Office Overhead | 10% | $ 3,931 | $ 4,364 | $ 7,134 | $ 5,476 | $ 5,909 | $ 8,679 |
| Total including O/H | | $ 43,239 | $ 48,004 | $ 78,474 | $ 60,237 | $ 65,002 | $ 95,472 |
| Bond, Taxes, Fees | 8% | $ 3,459 | $ 3,840 | $ 6,278 | $ 4,819 | $ 5,200 | $ 7,638 |
| Overall Daily Rate | | $ 46,698 | $ 51,844 | $ 84,752 | $ 65,056 | $ 70,202 | $ 103,109 |
| Profit | 15% | $ 7,005 | $ 7,777 | $ 12,713 | $ 9,758 | $ 10,530 | $ 15,466 |
| Total With Profit | | $ 53,702 | $ 59,621 | $ 97,464 | $ 74,814 | $ 80,732 | $ 118,576 |

# DAILY COST FOR MECHANICAL DREDGING

| | |
|---|---|
| Fuel Price | $ 1.25 |
| Hours per Day | 24 |

ANNUAL COST

| Equipment | Marine Equipment | | | | | Blasting Equipment | |
|---|---|---|---|---|---|---|---|
| | 19 m³ Backhoe Dredge | Workboat | 3000 Hp Tug | 4000 m³ Scows | Survey Launch | Drillboat | Workboat |
| Quantity - Short Haul | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| Quantity - Long Haul | 1 | 1 | 2 | 3 | 1 | 1 | 1 |
| Purchase Price | $25,000,000 | $500,000 | $1,250,000 | $1,200,000 | $300,000 | $9,000,000 | $500,000 |
| Salvage Value | $2,500,000 | $50,000 | $125,000 | $120,000 | $30,000 | $900,000 | $50,000 |
| Useful life (Years) | 20 | 10 | 10 | 12 | 20 | 20 | 10 |
| Revenue Hours per Year | 3,500 | 3,000 | 3,500 | 3,000 | 3,000 | 2,500 | 3,000 |
| Interest Rate | 8% | 8% | 8% | 8% | 8% | 8% | 8% |
| Annual Fixed Maintenance | $ 1,250,000 | $ 50,000 | $ 125,000 | $ 100,000 | $ 15,000 | $ 450,000 | $ 50,000 |
| Annual Depreciation | $ 2,291,675 | $ 67,063 | $ 167,658 | $ 143,311 | $ 27,500 | $ 825,003 | $ 67,063 |
| Annual Insurance | $ 250,000 | $ 5,000 | $ 12,500 | $ 12,000 | $ 3,000 | $ 90,000 | $ 5,000 |
| Fuel per Hour (gal) | 100 | 20 | 50 | 0 | 6 | 35 | 20 |

HOURLY COST

| Cost Type | 19 m³ Backhoe Dredge | Workboat | 3000 Hp Tug | 4000 m³ Scows | Survey Launch | Drillboat | Workboat |
|---|---|---|---|---|---|---|---|
| Fixed Maintenance | $ 357.14 | $ 16.67 | $ 35.71 | $ 33.33 | $ 5.00 | $ 180.00 | $ 16.67 |
| Ownership | $ 654.76 | $ 22.35 | $ 47.90 | $ 47.77 | $ 9.17 | $ 330.00 | $ 22.35 |
| Marine Insurance | $ 71.43 | $ 1.67 | $ 3.57 | $ 4.00 | $ 1.00 | $ 36.00 | $ 1.67 |
| Fuel | $ 125.00 | $ 25.00 | $ 62.50 | $ - | $ 7.50 | $ 43.75 | $ 25.00 |
| Lubricants | $ 18.75 | $ 3.75 | $ 9.38 | $ - | $ 1.13 | $ 6.56 | $ 3.75 |
| Variable Maintenance | $ 178.57 | $ 8.33 | $ 17.86 | $ 16.67 | $ 2.50 | $ 90.00 | $ 8.33 |
| Labor (see Attachment 8) | $ 117.50 | $ 25.00 | $ 55.00 | $ 20.00 | $ 10.00 | $ 108.00 | $ 25.00 |
| Powder and Drill Bits | | | | | | $ 200.00 | |
| Hourly Total | $ 1,523.16 | $ 102.77 | $ 231.92 | $ 121.77 | $ 36.29 | $ 994.31 | $ 102.77 |
| Daily Rates | $ 36,556 | $ 2,467 | $ 5,566 | $ 2,922 | $ 871 | $ 23,864 | $ 2,467 |
| Daily Total - Short Haul | $ 36,556 | $ 2,467 | $ 5,566 | $ 2,922 | $ 871 | $ 23,864 | $ 2,467 |
| Daily Total - Long Haul | $ 36,556 | $ 2,467 | $ 11,132 | $ 8,767 | $ 871 | $ 23,864 | $ 2,467 |

| | | Short Haul | | | Long Haul | | |
|---|---|---|---|---|---|---|---|
| | | Overburden | Unblasted Rock | Blasted Rock | Overburden | Unblasted Rock | Blasted Rock |
| Total Daily Package | | $ 48,382 | $ 48,382 | $ 74,712 | 59,793 | 59,793 | $ 86,123 |
| Site Overhead | 15% | $ 7,257 | $ 7,257 | $ 11,207 | $ 8,969 | $ 8,969 | $ 12,918 |
| Home Office Overhead | 10% | $ 5,564 | $ 5,564 | $ 8,592 | $ 6,876 | $ 6,876 | $ 9,904 |
| Total inc. O/H | | $ 61,203 | $ 61,203 | $ 94,511 | $ 75,638 | $ 75,638 | $ 108,946 |
| Bond, Taxes, Fees | 8% | $ 4,896 | $ 4,896 | $ 7,561 | $ 6,051 | $ 6,051 | $ 8,716 |
| Overall Daily Rate | | $ 66,099 | $ 66,099 | $ 102,071 | $ 81,689 | $ 81,689 | $ 117,661 |
| Profit | 15% | $ 9,915 | $ 9,915 | $ 15,311 | $ 12,253 | $ 12,253 | $ 17,649 |
| Total With Profit | | $ 76,014 | $ 76,014 | $ 117,382 | $ 93,942 | $ 93,942 | $ 135,310 |

# DAILY COST FOR HYDRAULIC DREDGING

| | |
|---|---|
| Fuel Price | $ 1.25 |
| Hours per Day | 24 |

ANNUAL COST

| Equipment | Marine Equipment | | | | | | Land Equipment | | Blasting Equipment | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30" Hydraulic Dredge | 1500 Hp Tug | Derrick Barge | Workboat | Anchor Barge | Survey Launch | Dozers (2) | Other | Drillboat | Workboat |
| Purchase Price | **$80,000,000** | **$500,000** | **$1,000,000** | **$500,000** | **$250,000** | **$300,000** | **$1,270,000** | **$300,000** | **$9,000,000** | **$500,000** |
| Salvage Value | **$8,000,000** | **$50,000** | **$100,000** | **$50,000** | **$25,000** | **$30,000** | **$127,000** | **$30,000** | **$900,000** | **$50,000** |
| Useful life (Years) | **30** | **20** | **20** | **10** | **20** | **20** | **5** | **5** | **20** | **10** |
| Revenue Hours per Year | **4,500** | **3,500** | **3,500** | **3,000** | **3,000** | **3,000** | **3,000** | **3,000** | **3,000** | **3,000** |
| Interest rate | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% |
| Annual Fixed Maintenance | $ 2,666,667 | $ 25,000 | $ 50,000 | $ 50,000 | $ 12,500 | $ 15,000 | $ 254,000 | $ 60,000 | $ 450,000 | $ 50,000 |
| Annual Depreciation | $ 6,395,575 | $ 45,833 | $ 91,667 | $ 67,063 | $ 22,917 | $ 27,500 | $ 286,272 | $ 67,623 | $ 825,003 | $ 67,063 |
| Annual Insurance | $ 800,000 | $ 5,000 | $ 10,000 | $ 5,000 | $ 2,500 | $ 3,000 | $ 12,700 | $ 3,000 | $ 90,000 | $ 5,000 |
| Fuel per Hour (gal) | **325** | **25** | **10** | **20** | **5** | **6** | **30** | **10** | **35** | **20** |

HOURLY COST

| Cost Type | Dredge | Tug | Derrick | Workboat | Barge | Launch | Dozers | Other | Drillboat | Workboat |
|---|---|---|---|---|---|---|---|---|---|---|
| Maintenance | $ 592.59 | $ 7.14 | $ 14.29 | $ 16.67 | $ 4.17 | $ 5.00 | $ 84.67 | $ 20.00 | $ 150.00 | $ 16.67 |
| Ownership | $ 1,421.24 | $ 13.10 | $ 26.19 | $ 22.35 | $ 7.64 | $ 9.17 | $ 95.42 | $ 22.54 | $ 275.00 | $ 22.35 |
| Marine Insurance | $ 177.78 | $ 1.43 | $ 2.86 | $ 1.67 | $ 0.83 | $ 1.00 | $ 4.23 | $ 1.00 | $ 30.00 | $ 1.67 |
| Fuel | $ 406.25 | $ 31.25 | $ 12.50 | $ 25.00 | $ 6.25 | $ 7.50 | $ 37.50 | $ 12.50 | $ 43.75 | $ 25.00 |
| Lubricants | $ 60.94 | $ 4.69 | $ 1.88 | $ 3.75 | $ 0.94 | $ 1.13 | $ 5.63 | $ 1.88 | $ 6.56 | $ 3.75 |
| Variable Maint. | $ 296.30 | $ 3.57 | $ 7.14 | $ 8.33 | $ 2.08 | $ 2.50 | $ 42.33 | $ 10.00 | $ 75.00 | $ 8.33 |
| Labor (see Attachment 8) | $ 210.50 | $ 50.00 | $ 63.00 | $ 25.00 | $ 20.00 | $ 10.00 | $ 45.00 | $ 78.00 | $ 108.00 | $ 25.00 |
| Powder and Drill Bits | | | | | | | | | **$ 300.00** | |
| Pipe Wear (Rock Only) | $ 400.00 | | | | | | | | | |
| Hourly Total | $ 3,565.59 | $ 111.18 | $ 127.85 | $ 102.77 | $ 41.91 | $ 36.29 | $ 314.78 | $ 145.92 | $ 988.31 | $ 102.77 |
| Daily Total | $ 85,574 | $ 2,668 | $ 3,068 | $ 2,467 | $ 1,006 | $ 871 | $ 7,555 | $ 3,502 | $ 23,720 | $ 2,467 |

| | | Overburden | Unblasted Rock | Blasted Rock |
|---|---|---|---|---|
| Total Daily Package | | $ 97,111 | $ 106,711 | $ 132,897 |
| Site Overhead | 15% | $ 14,567 | $ 16,007 | $ 19,935 |
| Home Office Overhead | 10% | $ 11,168 | $ 12,272 | $ 15,283 |
| Total inc. O/H | | $ 122,845 | $ 134,989 | $ 168,115 |
| Bond, Taxes, Fees | 8% | $ 9,828 | $ 10,799 | $ 13,449 |
| Overall Daily Rate | | $ 132,673 | $ 145,789 | $ 181,564 |
| Profit | 15% | $ 19,901 | $ 21,868 | $ 27,235 |
| Total With Profit | | $ 152,574 | $ 167,657 | $ 208,798 |

# LABOR COST SUMMARY

### 19 m³ Backhoe Dredge with 4000 m³ Bottom-Dump Scows

| | Hourly Cost | 19 m³ Backhoe Dredge | 3000 Hp Tug | 4000 m³ Scows (2) | Survey Launch | Drillboat | Workboat | 3000 Hp Tug | 4000 m³ Scows |
|---|---|---|---|---|---|---|---|---|---|
| General Superintendent | $ 45.00 | 0.5 | | | | | | | |
| Shift Foreman | $ 33.00 | | | | | 1 | | | |
| Tug Master | $ 30.00 | | 1 | | | | | 1 | |
| Launch Operator | $ 10.00 | | | | 1 | | 1 | | |
| Equipment Operator 1 | $ 30.00 | 1 | | | | | | | |
| Equipment Operator 2 | $ 15.00 | | | | | 1 | | | |
| Engineer 1 | $ 30.00 | 1 | | | | 1 | | | |
| Engineer 2 (Mechanic) | $ 15.00 | 1 | 1 | | | | | 1 | |
| Laborer 1/Welder | $ 10.00 | 1 | 1 | 2 | | 2 | 1 | 1 | 1 |
| Laborer 2 | $ 5.00 | 2 | | | | 2 | 1 | | |
| Total Hourly Labor Cost | | $ 117.50 | $ 55.00 | $ 20.00 | $ 10.00 | $ 108.00 | $ 25.00 | $ 55.00 | $ 10.00 |

### 15,000 kW Cutter Suction Dredge and Auxillary Equipment

| | Hourly Cost | 30" Hydraulic Dredge | 1500 Hp Tug | Derrick Barge | Workboat | Anchor Barge | Survey Launch | Dozers | Other | Drillboat | Workboat |
|---|---|---|---|---|---|---|---|---|---|---|---|
| General Superintendent | $ 45.00 | 0.5 | | | | | | | | | |
| Shift Foreman | $ 33.00 | 1 | | 1 | | | | | 1 | 1 | |
| Tug Master | $ 30.00 | | 1 | | | | | | | | |
| Launch Operator | $ 10.00 | | | | 1 | | 1 | | | | 1 |
| Equipment Operator 1 | $ 30.00 | 1 | | | | | | | | | |
| Equipment Operator 2 | $ 15.00 | | | 1 | | 1 | | 3 | | 1 | |
| Engineer 1 | $ 30.00 | 1 | | | | | | | | 1 | |
| Engineer 2 (Mechanic) | $ 15.00 | 2 | 1 | | | | | | 1 | | |
| Laborer 1/Welder | $ 10.00 | 5 | | 1 | 1 | | | | 2 | 2 | 1 |
| Laborer 2 | $ 5.00 | 3 | 1 | 1 | 1 | 1 | | | 2 | 2 | 1 |
| Total Hourly Labor Cost | | $ 210.50 | $ 50.00 | $ 63.00 | $ 25.00 | $ 20.00 | $ 10.00 | $ 45.00 | $ 78.00 | $ 108.00 | $ 25.00 |

# LABOR COST SUMMARY

**22 $m^3$ Front Shovel with 200 Ton Off-Road Dump Trucks**

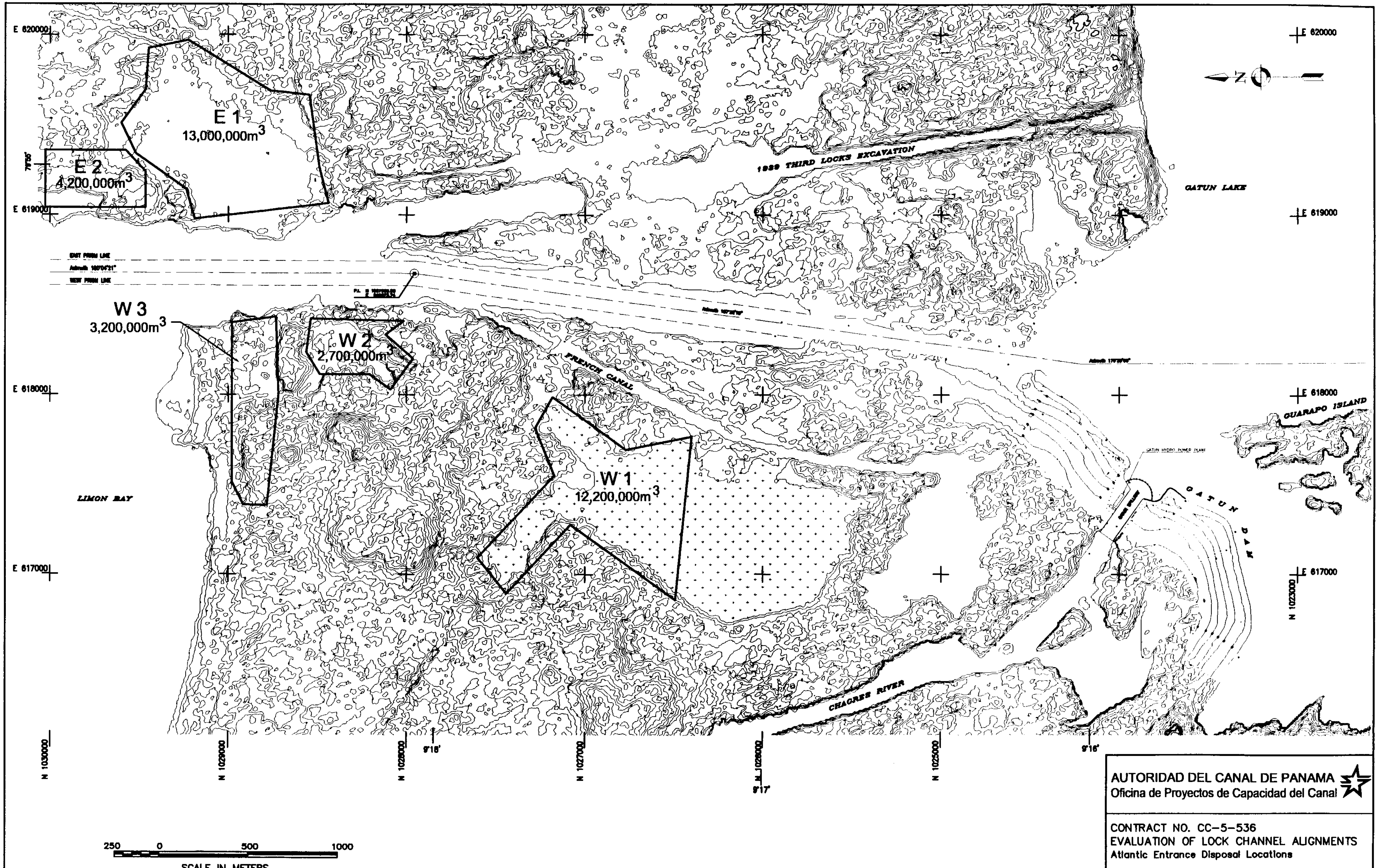
| | Hourly Cost | CAT 5230 Front Shovel | CAT 789 Off-Road Trucks | CAT D10 Ripper | CAT D9 Bull Dozer | CAT 16 H Grader | CAT 773 Water Truck | Auxillary Equipment | Quarry Rock Drill | Blasting Truck |
|---|---|---|---|---|---|---|---|---|---|---|
| General Superintendent | $ 45.00 | | | | | | | | | |
| Shift Foreman | $ 33.00 | | | | | | | | | 1 |
| Tug Master | $ 30.00 | | | | | | | | | |
| Launch Operator | $ 10.00 | | | | | | | | | |
| Equipment Operator 1 | $ 30.00 | 1 | | | | | | | | |
| Equipment Operator 2 | $ 15.00 | | 1 | 1 | 1 | 1 | 1 | | 1 | |
| Engineer 1 | $ 30.00 | | | | | | | 1 | | |
| Engineer 2 (Mechanic) | $ 15.00 | | | | | | | 2 | | |
| Laborer 1/Welder | $ 10.00 | | | | | | | 1 | 0.33 | 2 |
| Laborer 2 | $ 5.00 | | | | | | | 2 | | 2 |
| Total Hourly Labor Cost | | $ 30.00 | $ 15.00 | $ 15.00 | $ 15.00 | $ 15.00 | $ 15.00 | $ 80.00 | $ 18.30 | $ 63.00 |

# SHEETPILE CELL BARRIER DAM PRELIMINARY COST ESTIMATE

Calculated: JMH
Checked: JR

| Item No. | Description | Panama Barrier Dam | | | | Notes |
|---|---|---|---|---|---|---|
| | | QTY | Unit | Unit Cost | Total | |
| 1 | Mobilization/Demobilization of Marine Equipment | 1 | LS | $ 5,000,000.00 | $5,000,000 | Mobilize heavy-duty equipment from Europe or the US. |
| 2 | Purchase Sheetpile | 31,000 | Ton | $ 800.00 | $24,800,000 | Based on $.40 per pound. |
| 3 | Ship Sheetpile to Site | 31,000 | Ton | $ 200.00 | $6,200,000 | |
| 4 | Strip Overburden | 1,120,000 | CM | $ 6.00 | $6,720,000 | Excavate with dragline dredge and dump for later removal in the dry. |
| 5 | Set Sheetpile | 31,000 | Ton | $ 160.00 | $4,960,000 | |
| 6 | Fondation Preparation | 21,000 | SM | $ 50.00 | $1,050,000 | Hydraulic suction of loose overburden. |
| 7 | Tremie Concrete | 275,000 | CM | $ 160.00 | $44,000,000 | Below elevation +16.4. |
| 8 | Normal Concrete | 335,000 | CM | $ 120.00 | $40,200,000 | Above elevation +16.4. |
| 9 | Foundation Treatment | 55,000 | VLM | $ 65.00 | $3,575,000 | To prevent seepage during dry excavation of Alignment P2. |
| 10 | Rip Rap Protection | 6,400,000 | Ton | $ 6.00 | $38,400,000 | Dumped from trucks and rehandled by crane or placed by conveyor. |
| 11 | Miscellaneous (5%) | 1 | LS | $8,745,250 | $8,745,250 | Lights, mooring facilities, etc. |
| 12 | | | | | | |
| 13 | | | | | | |
| | | | | | $178,650,250 | |

| | | | |
|---|---|---|---|
| Total Direct Expense | | $ | 178,650,250 |
| Site Overhead | 15% | $ | 26,797,538 |
| Home Office Overhead | 10% | $ | 20,544,779 |
| Total inc. Overhead | | $ | 225,992,566 |
| Bond, Taxes, Fees | 8% | $ | 18,079,405 |
| Total Direct + Indirect | | $ | 244,071,972 |
| Profit | 15% | $ | 36,610,796 |
| Total With Profit | 57% | $ | 280,682,767 |



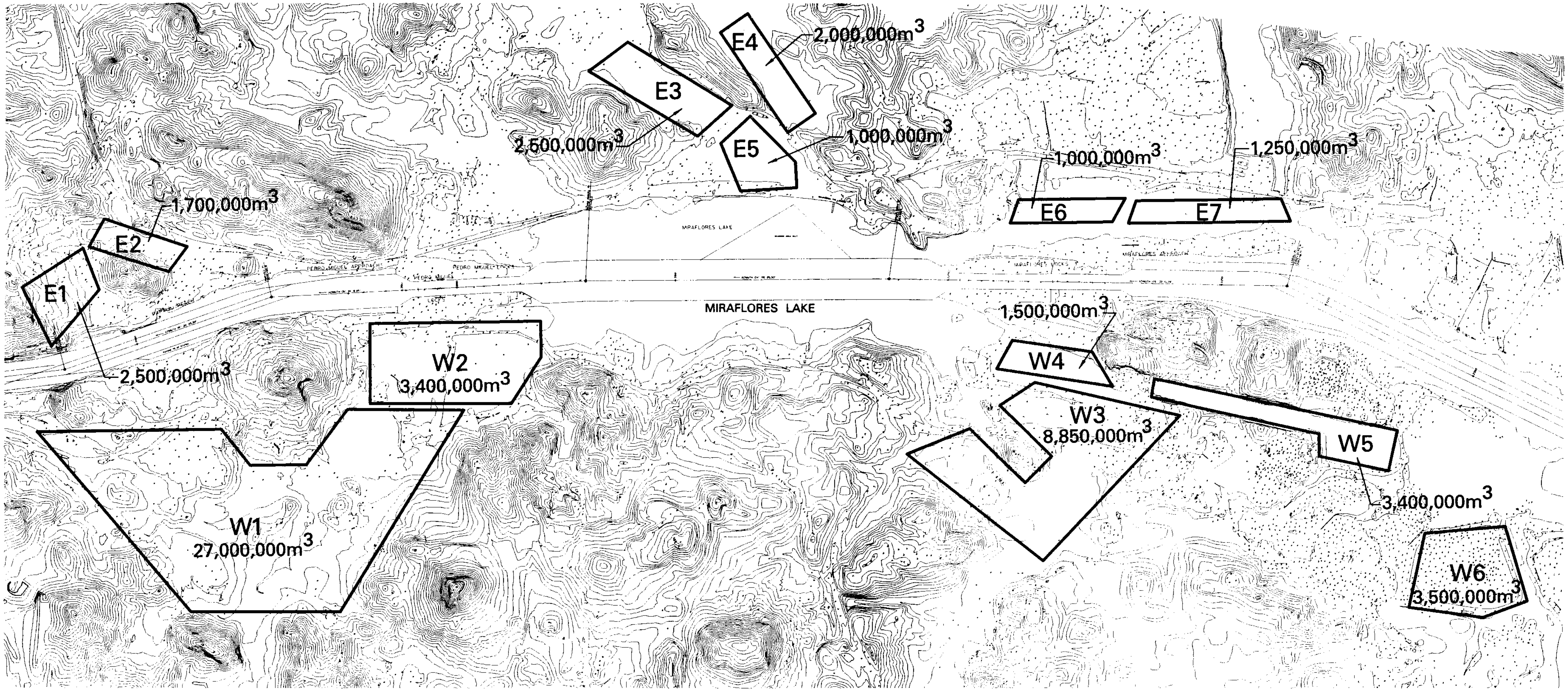

**AUTORIDAD DEL CANAL DE PANAMA**
Oficina de Proyectos de Capacidad del Canal

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Atlantic Entrance Disposal Locations

| HARZA TAMS | August 2000 | Attachment A-3 |
|---|---|---|

# SHORT HAUL/PUMP CAPACITIES FOR ATLANTIC ENTRANCE ALIGNMENTS

| | | Alignment A1 | | Alignment A2 | | Alignment A3 | |
|---|---|---|---|---|---|---|---|
| Disposal Area | Capacity | Qty | Capacity | Qty | Capacity | Qty | Capacity |
| E1 | 13,000,000 | 100% | 13,000,000 | 70% | 9,100,000 | | - |
| E2 | 4,200,000 | 100% | 4,200,000 | 100% | 4,200,000 | | - |
| W1 | 12,200,000 | | - | | - | 100% | 12,200,000 |
| W2 | 2,700,000 | | - | | - | 100% | 2,700,000 |
| W3 | 3,200,000 | | - | 100% | 3,200,000 | 100% | 3,200,000 |
| Gatun Lake | - | | - | | - | | - |
| Atlantic Entrance | - | | - | | - | | - |
| Total | 35,300,000 | | 17,200,000 | | 16,500,000 | | 18,100,000 |




AUTORIDAD DEL CANAL DE PANAMA
**Oficina de Proyectos de Capacidad del Canal**

CONTRACT NO. CC-5-536
EVALUATION OF LOCK CHANNEL ALIGNMENTS
Preliminary Cost Estimate
Pacific Entrance Disposal Locations

| HARZA TAMS | August 2000 | Attachment A-5 |
|---|---|---|

# SHORT HAUL/PUMP CAPACITIES FOR PACIFIC ENTRANCE ALIGNMENTS

| | | Alignment P1 | | Alignment P2 | | Alignment P3 | | Alignment P4 | | Alignment P5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Disposal Area | Capacity | Qty. | Capacity | Qty. | Capacity | Qty. | Capacity | Qty. | Capacity | Qty. | Capacity |
| E1 | 2,500,000 | | - | | - | 100% | 2,500,000 | | - | | - |
| E2 | 1,700,000 | | - | | - | 100% | 1,700,000 | | - | | - |
| E3 | 2,500,000 | | - | | - | 100% | 2,500,000 | | - | | - |
| E4 | 2,000,000 | | - | | - | 100% | 2,000,000 | | - | | - |
| E5 | 1,000,000 | | - | | - | 100% | 1,000,000 | | - | | - |
| E6 | 1,000,000 | | - | | - | 100% | 1,000,000 | | - | | - |
| E7 | 1,250,000 | | - | | - | 100% | 1,250,000 | | - | | - |
| W1 | 27,000,000 | 100% | 27,000,000 | 80% | 21,600,000 | | - | 85% | 22,950,000 | 85% | 22,950,000 |
| W2 | 3,400,000 | 50% | 1,700,000 | 20% | 680,000 | 50% | 1,700,000 | | - | | - |
| W3 | 8,850,000 | 70% | 6,195,000 | 100% | 8,850,000 | | - | 100% | 8,850,000 | 100% | 8,850,000 |
| W4 | 1,500,000 | 100% | 1,500,000 | | - | 25% | 375,000 | 25% | 375,000 | | - |
| W5 | 3,400,000 | 25% | 850,000 | | - | 50% | 1,700,000 | 100% | 3,400,000 | | - |
| W6 | 3,500,000 | 100% | 3,500,000 | 100% | 3,500,000 | | - | 100% | 3,500,000 | 100% | 3,500,000 |
| Gatun Lake | - | | - | | - | | - | | - | | - |
| Pacific Entrance | - | | - | | - | | - | | - | | - |
| Total | 59,600,000 | | 40,745,000 | | 34,630,000 | | 15,725,000 | | 39,075,000 | | 35,300,000 |

# THE PANAMA CANAL
# EVALUATION OF LOCK CHANNEL ALIGNMENTS
# PART 3 - FINAL EVALUATION AND OPTIMIZATION

# APPENDIX B

# SUMMARY OF EXCAVATION QUANTITIES

# THE PANAMA CANAL
# EVALUATION OF LOCK CHANNEL ALIGNMENTS
# PART 3 - FINAL EVALUATION AND OPTIMIZATION

## APPENDIX B
## SUMMARY OF EXCAVATION QUANTITIES

## TABLES

# Table B - 1

## Summary of Excavation Quantities

## Alignment A1 - Channel Bottom 184m Wide at El. 9.9

Computed: JLM
Checked : JPM

| Station Number | Total Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 0+000 | 2,079 | - | | - |
| 0+150 | 2,371 | 333,750 | Wet | 333,750 |
| 0+300 | 2,539 | 368,250 | Wet | 702,000 |
| 0+450 | 2,824 | 402,225 | Wet | 1,104,225 |
| 0+600 | 2,097 | 369,075 | Wet | 1,473,300 |
| 0+750 | 1,695 | 284,400 | Wet | 1,757,700 |
| 0+900 | 1,776 | 260,325 | Wet | 2,018,025 |
| 1+050 | 1,864 | 273,000 | Wet | 2,291,025 |
| 1+200 | 1,838 | 277,650 | Wet | 2,568,675 |
| 1+350 | 1,929 | 282,525 | Dry | 2,851,200 |
| 1+500 | 1,510 | 257,925 | Dry | 3,109,125 |
| 1+650 | 2,298 | 285,600 | Dry | 3,394,725 |
| 1+800 | 1,560 | 289,350 | Dry | 3,684,075 |
| 1+950 | 2,089 | 273,675 | Dry | 3,957,750 |
| 2+100 | 2,621 | 353,250 | Dry | 4,311,000 |
| 2+250 | 4,693 | 548,550 | Dry | 4,859,550 |
| 2+326 | 4,823 | 361,608 | Dry | 5,221,158 |
| 2+476 | 3,222 | 603,375 | Dry | 5,824,533 |
| 2+626 | 2,417 | 422,925 | Dry | 6,247,458 |
| 2+776 | 419 | 212,700 | Dry | 6,460,158 |
| 2+926 | 405 | 61,800 | Dry | 6,521,958 |
| 3+076 | 607 | 75,900 | Dry | 6,597,858 |
| 3+226 | 808 | 106,125 | Dry | 6,703,983 |
| 3+376 | 1,946 | 206,550 | Dry | 6,910,533 |
| 3+526 | 2,394 | 325,500 | Dry | 7,236,033 |
| 3+676 | 1,157 | 266,325 | Dry | 7,502,358 |
| 3+826 | 1,801 | 221,850 | Dry | 7,724,208 |
| 3+976 | 2,921 | 354,150 | Dry | 8,078,358 |
| 4+126 | 2,023 | 370,800 | Dry | 8,449,158 |
| 4+276 | 2,355 | 328,350 | Dry | 8,777,508 |
| 4+426 | 3,010 | 402,375 | Dry | 9,179,883 |
| 4+576 | 508 | 263,850 | Dry | 9,443,733 |
| 4+726 | 813 | 99,075 | Dry | 9,542,808 |
| 4+876 | 1,729 | 190,650 | Dry | 9,733,458 |
| 5+026 | 5,206 | 520,125 | Dry | 10,253,583 |
| 5+176 | 6,776 | 898,650 | Dry | 11,152,233 |
| 5+326 | 5,393 | 912,675 | Dry | 12,064,908 |
| 5+400 | 400 | 214,341 | Wet | 12,279,249 |

| | |
|---|---|
| **Wet Excavation** | **2,783,016** |
| **Dry Excavation** | **9,496,233** |
| **Total** | **12,279,249** |

# Table B - 2

## Summary of Excavation Quantities

## Alignment A2 - Channel Bottom 184m Wide at El. 9.9

Computed: JLM
Checked : JPM

| Station Number | Total Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| 0+300 | 465 | | | |
| 0+450 | 913 | 103,350 | Wet | 103,350 |
| 0+600 | 2,158 | 230,325 | Wet | 333,675 |
| 0+750 | 2,952 | 383,250 | Wet | 716,925 |
| 0+900 | 3,228 | 463,500 | Wet | 1,180,425 |
| 1+050 | 3,956 | 538,800 | Wet | 1,719,225 |
| 1+200 | 3,775 | 579,825 | Wet/Dry | 2,299,050 |
| 1+350 | 4,589 | 627,300 | Wet/Dry | 2,926,350 |
| 1+500 | 4,248 | 662,775 | Wet/Dry | 3,589,125 |
| 1+650 | 3,752 | 600,000 | Wet/Dry | 4,189,125 |
| 1+800 | 3,591 | 550,725 | Wet/Dry | 4,739,850 |
| 1+950 | 3,609 | 540,000 | Wet/Dry | 5,279,850 |
| 2+100 | 3,662 | 545,325 | Wet/Dry | 5,825,175 |
| 2+250 | 3,802 | 559,800 | Wet/Dry | 6,384,975 |
| 2+400 | 3,579 | 553,575 | Wet/Dry | 6,938,550 |
| 2+550 | 1,921 | 412,500 | Wet/Dry | 7,351,050 |
| 2+700 | 2,200 | 309,075 | Wet/Dry | 7,660,125 |
| 2+850 | 1,680 | 291,000 | Wet/Dry | 7,951,125 |
| 3+000 | 2,514 | 314,550 | Wet/Dry | 8,265,675 |
| 3+150 | 2,747 | 394,575 | Dry | 8,660,250 |
| 3+300 | 2,837 | 418,800 | Dry | 9,079,050 |
| 3+450 | 1,998 | 362,625 | Dry | 9,441,675 |
| 3+600 | 2,231 | 317,175 | Dry | 9,758,850 |
| 3+750 | 2,759 | 374,250 | Dry | 10,133,100 |
| 3+900 | 3,005 | 432,300 | Dry | 10,565,400 |
| 4+050 | 4,505 | 563,250 | Dry | 11,128,650 |
| 4+200 | 4,097 | 645,150 | Dry | 11,773,800 |
| 4+350 | 290 | 329,025 | Wet/Dry | 12,102,825 |
| 4+500 | 101 | 29,325 | Wet/Dry | 12,132,150 |
| 4+750 | - | 12,625 | Wet/Dry | 12,144,775 |
| | **Wet Excavation** | **5,603,475** | | |
| | **Dry Excavation** | **6,541,300** | | |
| | **Total** | **12,144,775** | | |

# Table B - 3

## Summary of Excavation Quantities

### Alignment A3 - Channel Bottom 184m Wide at El. 9.9

Computed: JLM
Checked : JPM

| Station Number | Total Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 0+000 | 626 | - | | - |
| 0+150 | 626 | 93,900 | Wet | 93,900 |
| 0+300 | 625 | 93,825 | Wet | 187,725 |
| 0+450 | 625 | 93,750 | Wet | 281,475 |
| 0+600 | 947 | 117,900 | Wet | 399,375 |
| 0+750 | 705 | 123,900 | Wet | 523,275 |
| 0+900 | 863 | 117,600 | Wet | 640,875 |
| 1+050 | 1,506 | 177,675 | Wet | 818,550 |
| 1+200 | 2,322 | 287,100 | Wet | 1,105,650 |
| 1+350 | 3,026 | 401,100 | Wet | 1,506,750 |
| 1+500 | 3,785 | 510,825 | Wet | 2,017,575 |
| 1+600 | 4,602 | 419,350 | Wet | 2,436,925 |
| 1+750 | 4,923 | 714,375 | Dry | 3,151,300 |
| 1+900 | 4,567 | 711,750 | Dry | 3,863,050 |
| 2+050 | 4,562 | 684,675 | Dry | 4,547,725 |
| 2+200 | 4,057 | 646,425 | Dry | 5,194,150 |
| 2+350 | 3,964 | 601,575 | Dry | 5,795,725 |
| 2+500 | 4,087 | 603,825 | Dry | 6,399,550 |
| 2+650 | 4,583 | 650,250 | Dry | 7,049,800 |
| 2+800 | 4,987 | 717,750 | Dry | 7,767,550 |
| 2+950 | 3,664 | 648,825 | Dry | 8,416,375 |
| 3+100 | 3,349 | 525,975 | Dry | 8,942,350 |
| 3+250 | 2,642 | 449,325 | Dry | 9,391,675 |
| 3+400 | 2,910 | 416,400 | Dry | 9,808,075 |
| 3+550 | 3,349 | 469,425 | Dry | 10,277,500 |
| 3+700 | 3,576 | 519,375 | Dry | 10,796,875 |
| 3+850 | 2,813 | 479,175 | Dry | 11,276,050 |
| 4+000 | 3,382 | 464,625 | Dry | 11,740,675 |
| 4+150 | 2,110 | 411,900 | Dry | 12,152,575 |
| 4+300 | 2,681 | 359,325 | Dry | 12,511,900 |
| 4+450 | 2,957 | 422,850 | Dry | 12,934,750 |
| 4+600 | 3,247 | 465,300 | Dry | 13,400,050 |
| 4+750 | 1,346 | 344,475 | Dry | 13,744,525 |
| 4+900 | 794 | 160,500 | Dry | 13,905,025 |
| 5+050 | - | 59,550 | Wet | 13,964,575 |

| | |
|---|---|
| **Wet Excavation** | **2,496,475** |
| **Dry Excavation** | **11,468,100** |
| **Total** | **13,964,575** |

# Table B - 4

## Summary of Excavation Quantities

### Alignment P1 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 1+000 | 629 | - | Wet | - |
| 1+100 | 1010 | 81,954 | Wet/Dry | 81,954 |
| 1+200 | 3862 | 243,620 | Wet/Dry | 325,574 |
| 1+300 | 3193 | 352,764 | Wet/Dry | 678,338 |
| 1+400 | 3727 | 346,009 | Wet/Dry | 1,024,347 |
| 1+500 | 4676 | 420,139 | Dry | 1,444,485 |
| 1+600 | 5104 | 489,007 | Dry | 1,933,492 |
| 1+700 | 5235 | 516,958 | Dry | 2,450,450 |
| 1+800 | 5624 | 542,931 | Dry | 2,993,381 |
| 1+900 | 6841 | 623,237 | Dry | 3,616,618 |
| 2+000 | 9733 | 828,677 | Dry | 4,445,295 |
| 2+100 | 16203 | 1,296,765 | Dry | 5,742,060 |
| 2+200 | 21081 | 1,864,177 | Dry | 7,606,237 |
| 2+300 | 25402 | 2,324,161 | Dry | 9,930,397 |
| 2+400 | 32566 | 2,898,424 | Dry | 12,828,821 |
| 2+500 | 25657 | 2,911,134 | Dry | 15,739,955 |
| 2+600 | 16143 | 2,089,965 | Dry | 17,829,920 |
| 2+700 | 8307 | 1,222,500 | Dry | 19,052,420 |
| 2+800 | 5186 | 674,643 | Dry | 19,727,063 |
| 2+900 | 3500 | 434,254 | Dry | 20,161,316 |
| 3+000 | 2826 | 316,285 | Dry | 20,477,601 |
| 3+100 | 2914 | 287,032 | Dry | 20,764,632 |
| 3+200 | 3004 | 295,914 | Dry | 21,060,546 |
| 3+300 | 3001 | 300,246 | Dry | 21,360,792 |
| 3+400 | 2920 | 296,040 | Dry | 21,656,831 |
| 3+500 | 2375 | 264,757 | Dry | 21,921,588 |
| 3+600 | 2086 | 223,054 | Dry | 22,144,642 |
| 3+700 | 2897 | 249,130 | Dry | 22,393,771 |
| 3+800 | 4113 | 350,488 | Dry | 22,744,259 |
| 3+900 | 8055 | 608,391 | Dry | 23,352,649 |
| 4+000 | 11857 | 995,607 | Dry | 24,348,256 |
| 4+100 | 18908 | 1,538,242 | Dry | 25,886,498 |
| 4+200 | 18141 | 1,852,429 | Dry | 27,738,927 |
| 4+300 | 13838 | 1,598,933 | Dry | 29,337,860 |
| 4+400 | 9197 | 1,151,731 | Dry | 30,489,591 |
| 4+500 | 11296 | 1,024,648 | Dry | 31,514,239 |
| 4+600 | 12874 | 1,208,522 | Dry | 32,722,760 |
| 4+700 | 14427 | 1,365,078 | Dry | 34,087,838 |

# Table B - 4

## Summary of Excavation Quantities

### Alignment P1 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 4+800 | 13336 | 1,388,168 | Dry | 35,476,005 |
| 4+900 | 15861 | 1,459,830 | Dry | 36,935,835 |
| 5+000 | 13644 | 1,475,242 | Dry | 38,411,077 |
| 5+100 | 17411 | 1,552,787 | Dry | 39,963,864 |
| 5+200 | 17455 | 1,743,323 | Dry | 41,707,187 |
| 5+300 | 16631 | 1,704,307 | Dry | 43,411,494 |
| 5+400 | 15485 | 1,605,824 | Dry | 45,017,317 |
| 5+500 | 14195 | 1,484,006 | Dry | 46,501,323 |
| 5+600 | 12032 | 1,311,319 | Dry | 47,812,642 |
| 5+700 | 9737 | 1,088,446 | Dry | 48,901,088 |
| 5+800 | 6900 | 831,857 | Dry | 49,732,944 |
| 5+900 | 5720 | 630,985 | Dry | 50,363,929 |
| 6+000 | 3972 | 484,602 | Dry | 50,848,531 |
| 6+100 | 3523 | 374,760 | Dry | 51,223,290 |
| 6+200 | 3451 | 348,703 | Dry | 51,571,993 |
| 6+300 | 3039 | 324,479 | Dry | 51,896,472 |
| 6+400 | 3533 | 328,594 | Dry | 52,225,066 |
| 6+500 | 5814 | 467,357 | Dry | 52,692,423 |
| 6+600 | 3420 | 461,689 | Dry | 53,154,111 |
| 6+700 | 1938 | 267,919 | Dry | 53,422,030 |
| 6+800 | 2589 | 226,366 | Dry | 53,648,395 |
| 6+900 | 2567 | 257,782 | Dry | 53,906,177 |
| 7+000 | 2637 | 260,192 | Dry | 54,166,369 |
| 7+100 | 2565 | 260,122 | Dry | 54,426,491 |
| 7+200 | 2635 | 260,004 | Dry | 54,686,495 |
| 7+300 | 3939 | 328,696 | Dry | 55,015,190 |
| 7+400 | 4561 | 425,031 | Dry | 55,440,221 |
| 7+500 | 4416 | 448,864 | Dry | 55,889,085 |
| 7+600 | 6369 | 539,253 | Dry | 56,428,337 |
| 7+700 | 5919 | 614,404 | Dry | 57,042,741 |
| 7+800 | 5766 | 584,261 | Dry | 57,627,002 |
| 7+900 | 6222 | 599,404 | Dry | 58,226,405 |
| 8+000 | 5692 | 595,662 | Dry | 58,822,067 |
| 8+100 | 6925 | 630,834 | Dry | 59,452,901 |
| 8+200 | 5591 | 625,800 | Dry | 60,078,701 |
| 8+300 | 4719 | 515,513 | Dry | 60,594,213 |
| 8+400 | 4939 | 482,904 | Dry | 61,077,117 |
| 8+500 | 4283 | 461,093 | Dry | 61,538,210 |
| 8+600 | 4723 | 450,309 | Dry | 61,988,519 |
| 8+700 | 5472 | 509,762 | Dry | 62,498,281 |

# Table B - 4

## Summary of Excavation Quantities

## Alignment P1 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 8+800 | 5078 | 527,504 | Wet | 63,025,785 |
| 8+900 | 7101 | 608,959 | Wet | 63,634,744 |
| 9+000 | 6939 | 702,038 | Wet | 64,336,781 |
| 9+100 | 6492 | 671,554 | Wet | 65,008,335 |
| 9+200 | 5409 | 595,013 | Wet | 65,603,347 |
| 9+300 | 4717 | 506,263 | Wet | 66,109,610 |
| 9+400 | 4844 | 478,021 | Wet | 66,587,631 |
| 9+500 | 5419 | 513,156 | Wet | 67,100,786 |
| 9+600 | 4768 | 509,370 | Wet | 67,610,156 |
| 9+700 | 4478 | 462,306 | Wet | 68,072,462 |
| 9+800 | 3791 | 413,456 | Wet | 68,485,917 |
| 9+900 | 2792 | 329,162 | Wet | 68,815,079 |
| 10+000 | 2347 | 256,961 | Wet | 69,072,040 |
| 10+100 | 1976 | 216,161 | Wet | 69,288,201 |
| 10+200 | 1673 | 182,469 | Wet | 69,470,670 |
| 10+264 | 1499 | 101,497 | Wet | 69,572,166 |

| | |
|---|---|
| **Wet Excavation** | **7,293,103** |
| **Dry Excavation** | **62,279,064** |
| **Total** | **69,572,166** |

# Table B - 5

## Summary of Excavation Quantities

### Alignment P2 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 1+000 | 605 | - | Wet | - |
| 1+100 | 731 | 66,809 | Wet/Dry | 66,809 |
| 1+200 | 1319 | 102,490 | Wet/Dry | 169,298 |
| 1+300 | 2398 | 185,827 | Wet/Dry | 355,125 |
| 1+400* | 4604 | 260,097 | Dry | 615,222 |
| 1+500* | 10960 | 598,233 | Dry | 1,213,455 |
| 1+600* | 16922 | 1,034,141 | Dry | 2,247,596 |
| 1+700* | 22337 | 1,512,985 | Dry | 3,760,580 |
| 1+800* | 28986 | 2,026,142 | Dry | 5,786,722 |
| 1+900* | 22331 | 2,205,853 | Dry | 7,992,574 |
| 2+000* | 13644 | 1,618,785 | Dry | 9,611,359 |
| 2+100* | 6974 | 940,889 | Dry | 10,552,248 |
| 2+200 | 3309 | 514,138 | Dry | 11,066,386 |
| 2+300 | 3108 | 320,869 | Dry | 11,387,254 |
| 2+400 | 2923 | 301,540 | Dry | 11,688,794 |
| 2+500 | 2941 | 293,201 | Dry | 11,981,995 |
| 2+600 | 2699 | 282,018 | Dry | 12,264,013 |
| 2+700 | 2252 | 247,529 | Dry | 12,511,542 |
| 2+800 | 2028 | 214,003 | Dry | 12,725,545 |
| 2+900 | 1929 | 197,860 | Dry | 12,923,404 |
| 3+000 | 1880 | 190,435 | Dry | 13,113,839 |
| 3+100 | 1971 | 192,571 | Dry | 13,306,409 |
| 3+200 | 2489 | 223,010 | Dry | 13,529,419 |
| 3+300 | 3611 | 304,970 | Dry | 13,834,389 |
| 3+400 | 3032 | 332,134 | Dry | 14,166,523 |
| 3+500 | 2779 | 290,564 | Dry | 14,457,087 |
| 3+600 | 2932 | 285,573 | Dry | 14,742,659 |
| 3+700 | 2421 | 267,674 | Dry | 15,010,333 |
| 3+800 | 2071 | 224,626 | Dry | 15,234,959 |
| 3+900 | 2159 | 211,491 | Dry | 15,446,449 |
| 4+000 | 1589 | 187,382 | Dry | 15,633,831 |
| 4+100 | 2516 | 205,261 | Dry | 15,839,092 |
| 4+200 | 3522 | 301,923 | Dry | 16,141,015 |
| 4+300 | 3386 | 345,409 | Dry | 16,486,424 |
| 4+400 | 2911 | 314,820 | Dry | 16,801,243 |
| 4+500 | 3987 | 344,855 | Dry | 17,146,098 |
| 4+600 | 3220 | 360,344 | Dry | 17,506,442 |
| 4+700 | 3108 | 316,432 | Dry | 17,822,874 |

* Modified volume to reflect Gaillard Cut Widening Program

# Table B - 5

## Summary of Excavation Quantities

### Alignment P2 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area (m$^2$) | Station Volume (m$^3$) | Excavation Type | Cumulative Volume (m$^3$) |
|---|---|---|---|---|
| 4+800 | 3250 | 317,901 | Dry | 18,140,775 |
| 4+900 | 3292 | 327,077 | Dry | 18,467,852 |
| 5+000 | 2923 | 310,763 | Dry | 18,778,615 |
| 5+100 | 978 | 195,063 | Dry | 18,973,677 |
| 5+192 | 594 | 72,284 | Dry | 19,045,961 |
| 5+200 | 578 | 4,686 | Dry | 19,050,646 |
| 5+300 | 727 | 65,264 | Dry | 19,115,910 |
| 5+400 | 486 | 60,648 | Dry | 19,176,558 |
| 5+500 | 559 | 52,213 | Dry | 19,228,771 |
| 5+600 | 3075 | 181,681 | Dry | 19,410,452 |
| 5+700 | 2788 | 293,159 | Dry | 19,703,610 |
| 5+800 | 1891 | 233,980 | Dry | 19,937,590 |
| 5+900 | 1788 | 183,978 | Dry | 20,121,568 |
| 6+000 | 894 | 134,091 | Dry | 20,255,658 |
| 6+100 | 2486 | 169,004 | Dry | 20,424,662 |
| 6+200 | 2595 | 254,072 | Dry | 20,678,734 |
| 6+300 | 2587 | 259,087 | Dry | 20,937,821 |
| 6+400 | 2660 | 262,337 | Dry | 21,200,158 |
| 6+500 | 4030 | 334,522 | Dry | 21,534,680 |
| 6+600 | 4021 | 402,557 | Dry | 21,937,236 |
| 6+700 | 1693 | 285,701 | Dry | 22,222,937 |
| 6+800 | 1269 | 148,122 | Dry | 22,371,059 |
| 6+900 | 0 | 63,453 | Dry | 22,434,511 |
| 7+000 | 2191 | 109,564 | Dry | 22,544,075 |
| 7+100 | 2252 | 222,164 | Dry | 22,766,238 |
| 7+200 | 2485 | 236,845 | Dry | 23,003,083 |
| 7+300 | 3963 | 322,395 | Dry | 23,325,478 |
| 7+400 | 5885 | 492,391 | Dry | 23,817,869 |
| 7+500 | 4708 | 529,621 | Dry | 24,347,490 |
| 7+600 | 4753 | 473,051 | Dry | 24,820,541 |
| 7+700 | 3764 | 425,876 | Dry | 25,246,416 |
| 7+800 | 3449 | 360,646 | Dry | 25,607,062 |
| 7+900 | 3194 | 332,147 | Dry | 25,939,209 |
| 8+000 | 2491 | 284,247 | Dry | 26,223,455 |
| 8+100 | 5044 | 376,760 | Dry | 26,600,215 |
| 8+200 | 2132 | 358,812 | Dry | 26,959,027 |
| 8+300 | 6114 | 412,274 | Wet | 27,371,301 |
| 8+400 | 6210 | 616,160 | Wet | 27,987,461 |
| 8+500 | 6705 | 645,707 | Wet | 28,633,167 |
| 8+600 | 6207 | 645,601 | Wet | 29,278,768 |

# Table B - 5

## Summary of Excavation Quantities

### Alignment P2 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 8+700 | 5395 | 580,139 | Wet | 29,858,907 |
| 8+800 | 5068 | 523,164 | Wet | 30,382,070 |
| 8+900 | 4751 | 490,924 | Wet | 30,872,994 |
| 9+000 | 5808 | 527,914 | Wet | 31,400,908 |
| 9+100 | 5674 | 574,081 | Wet | 31,974,989 |
| 9+200 | 5481 | 557,724 | Wet | 32,532,712 |
| 9+300 | 5065 | 527,302 | Wet | 33,060,014 |
| 9+400 | 4969 | 501,738 | Wet | 33,561,752 |
| 9+500 | 4610 | 478,991 | Wet | 34,040,742 |
| 9+600 | 4249 | 442,981 | Wet | 34,483,723 |
| 9+700 | 3634 | 394,174 | Wet | 34,877,896 |
| 9+800 | 3232 | 343,313 | Wet | 35,221,209 |
| 9+900 | 3079 | 315,527 | Wet | 35,536,736 |
| 10+000 | 2873 | 297,574 | Wet | 35,834,310 |
| 10+100 | 2737 | 280,490 | Wet | 36,114,800 |
| 10+200 | 2481 | 260,872 | Wet | 36,375,671 |
| 10+300 | 2243 | 236,165 | Wet | 36,611,836 |
| 10+400 | 1992 | 211,745 | Wet | 36,823,580 |
| 10+453 | 1788 | 100,174 | Wet | 36,923,754 |
| | **Wet Excavation** | **10,116,833** | | |
| | **Dry Excavation** | **26,806,922** | | |
| | **Total** | **36,923,754** | | |

# Table B - 6

## Summary of Excavation Quantities

### Alignment P3 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| 1+000 | 4109 | - | Wet | - |
| 1+100 | 1418 | 276,352 | Wet/Dry | 276,352 |
| 1+200 | 1667 | 154,220 | Wet/Dry | 430,571 |
| 1+300 | 2044 | 185,552 | Wet/Dry | 616,123 |
| 1+400 | 3199 | 262,176 | Wet/Dry | 878,299 |
| 1+500 | 3905 | 355,224 | Wet/Dry | 1,233,522 |
| 1+600 | 5317 | 461,113 | Wet/Dry | 1,694,635 |
| 1+700 | 3908 | 461,267 | Wet/Dry | 2,155,902 |
| 1+800 | 3723 | 381,557 | Wet/Dry | 2,537,458 |
| 1+900 | 3907 | 381,476 | Wet/Dry | 2,918,934 |
| 2+000 | 3374 | 364,019 | Wet/Dry | 3,282,953 |
| 2+100 | 5602 | 448,808 | Wet/Dry | 3,731,761 |
| 2+200 | 5823 | 571,277 | Wet/Dry | 4,303,037 |
| 2+300 | 5480 | 565,129 | Dry | 4,868,166 |
| 2+400 | 7160 | 631,967 | Dry | 5,500,133 |
| 2+500 | 14094 | 1,062,690 | Dry | 6,562,822 |
| 2+600 | 18141 | 1,611,736 | Dry | 8,174,558 |
| 2+700 | 24269 | 2,120,490 | Dry | 10,295,048 |
| 2+800 | 23349 | 2,380,881 | Dry | 12,675,929 |
| 2+900 | 16523 | 1,993,556 | Dry | 14,669,485 |
| 3+000 | 7240 | 1,188,134 | Dry | 15,857,619 |
| 3+100 | 3905 | 557,255 | Wet | 16,414,874 |
| 3+200 | 3078 | 349,140 | Wet | 16,764,013 |
| 3+300 | 2801 | 293,929 | Wet | 17,057,942 |
| 3+400 | 5063 | 393,177 | Wet | 17,451,119 |
| 3+500 | 4974 | 501,859 | Wet | 17,952,978 |
| 3+600 | 4799 | 488,671 | Wet | 18,441,648 |
| 3+700 | 3810 | 430,439 | Wet | 18,872,087 |
| 3+800 | 2987 | 339,829 | Wet | 19,211,916 |
| 3+900 | 2730 | 285,862 | Wet | 19,497,778 |
| 4+000 | 2644 | 268,716 | Wet | 19,766,494 |
| 4+100 | 2706 | 267,503 | Wet | 20,033,997 |
| 4+200 | 2712 | 270,929 | Wet | 20,304,925 |
| 4+300 | 2905 | 280,855 | Wet | 20,585,780 |
| 4+400 | 3270 | 308,717 | Wet | 20,894,497 |
| 4+500 | 3044 | 315,703 | Wet | 21,210,200 |
| 4+600 | 2551 | 279,756 | Wet | 21,489,956 |

# Table B - 6

## Summary of Excavation Quantities

### Alignment P3 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 4+700 | 2299 | 242,492 | Wet | 21,732,447 |
| 4+800 | 2238 | 226,841 | Wet | 21,959,288 |
| 4+900 | 2134 | 218,567 | Wet | 22,177,855 |
| 5+000 | 1712 | 192,258 | Wet | 22,370,113 |
| 5+100 | 1800 | 175,594 | Wet | 22,545,707 |
| 5+200 | 1996 | 189,813 | Wet | 22,735,519 |
| 5+300 | 1877 | 193,652 | Wet | 22,929,171 |
| 5+400 | 1345 | 161,099 | Wet | 23,090,270 |
| 5+500 | 1630 | 148,746 | Wet | 23,239,015 |
| 5+600 | 2450 | 203,988 | Wet | 23,443,003 |
| 5+700 | 2212 | 233,084 | Wet | 23,676,087 |
| 5+800 | 3015 | 261,364 | Wet | 23,937,451 |
| 5+900 | 5910 | 446,283 | Dry | 24,383,734 |
| 6+000 | 5138 | 552,420 | Dry | 24,936,154 |
| 6+100 | 3340 | 423,889 | Dry | 25,360,042 |
| 6+200 | 1976 | 265,773 | Dry | 25,625,815 |
| 6+300 | 1633 | 180,413 | Dry | 25,806,228 |
| 6+400 | 893 | 126,293 | Dry | 25,932,521 |
| 6+500 | 1415 | 115,424 | Dry | 26,047,945 |
| 6+600 | 4976 | 319,536 | Dry | 26,367,480 |
| 6+700 | 5465 | 522,012 | Dry | 26,889,492 |
| 6+800 | 4634 | 504,960 | Dry | 27,394,452 |
| 6+900 | 4372 | 450,324 | Dry | 27,844,776 |
| 7+000 | 5332 | 485,176 | Dry | 28,329,952 |
| 7+100 | 4657 | 499,407 | Dry | 28,829,359 |
| 7+200 | 4364 | 451,022 | Dry | 29,280,381 |
| 7+300 | 4481 | 442,236 | Dry | 29,722,617 |
| 7+400 | 4659 | 457,013 | Dry | 30,179,630 |
| 7+500 | 4645 | 465,197 | Dry | 30,644,826 |
| 7+600 | 4617 | 463,053 | Dry | 31,107,879 |
| 7+700 | 4831 | 472,368 | Dry | 31,580,246 |
| 7+800 | 4838 | 483,454 | Dry | 32,063,700 |
| 7+900 | 4485 | 466,185 | Dry | 32,529,885 |
| 8+000 | 4996 | 474,063 | Dry | 33,003,948 |
| 8+100 | 4570 | 478,270 | Dry | 33,482,218 |
| 8+200 | 3728 | 414,888 | Dry | 33,897,106 |
| 8+300 | 3077 | 340,260 | Wet | 34,237,366 |
| 8+400 | 2969 | 302,298 | Wet | 34,539,663 |
| 8+500 | 3035 | 300,194 | Wet | 34,839,857 |

# Table B - 6

## Summary of Excavation Quantities

### Alignment P3 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 8+600 | 2799 | 291,702 | Wet | 35,131,559 |
| 8+700 | 2528 | 266,332 | Wet | 35,397,891 |
| 8+800 | 2375 | 245,121 | Wet | 35,643,012 |
| 8+900 | 2208 | 229,127 | Wet | 35,872,139 |
| 9+000 | 1998 | 210,291 | Wet | 36,082,429 |
| 9+100 | 1757 | 187,769 | Wet | 36,270,198 |
| 9+200 | 1568 | 166,241 | Wet | 36,436,438 |
| 9+207 | 1552 | 10,917 | Wet | 36,447,355 |
| | **Wet Excavation** | **11,396,082** | | |
| | **Dry Excavation** | **25,051,273** | | |
| | **Total** | **36,447,355** | | |

# Table B - 7

## Summary of Excavation Quantities

### Alignment P4 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 1+000 | 918 | - | Wet | - |
| 1+100 | 604 | 76,083 | Wet | 76,083 |
| 1+200 | 1204 | 90,405 | Wet/Dry | 166,488 |
| 1+300 | 1985 | 159,493 | Wet/Dry | 325,981 |
| 1+400* | 3246 | 171,594 | Wet/Dry | 497,574 |
| 1+500* | 8489 | 406,792 | Dry | 904,366 |
| 1+600* | 14148 | 771,869 | Dry | 1,676,235 |
| 1+700* | 20385 | 1,276,644 | Dry | 2,952,878 |
| 1+800* | 26156 | 1,787,067 | Dry | 4,739,945 |
| 1+900* | 22902 | 2,092,920 | Dry | 6,832,864 |
| 2+000* | 15384 | 1,734,315 | Dry | 8,567,179 |
| 2+100* | 7575 | 1,057,977 | Dry | 9,625,156 |
| 2+200 | 4014 | 579,459 | Dry | 10,204,615 |
| 2+300 | 3364 | 368,912 | Dry | 10,573,526 |
| 2+400 | 3239 | 330,149 | Dry | 10,903,675 |
| 2+500 | 3323 | 328,081 | Dry | 11,231,755 |
| 2+600 | 3075 | 319,877 | Dry | 11,551,632 |
| 2+700 | 2826 | 295,020 | Dry | 11,846,652 |
| 2+800 | 2556 | 269,099 | Dry | 12,115,751 |
| 2+900 | 4274 | 341,493 | Dry | 12,457,243 |
| 3+000 | 3748 | 401,099 | Dry | 12,858,342 |
| 3+100 | 4090 | 391,934 | Dry | 13,250,276 |
| 3+200 | 4464 | 427,710 | Dry | 13,677,986 |
| 3+300 | 5458 | 496,103 | Dry | 14,174,088 |
| 3+400 | 4664 | 506,129 | Dry | 14,680,217 |
| 3+500 | 3831 | 424,747 | Wet/Dry | 15,104,964 |
| 3+535 | 3507 | 128,410 | Wet/Dry | 15,233,374 |
| 3+600 | 3264 | 220,080 | Wet/Dry | 15,453,454 |
| 3+700 | 3321 | 329,278 | Wet/Dry | 15,782,732 |
| 3+800 | 2795 | 305,792 | Wet | 16,088,524 |
| 3+900 | 2625 | 271,009 | Wet | 16,359,533 |
| 4+000 | 2691 | 265,813 | Wet | 16,625,346 |
| 4+100 | 2722 | 270,630 | Wet | 16,895,976 |
| 4+200 | 2727 | 272,444 | Wet | 17,168,420 |
| 4+300 | 3025 | 287,591 | Wet/Dry | 17,456,011 |
| 4+400 | 2952 | 298,852 | Wet/Dry | 17,754,863 |
| 4+500 | 3034 | 299,317 | Wet/Dry | 18,054,180 |

* Modified volume to reflect Gaillard Cut Widening Program

# Table B - 7

## Summary of Excavation Quantities

### Alignment P4 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 4+600 | 2796 | 291,497 | Wet/Dry | 18,345,677 |
| 4+700 | 2537 | 266,634 | Wet/Dry | 18,612,310 |
| 4+800 | 2397 | 246,708 | Wet/Dry | 18,859,018 |
| 4+900 | 2444 | 242,070 | Wet/Dry | 19,101,088 |
| 5+000 | 2369 | 240,634 | Wet/Dry | 19,341,721 |
| 5+097 | 2343 | 228,527 | Wet/Dry | 19,570,248 |
| 5+100 | 2279 | 6,933 | Wet/Dry | 19,577,181 |
| 5+200 | 1123 | 170,128 | Wet | 19,747,309 |
| 5+300 | 1015 | 106,930 | Wet | 19,854,239 |
| 5+400 | 884 | 94,945 | Wet | 19,949,184 |
| 5+500 | 1166 | 102,486 | Wet | 20,051,670 |
| 5+600 | 4041 | 260,370 | Wet | 20,312,039 |
| 5+700 | 4087 | 406,438 | Wet | 20,718,477 |
| 5+800 | 4029 | 405,832 | Wet/Dry | 21,124,309 |
| 5+900 | 4049 | 403,922 | Dry | 21,528,230 |
| 6+000 | 3500 | 377,477 | Dry | 21,905,707 |
| 6+100 | 7768 | 563,399 | Dry | 22,469,105 |
| 6+200 | 7558 | 766,263 | Dry | 23,235,368 |
| 6+300 | 6898 | 722,768 | Dry | 23,958,136 |
| 6+400 | 8751 | 782,447 | Dry | 24,740,583 |
| 6+500 | 10733 | 974,233 | Dry | 25,714,816 |
| 6+600 | 10893 | 1,081,312 | Dry | 26,796,127 |
| 6+700 | 12158 | 1,152,538 | Dry | 27,948,665 |
| 6+800 | 12569 | 1,236,358 | Dry | 29,185,023 |
| 6+900 | 12873 | 1,272,128 | Dry | 30,457,151 |
| 7+000 | 10772 | 1,182,273 | Dry | 31,639,424 |
| 7+100 | 6639 | 870,578 | Dry | 32,510,002 |
| 7+200 | 9758 | 819,888 | Dry | 33,329,890 |
| 7+300 | 15092 | 1,242,493 | Dry | 34,572,382 |
| 7+400 | 11893 | 1,349,241 | Wet/Dry | 35,921,623 |
| 7+500 | 6363 | 912,800 | Wet/Dry | 36,834,423 |
| 7+600 | 3568 | 496,534 | Wet/Dry | 37,330,957 |
| 7+700 | 2952 | 326,012 | Wet/Dry | 37,656,969 |
| 7+800 | 2121 | 253,648 | Wet/Dry | 37,910,617 |
| 7+900 | 1378 | 174,951 | Wet | 38,085,568 |
| 7+949 | 1239 | 64,130 | Wet | 38,149,698 |
| | **Wet Excavation** | **5,938,666** | | |
| | **Dry Excavation** | **32,211,032** | | |
| | **Total** | **38,149,698** | | |

# Table B - 8

## Summary of Excavation Quantities

### Alignment P5 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 1+000 | 605 | - | Wet | - |
| 1+100 | 731 | 66,809 | Wet/Dry | 66,809 |
| 1+200 | 1319 | 102,490 | Wet/Dry | 169,298 |
| 1+300 | 2398 | 185,827 | Wet/Dry | 355,125 |
| 1+400* | 4604 | 260,097 | Wet/Dry | 615,222 |
| 1+500* | 10960 | 598,233 | Dry | 1,213,455 |
| 1+600* | 16922 | 1,034,141 | Dry | 2,247,596 |
| 1+700* | 22337 | 1,512,985 | Dry | 3,760,580 |
| 1+800* | 28986 | 2,026,142 | Dry | 5,786,722 |
| 1+900* | 22331 | 2,205,853 | Dry | 7,992,574 |
| 2+000* | 13644 | 1,618,785 | Dry | 9,611,359 |
| 2+100* | 6974 | 940,889 | Dry | 10,552,248 |
| 2+200 | 3309 | 514,138 | Dry | 11,066,386 |
| 2+300 | 3108 | 320,869 | Dry | 11,387,254 |
| 2+400 | 2923 | 301,540 | Dry | 11,688,794 |
| 2+500 | 2941 | 293,201 | Dry | 11,981,995 |
| 2+600 | 2699 | 282,018 | Dry | 12,264,013 |
| 2+700 | 2252 | 247,529 | Dry | 12,511,542 |
| 2+800 | 3942 | 309,701 | Dry | 12,821,243 |
| 2+900 | 3817 | 387,951 | Dry | 13,209,194 |
| 3+000 | 3768 | 379,221 | Dry | 13,588,415 |
| 3+100 | 3897 | 383,253 | Dry | 13,971,668 |
| 3+200 | 4388 | 414,263 | Dry | 14,385,931 |
| 3+300 | 5591 | 498,974 | Dry | 14,884,904 |
| 3+400 | 5004 | 529,798 | Wet/Dry | 15,414,702 |
| 3+500 | 4778 | 489,102 | Wet/Dry | 15,903,804 |
| 3+600 | 4820 | 479,858 | Wet/Dry | 16,383,662 |
| 3+700 | 4301 | 456,040 | Wet/Dry | 16,839,702 |
| 3+800 | 3991 | 414,614 | Wet/Dry | 17,254,316 |
| 3+900 | 4086 | 403,844 | Wet/Dry | 17,658,160 |
| 4+000 | 3493 | 378,922 | Wet/Dry | 18,037,081 |
| 4+100 | 4426 | 395,939 | Wet/Dry | 18,433,020 |
| 4+200 | 5483 | 495,436 | Wet/Dry | 18,928,456 |
| 4+300 | 5430 | 545,632 | Dry | 19,474,088 |
| 4+400 | 4805 | 511,768 | Dry | 19,985,856 |
| 4+500 | 5938 | 537,188 | Wet/Dry | 20,523,043 |
| 4+600 | 5088 | 551,345 | Wet/Dry | 21,074,388 |

* Modified volume to reflect Gaillard Cut Widening Program

# Table B - 8

## Summary of Excavation Quantities

### Alignment P5 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 4+700 | 4960 | 502,401 | Wet/Dry | 21,576,788 |
| 4+800 | 5133 | 504,627 | Wet/Dry | 22,081,415 |
| 4+900 | 5274 | 520,371 | Wet/Dry | 22,601,786 |
| 5+000 | 5127 | 520,067 | Wet/Dry | 23,121,852 |
| 5+100 | 2705 | 391,585 | Wet/Dry | 23,513,437 |
| 5+114 | 2481 | 36,302 | Wet/Dry | 23,549,739 |
| 5+200 | 2156 | 199,384 | Wet/Dry | 23,749,123 |
| 5+234 | 2158 | 73,341 | Wet/Dry | 23,822,463 |
| 5+300 | 2020 | 137,901 | Wet/Dry | 23,960,364 |
| 5+400 | 1764 | 189,215 | Wet/Dry | 24,149,579 |
| 5+500 | 2188 | 197,617 | Wet | 24,347,196 |
| 5+600 | 5002 | 359,541 | Wet | 24,706,737 |
| 5+700 | 4715 | 485,884 | Dry | 25,192,621 |
| 5+800 | 3778 | 424,682 | Dry | 25,617,302 |
| 5+900 | 3798 | 378,840 | Dry | 25,996,142 |
| 6+000 | 3585 | 369,181 | Dry | 26,365,323 |
| 6+100 | 3572 | 357,867 | Dry | 26,723,190 |
| 6+200 | 3729 | 365,071 | Dry | 27,088,261 |
| 6+300 | 3711 | 372,034 | Dry | 27,460,294 |
| 6+400 | 4299 | 400,534 | Dry | 27,860,828 |
| 6+500 | 4382 | 434,058 | Dry | 28,294,886 |
| 6+600 | 9000 | 669,092 | Dry | 28,963,978 |
| 6+700 | 6090 | 754,517 | Dry | 29,718,494 |
| 6+800 | 5749 | 591,951 | Dry | 30,310,445 |
| 6+900 | 5811 | 578,004 | Dry | 30,888,449 |
| 7+000 | 4224 | 501,793 | Dry | 31,390,242 |
| 7+100 | 4499 | 436,148 | Dry | 31,826,389 |
| 7+200 | 5648 | 507,325 | Dry | 32,333,714 |
| 7+300 | 7558 | 660,275 | Dry | 32,993,988 |
| 7+400 | 5878 | 671,773 | Dry | 33,665,761 |
| 7+500 | 4703 | 529,057 | Dry | 34,194,817 |
| 7+600 | 4751 | 472,735 | Dry | 34,667,552 |
| 7+700 | 3756 | 425,391 | Dry | 35,092,943 |
| 7+800 | 3446 | 360,140 | Dry | 35,453,082 |
| 7+900 | 3192 | 331,899 | Dry | 35,784,981 |
| 8+000 | 2490 | 284,072 | Dry | 36,069,053 |
| 8+100 | 5046 | 376,791 | Dry | 36,445,844 |
| 8+200 | 2367 | 370,640 | Wet/Dry | 36,816,484 |
| 8+300 | 6115 | 424,086 | Wet | 37,240,570 |
| 8+400 | 6220 | 616,738 | Wet | 37,857,307 |

# Table B - 8

## Summary of Excavation Quantities

## Alignment P5 - Channel Bottom 184m Wide at El. 9.9

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 8+500 | 6705 | 646,254 | Wet | 38,503,561 |
| 8+600 | 6204 | 645,478 | Wet | 39,149,039 |
| 8+700 | 5392 | 579,802 | Wet | 39,728,841 |
| 8+800 | 5065 | 522,832 | Wet | 40,251,672 |
| 8+900 | 4749 | 490,712 | Wet | 40,742,384 |
| 9+000 | 5811 | 528,004 | Wet | 41,270,388 |
| 9+100 | 5675 | 574,315 | Wet | 41,844,702 |
| 9+200 | 5477 | 557,639 | Wet | 42,402,341 |
| 9+300 | 5067 | 527,192 | Wet | 42,929,533 |
| 9+400 | 4967 | 501,665 | Wet | 43,431,198 |
| 9+500 | 4608 | 478,712 | Wet | 43,909,910 |
| 9+600 | 4248 | 442,750 | Wet | 44,352,660 |
| 9+700 | 3629 | 393,828 | Wet | 44,746,488 |
| 9+800 | 3231 | 342,994 | Wet | 45,089,482 |
| 9+900 | 3078 | 315,424 | Wet | 45,404,905 |
| 10+000 | 2871 | 297,440 | Wet | 45,702,345 |
| 10+100 | 2736 | 280,343 | Wet | 45,982,688 |
| 10+200 | 2480 | 260,777 | Wet | 46,243,465 |
| 10+300 | 2242 | 236,089 | Wet | 46,479,554 |
| 10+400 | 1989 | 211,526 | Wet | 46,691,080 |
| 10+452 | 1788 | 98,192 | Wet | 46,789,272 |

| | |
|---|---|
| **Wet Excavation** | **14,030,450** |
| **Dry Excavation** | **32,758,822** |
| **Total** | **46,789,272** |

# THE PANAMA CANAL
# EVALUATION OF LOCK CHANNEL ALIGNMENTS
# PART 3 - FINAL EVALUATION AND OPTIMIZATION

# APPENDIX C

# EXCAVATION QUANTITIES FOR PHASED CONSTRUCTION APPROACH

# THE PANAMA CANAL
# EVALUATION OF LOCK CHANNEL ALIGNMENTS
# PART 3 - FINAL EVALUATION AND OPTIMIZATION

## APPENDIX C
## EXCAVATION QUANTITIES FOR PHASED CONSTRUCTION APPROACH

## TABLES

# Table C - 1

## Summary of Excavation Quantities

### Alignment A1 Phase 1 - Channel Bottom 184m Wide at El. 10.36

Computed: PLM
Checked : JPM

| Station Number | Total Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| 0+000 | 2,260 | - | | - |
| 0+150 | 2,553 | 360,975 | Wet | 360,975 |
| 0+300 | 2,717 | 395,250 | Wet | 756,225 |
| 0+450 | 2,998 | 428,625 | Wet | 1,184,850 |
| 0+600 | 2,276 | 395,550 | Wet | 1,580,400 |
| 0+750 | 1,860 | 310,200 | Wet | 1,890,600 |
| 0+900 | 1,935 | 284,625 | Wet | 2,175,225 |
| 1+050 | 2,024 | 296,925 | Wet | 2,472,150 |
| 1+200 | 1,913 | 295,275 | Wet | 2,767,425 |
| 1+350 | 2,097 | 300,750 | Dry | 3,068,175 |
| 1+500 | 1,679 | 283,200 | Dry | 3,351,375 |
| 1+650 | 2,472 | 311,325 | Dry | 3,662,700 |
| 1+800 | 1,725 | 314,775 | Dry | 3,977,475 |
| 1+950 | 2,257 | 298,650 | Dry | 4,276,125 |
| 2+100 | 2,836 | 381,975 | Dry | 4,658,100 |
| 2+250 | 4,905 | 580,575 | Dry | 5,238,675 |
| 2+326 | 5,043 | 378,024 | Dry | 5,616,699 |
| 2+476 | 3,453 | 637,200 | Dry | 6,253,899 |
| 2+626 | 2,624 | 455,775 | Dry | 6,709,674 |
| 2+776 | 419 | 228,225 | Dry | 6,937,899 |
| 2+926 | 405 | 61,800 | Dry | 6,999,699 |
| 3+076 | 607 | 75,900 | Dry | 7,075,599 |
| 3+226 | 808 | 106,125 | Dry | 7,181,724 |
| 3+376 | 1,946 | 206,550 | Dry | 7,388,274 |
| 3+526 | 2,394 | 325,500 | Dry | 7,713,774 |
| 3+676 | 1,157 | 266,325 | Dry | 7,980,099 |
| 3+826 | 1,801 | 221,850 | Dry | 8,201,949 |
| 3+976 | 2,921 | 354,150 | Dry | 8,556,099 |
| 4+126 | 2,023 | 370,800 | Dry | 8,926,899 |
| 4+276 | 2,355 | 328,350 | Dry | 9,255,249 |
| 4+426 | 3,010 | 402,375 | Dry | 9,657,624 |
| 4+576 | 608 | 271,350 | Dry | 9,928,974 |
| 4+726 | 919 | 114,525 | Dry | 10,043,499 |
| 4+876 | 1,836 | 206,625 | Dry | 10,250,124 |
| 5+026 | 5,101 | 520,275 | Dry | 10,770,399 |
| 5+176 | 6,646 | 881,025 | Dry | 11,651,424 |
| 5+326 | 5,247 | 891,975 | Dry | 12,543,399 |
| 5+400 | 306 | 205,461 | Wet | 12,748,860 |
| | **Wet Excavation** | **2,972,886** | | |
| | **Dry Excavation** | **9,775,974** | | |
| | **Total** | **12,748,860** | | |

# Table C - 2

## Summary of Excavation Quantities

## Alignment A1 Phase 2 - Channel Bottom 184m Wide at El. 7.16

Computed: PLM
Checked : JPM

| Station Number | Total Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 0+000 | - | - | | - |
| 0+150 | - | - | Wet | - |
| 0+300 | - | - | Wet | - |
| 0+450 | - | - | Wet | - |
| 0+600 | - | - | Wet | - |
| 0+750 | - | - | Wet | - |
| 0+900 | - | - | Wet | - |
| 1+050 | - | - | Wet | - |
| 1+200 | - | - | Wet | - |
| 1+350 | - | - | Wet | - |
| 1+500 | - | - | Wet | - |
| 1+650 | - | - | Wet | - |
| 1+800 | - | - | Wet | - |
| 1+950 | - | - | Wet | - |
| 2+100 | - | - | Wet | - |
| 2+250 | - | - | Wet | - |
| 2+326 | - | - | Wet | - |
| 2+476 | - | - | Wet | - |
| 2+626 | - | - | Wet | - |
| 2+776 | - | - | Wet | - |
| 2+926 | - | - | Wet | - |
| 3+076 | - | - | Wet | - |
| 3+226 | - | - | Wet | - |
| 3+376 | - | - | Wet | - |
| 3+526 | - | - | Wet | - |
| 3+676 | - | - | Wet | - |
| 3+826 | - | - | Wet | - |
| 3+976 | - | - | Wet | - |
| 4+126 | - | - | Wet | - |
| 4+276 | - | - | Wet | - |
| 4+426 | - | - | Wet | - |
| 4+576 | - | - | Wet | - |
| 4+726 | - | - | Wet | - |
| 4+876 | - | - | Wet | - |
| 5+026 | 862 | 64,650 | Wet | 64,650 |
| 5+176 | 931 | 134,475 | Wet | 199,125 |
| 5+326 | 1,059 | 149,250 | Wet | 348,375 |
| 5+400 | 611 | 61,790 | Wet | 410,165 |
| | **Wet Excavation** | **410,165** | | |
| | **Dry Excavation** | **-** | | |
| | **Total** | **410,165** | | |

# Table C - 3

## Summary of Excavation Quantities

## Alignment A1 Phase 2a - Channel Bottom 184m Wide at El. 8.08

Computed: PLM
Checked : JPM

| Station Number | Total Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 0+000 | - | - | | - |
| 0+150 | - | - | Wet | - |
| 0+300 | - | - | Wet | - |
| 0+450 | - | - | Wet | - |
| 0+600 | - | - | Wet | - |
| 0+750 | - | - | Wet | - |
| 0+900 | - | - | Wet | - |
| 1+050 | - | - | Wet | - |
| 1+200 | - | - | Wet | - |
| 1+350 | - | - | Wet | - |
| 1+500 | - | - | Wet | - |
| 1+650 | - | - | Wet | - |
| 1+800 | - | - | Wet | - |
| 1+950 | - | - | Wet | - |
| 2+100 | - | - | Wet | - |
| 2+250 | - | - | Wet | - |
| 2+326 | - | - | Wet | - |
| 2+476 | - | - | Wet | - |
| 2+626 | - | - | Wet | - |
| 2+776 | - | - | Wet | - |
| 2+926 | - | - | Wet | - |
| 3+076 | - | - | Wet | - |
| 3+226 | - | - | Wet | - |
| 3+376 | - | - | Wet | - |
| 3+526 | - | - | Wet | - |
| 3+676 | - | - | Wet | - |
| 3+826 | - | - | Wet | - |
| 3+976 | - | - | Wet | - |
| 4+126 | - | - | Wet | - |
| 4+276 | - | - | Wet | - |
| 4+426 | - | - | Wet | - |
| 4+576 | - | - | Wet | - |
| 4+726 | - | - | Wet | - |
| 4+876 | - | - | Wet | - |
| 5+026 | 628 | 47,100 | Wet | 47,100 |
| 5+176 | 651 | 95,925 | Wet | 143,025 |
| 5+326 | 745 | 104,700 | Wet | 247,725 |
| 5+400 | 484 | 45,473 | Wet | 293,198 |

| | |
|---|---|
| **Wet Excavation** | **293,198** |
| **Dry Excavation** | **-** |
| **Total** | **293,198** |

# Table C - 4

## Summary of Excavation Quantities

### Alignment A2 - Channel Bottom 184m Wide at El. 10.36

Computed: PLM
Checked : JPM

| Station Number | Total Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| 0+300 | 609 | | | |
| 0+450 | 1,057 | 124,950 | Wet | 124,950 |
| 0+600 | 2,310 | 252,525 | Wet | 377,475 |
| 0+750 | 3,127 | 407,775 | Wet | 785,250 |
| 0+900 | 3,408 | 490,125 | Wet | 1,275,375 |
| 1+050 | 4,127 | 565,125 | Wet | 1,840,500 |
| 1+200 | 3,957 | 606,300 | Wet/Dry | 2,446,800 |
| 1+350 | 4,789 | 655,950 | Wet/Dry | 3,102,750 |
| 1+500 | 4,468 | 694,275 | Wet/Dry | 3,797,025 |
| 1+650 | 3,962 | 632,250 | Wet/Dry | 4,429,275 |
| 1+800 | 3,801 | 582,225 | Wet/Dry | 5,011,500 |
| 1+950 | 3,824 | 571,875 | Wet/Dry | 5,583,375 |
| 2+100 | 3,877 | 577,575 | Wet/Dry | 6,160,950 |
| 2+250 | 4,017 | 592,050 | Wet/Dry | 6,753,000 |
| 2+400 | 3,784 | 585,075 | Wet/Dry | 7,338,075 |
| 2+550 | 1,921 | 427,875 | Wet/Dry | 7,765,950 |
| 2+700 | 2,200 | 309,075 | Wet/Dry | 8,075,025 |
| 2+850 | 1,680 | 291,000 | Wet/Dry | 8,366,025 |
| 3+000 | 2,514 | 314,550 | Wet/Dry | 8,680,575 |
| 3+150 | 2,747 | 394,575 | Dry | 9,075,150 |
| 3+300 | 2,837 | 418,800 | Dry | 9,493,950 |
| 3+450 | 1,998 | 362,625 | Dry | 9,856,575 |
| 3+600 | 2,231 | 317,175 | Dry | 10,173,750 |
| 3+750 | 2,759 | 374,250 | Dry | 10,548,000 |
| 3+900 | 3,005 | 432,300 | Dry | 10,980,300 |
| 4+050 | 4,505 | 563,250 | Dry | 11,543,550 |
| 4+200 | 4,097 | 645,150 | Dry | 12,188,700 |
| 4+350 | 290 | 329,025 | Wet/Dry | 12,517,725 |
| 4+500 | 101 | 29,325 | Wet/Dry | 12,547,050 |
| 4+750 | - | 12,625 | Wet/Dry | 12,559,675 |
| | **Wet Excavation** | **5,603,475** | | |
| | **Dry Excavation** | **6,956,200** | | |
| | **Total** | **12,559,675** | | |

# Table C - 5

## Summary of Excavation Quantities

### Alignment P1 Phase 1 - Channel Bottom 184m Wide at El. 10.36

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 1+000 | 574 | - | Wet | - |
| 1+100 | 930 | 75,211 | Wet/Dry | 75,211 |
| 1+200 | 3756 | 234,285 | Wet/Dry | 309,496 |
| 1+300 | 3086 | 342,080 | Wet/Dry | 651,576 |
| 1+400 | 3635 | 336,052 | Wet/Dry | 987,628 |
| 1+500 | 4574 | 410,467 | Dry | 1,398,094 |
| 1+600 | 5008 | 479,118 | Dry | 1,877,212 |
| 1+700 | 5138 | 507,339 | Dry | 2,384,551 |
| 1+800 | 5520 | 532,898 | Dry | 2,917,449 |
| 1+900 | 6733 | 612,650 | Dry | 3,530,098 |
| 2+000 | 9609 | 817,100 | Dry | 4,347,198 |
| 2+100 | 16060 | 1,283,438 | Dry | 5,630,635 |
| 2+200 | 20915 | 1,848,738 | Dry | 7,479,373 |
| 2+300 | 25214 | 2,306,444 | Dry | 9,785,817 |
| 2+400 | 32367 | 2,879,043 | Dry | 12,664,859 |
| 2+500 | 25456 | 2,891,118 | Dry | 15,555,977 |
| 2+600 | 15996 | 2,072,587 | Dry | 17,628,564 |
| 2+700 | 8201 | 1,209,824 | Dry | 18,838,387 |
| 2+800 | 5092 | 664,616 | Dry | 19,503,003 |
| 2+900 | 3408 | 424,991 | Dry | 19,927,993 |
| 3+000 | 2735 | 307,156 | Dry | 20,235,149 |
| 3+100 | 2824 | 277,947 | Dry | 20,513,095 |
| 3+200 | 2912 | 286,819 | Dry | 20,799,914 |
| 3+300 | 2911 | 291,164 | Dry | 21,091,078 |
| 3+400 | 2829 | 286,976 | Dry | 21,378,054 |
| 3+500 | 2285 | 255,699 | Dry | 21,633,752 |
| 3+600 | 1995 | 214,027 | Dry | 21,847,779 |
| 3+700 | 2804 | 239,986 | Dry | 22,087,764 |
| 3+800 | 4013 | 340,885 | Dry | 22,428,649 |
| 3+900 | 7919 | 596,627 | Dry | 23,025,275 |
| 4+000 | 11731 | 982,509 | Dry | 24,007,784 |
| 4+100 | 18750 | 1,524,025 | Dry | 25,531,808 |
| 4+200 | 17982 | 1,836,593 | Dry | 27,368,401 |
| 4+300 | 13703 | 1,584,245 | Dry | 28,952,646 |
| 4+400 | 9086 | 1,139,411 | Dry | 30,092,057 |
| 4+500 | 11163 | 1,012,410 | Dry | 31,104,466 |
| 4+600 | 12746 | 1,195,454 | Dry | 32,299,920 |
| 4+700 | 14292 | 1,351,936 | Dry | 33,651,856 |

# Table C - 5

## Summary of Excavation Quantities

### Alignment P1 Phase 1 - Channel Bottom 184m Wide at El. 10.36

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 4+800 | 13205 | 1,374,881 | Dry | 35,026,737 |
| 4+900 | 15701 | 1,445,321 | Dry | 36,472,057 |
| 5+000 | 13508 | 1,460,451 | Dry | 37,932,508 |
| 5+100 | 17254 | 1,538,087 | Dry | 39,470,595 |
| 5+200 | 17307 | 1,728,050 | Dry | 41,198,645 |
| 5+300 | 16494 | 1,690,070 | Dry | 42,888,715 |
| 5+400 | 15338 | 1,591,617 | Dry | 44,480,331 |
| 5+500 | 14053 | 1,469,541 | Dry | 45,949,872 |
| 5+600 | 11912 | 1,298,213 | Dry | 47,248,085 |
| 5+700 | 9627 | 1,076,940 | Dry | 48,325,025 |
| 5+800 | 6797 | 821,230 | Dry | 49,146,254 |
| 5+900 | 5614 | 620,591 | Dry | 49,766,845 |
| 6+000 | 3876 | 474,529 | Dry | 50,241,374 |
| 6+100 | 3431 | 365,335 | Dry | 50,606,709 |
| 6+200 | 3358 | 339,424 | Dry | 50,946,133 |
| 6+300 | 2946 | 315,210 | Dry | 51,261,343 |
| 6+400 | 3441 | 319,363 | Dry | 51,580,705 |
| 6+500 | 5715 | 457,804 | Dry | 52,038,509 |
| 6+600 | 3323 | 451,927 | Dry | 52,490,436 |
| 6+700 | 1871 | 259,745 | Dry | 52,750,181 |
| 6+800 | 2589 | 223,016 | Dry | 52,973,196 |
| 6+900 | 2567 | 257,783 | Dry | 53,230,979 |
| 7+000 | 2637 | 260,192 | Dry | 53,491,171 |
| 7+100 | 2565 | 260,123 | Dry | 53,751,293 |
| 7+200 | 2635 | 260,004 | Dry | 54,011,297 |
| 7+300 | 3939 | 328,694 | Dry | 54,339,990 |
| 7+400 | 4561 | 425,031 | Dry | 54,765,021 |
| 7+500 | 4416 | 448,864 | Dry | 55,213,885 |
| 7+600 | 6369 | 539,251 | Dry | 55,753,136 |
| 7+700 | 5919 | 614,401 | Dry | 56,367,537 |
| 7+800 | 5766 | 584,260 | Dry | 56,951,796 |
| 7+900 | 6222 | 599,403 | Dry | 57,551,199 |
| 8+000 | 5692 | 595,663 | Dry | 58,146,861 |
| 8+100 | 7075 | 638,333 | Dry | 58,785,194 |
| 8+200 | 5746 | 641,048 | Dry | 59,426,241 |
| 8+300 | 4866 | 530,600 | Dry | 59,956,841 |
| 8+400 | 5084 | 497,486 | Dry | 60,454,327 |
| 8+500 | 4435 | 475,906 | Dry | 60,930,233 |
| 8+600 | 4871 | 465,269 | Dry | 61,395,501 |
| 8+700 | 5625 | 524,770 | Dry | 61,920,271 |

# Table C - 5

## Summary of Excavation Quantities

### Alignment P1 Phase 1 - Channel Bottom 184m Wide at El. 10.36

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 8+800 | 5230 | 542,719 | Wet | 62,462,989 |
| 8+900 | 7420 | 632,491 | Wet | 63,095,480 |
| 9+000 | 7270 | 734,513 | Wet | 63,829,993 |
| 9+100 | 6770 | 702,021 | Wet | 64,532,013 |
| 9+200 | 5642 | 620,588 | Wet | 65,152,601 |
| 9+300 | 4931 | 528,649 | Wet | 65,681,250 |
| 9+400 | 5055 | 499,332 | Wet | 66,180,582 |
| 9+500 | 5721 | 538,824 | Wet | 66,719,406 |
| 9+600 | 4993 | 535,701 | Wet | 67,255,106 |
| 9+700 | 4692 | 484,215 | Wet | 67,739,321 |
| 9+800 | 3981 | 433,617 | Wet | 68,172,938 |
| 9+900 | 2979 | 347,988 | Wet | 68,520,926 |
| 10+000 | 2532 | 275,541 | Wet | 68,796,466 |
| 10+100 | 2160 | 234,592 | Wet | 69,031,058 |
| 10+200 | 1857 | 200,864 | Wet | 69,231,922 |
| 10+264 | 1684 | 113,311 | Wet | 69,345,233 |

| | |
|---|---|
| **Wet Excavation** | **7,634,875** |
| **Dry Excavation** | **61,710,359** |
| **Total** | **69,345,233** |

# Table C - 6

## Summary of Excavation Quantities

## Alignment P1 Phase 2 - Channel Bottom 184m Wide at El. 7.16

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 1+000 | 624 | - | Wet | - |
| 1+100 | 660 | 64,215 | Wet | 64,215 |
| 1+200 | 916 | 78,769 | Wet | 142,984 |
| 1+300 | 765 | 84,025 | Wet | 227,010 |
| 1+400 | 702 | 73,346 | Wet | 300,356 |
| 1+500 | 713 | 70,743 | Wet | 371,099 |
| 1+600 | 716 | 71,462 | Wet | 442,561 |
| 1+700 | 708 | 71,244 | Wet | 513,805 |
| 1+800 | 729 | 71,881 | Wet | 585,686 |
| 1+900 | 815 | 77,226 | Wet | 662,912 |
| 2+000 | 867 | 84,114 | Wet | 747,026 |
| 2+100 | 996 | 93,143 | Wet | 840,169 |
| 2+200 | 1189 | 109,258 | Wet | 949,427 |
| 2+300 | 1357 | 127,322 | Wet | 1,076,749 |
| 2+400 | 1398 | 137,754 | Wet | 1,214,503 |
| 2+500 | 1432 | 141,505 | Wet | 1,356,008 |
| 2+600 | 1025 | 122,874 | Wet | 1,478,882 |
| 2+700 | 765 | 89,524 | Wet | 1,568,406 |
| 2+800 | 657 | 71,108 | Wet | 1,639,515 |
| 2+900 | 641 | 64,881 | Wet | 1,704,395 |
| 3+000 | 638 | 63,947 | Wet | 1,768,342 |
| 3+100 | 634 | 63,630 | Wet | 1,831,973 |
| 3+200 | 639 | 63,692 | Wet | 1,895,665 |
| 3+300 | 633 | 63,609 | Wet | 1,959,274 |
| 3+400 | 637 | 63,473 | Wet | 2,022,747 |
| 3+500 | 632 | 63,448 | Wet | 2,086,195 |
| 3+600 | 633 | 63,276 | Wet | 2,149,471 |
| 3+700 | 649 | 64,102 | Wet | 2,213,573 |
| 3+800 | 698 | 67,322 | Wet | 2,280,895 |
| 3+900 | 965 | 83,143 | Wet | 2,364,039 |
| 4+000 | 893 | 92,922 | Wet | 2,456,961 |
| 4+100 | 1104 | 99,878 | Wet | 2,556,839 |
| 4+200 | 1107 | 110,586 | Wet | 2,667,426 |
| 4+300 | 951 | 102,932 | Wet | 2,770,357 |
| 4+400 | 778 | 86,454 | Wet | 2,856,811 |
| 4+500 | 933 | 85,567 | Wet | 2,942,378 |
| 4+600 | 902 | 91,792 | Wet | 3,034,170 |
| 4+700 | 943 | 92,275 | Wet | 3,126,444 |

# Table C - 6

## Summary of Excavation Quantities

## Alignment P1 Phase 2 - Channel Bottom 184m Wide at El. 7.16

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 4+800 | 924 | 93,348 | Wet | 3,219,792 |
| 4+900 | 1161 | 104,217 | Wet | 3,324,009 |
| 5+000 | 1026 | 109,340 | Wet | 3,433,349 |
| 5+100 | 1101 | 106,343 | Wet | 3,539,692 |
| 5+200 | 1035 | 106,782 | Wet | 3,646,474 |
| 5+300 | 1001 | 101,814 | Wet | 3,748,287 |
| 5+400 | 1028 | 101,473 | Wet | 3,849,760 |
| 5+500 | 993 | 101,052 | Wet | 3,950,813 |
| 5+600 | 878 | 93,555 | Wet | 4,044,368 |
| 5+700 | 778 | 82,826 | Wet | 4,127,194 |
| 5+800 | 728 | 75,336 | Wet | 4,202,530 |
| 5+900 | 738 | 73,298 | Wet | 4,275,828 |
| 6+000 | 673 | 70,532 | Wet | 4,346,360 |
| 6+100 | 648 | 66,056 | Wet | 4,412,416 |
| 6+200 | 652 | 64,994 | Wet | 4,477,410 |
| 6+300 | 647 | 64,926 | Wet | 4,542,336 |
| 6+400 | 647 | 64,658 | Wet | 4,606,994 |
| 6+500 | 697 | 67,165 | Wet | 4,674,160 |
| 6+600 | 675 | 68,608 | Wet | 4,742,767 |
| 6+700 | 470 | 57,282 | Wet | 4,800,049 |
| | **Wet Excavation** | **4,800,049** | | |
| | **Dry Excavation** | **-** | | |
| | **Total** | **4,800,049** | | |

# Table C - 7

## Summary of Excavation Quantities

### Alignment P1 Phase 2a - Channel Bottom 184m Wide at El. 8.08

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 1+000 | 444 | - | Wet | - |
| 1+100 | 465 | 45,431 | Wet | 45,431 |
| 1+200 | 652 | 55,866 | Wet | 101,296 |
| 1+300 | 544 | 59,820 | Wet | 161,116 |
| 1+400 | 502 | 52,274 | Wet | 213,390 |
| 1+500 | 507 | 50,424 | Wet | 263,814 |
| 1+600 | 508 | 50,750 | Wet | 314,564 |
| 1+700 | 500 | 50,380 | Wet | 364,944 |
| 1+800 | 518 | 50,899 | Wet | 415,843 |
| 1+900 | 571 | 54,452 | Wet | 470,295 |
| 2+000 | 617 | 59,362 | Wet | 529,657 |
| 2+100 | 709 | 66,263 | Wet | 595,919 |
| 2+200 | 837 | 77,297 | Wet | 673,216 |
| 2+300 | 961 | 89,940 | Wet | 763,157 |
| 2+400 | 994 | 97,758 | Wet | 860,914 |
| 2+500 | 1003 | 99,828 | Wet | 960,742 |
| 2+600 | 729 | 86,617 | Wet | 1,047,359 |
| 2+700 | 533 | 63,149 | Wet | 1,110,508 |
| 2+800 | 467 | 50,019 | Wet | 1,160,527 |
| 2+900 | 455 | 46,120 | Wet | 1,206,647 |
| 3+000 | 454 | 45,458 | Wet | 1,252,105 |
| 3+100 | 451 | 45,235 | Wet | 1,297,340 |
| 3+200 | 455 | 45,279 | Wet | 1,342,619 |
| 3+300 | 450 | 45,217 | Wet | 1,387,836 |
| 3+400 | 453 | 45,122 | Wet | 1,432,958 |
| 3+500 | 449 | 45,104 | Wet | 1,478,063 |
| 3+600 | 450 | 44,973 | Wet | 1,523,036 |
| 3+700 | 461 | 45,558 | Wet | 1,568,594 |
| 3+800 | 496 | 47,842 | Wet | 1,616,436 |
| 3+900 | 684 | 58,961 | Wet | 1,675,397 |
| 4+000 | 634 | 65,889 | Wet | 1,741,286 |
| 4+100 | 786 | 71,007 | Wet | 1,812,293 |
| 4+200 | 788 | 78,685 | Wet | 1,890,978 |
| 4+300 | 676 | 73,205 | Wet | 1,964,182 |
| 4+400 | 553 | 61,470 | Wet | 2,025,653 |
| 4+500 | 664 | 60,859 | Wet | 2,086,512 |
| 4+600 | 641 | 65,229 | Wet | 2,151,741 |
| 4+700 | 671 | 65,582 | Wet | 2,217,323 |

# Table C - 7

## Summary of Excavation Quantities

### Alignment P1 Phase 2a - Channel Bottom 184m Wide at El. 8.08

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 4+800 | 655 | 66,296 | Wet | 2,283,619 |
| 4+900 | 821 | 73,788 | Wet | 2,357,407 |
| 5+000 | 733 | 77,708 | Wet | 2,435,115 |
| 5+100 | 783 | 75,827 | Wet | 2,510,943 |
| 5+200 | 735 | 75,916 | Wet | 2,586,858 |
| 5+300 | 683 | 70,923 | Wet | 2,657,781 |
| 5+400 | 732 | 70,753 | Wet | 2,728,534 |
| 5+500 | 706 | 71,900 | Wet | 2,800,434 |
| 5+600 | 618 | 66,218 | Wet | 2,866,652 |
| 5+700 | 552 | 58,475 | Wet | 2,925,128 |
| 5+800 | 517 | 53,413 | Wet | 2,978,541 |
| 5+900 | 525 | 52,061 | Wet | 3,030,602 |
| 6+000 | 478 | 50,139 | Wet | 3,080,741 |
| 6+100 | 461 | 46,946 | Wet | 3,127,687 |
| 6+200 | 463 | 46,202 | Wet | 3,173,889 |
| 6+300 | 460 | 46,152 | Wet | 3,220,041 |
| 6+400 | 460 | 45,964 | Wet | 3,266,004 |
| 6+500 | 493 | 47,640 | Wet | 3,313,645 |
| 6+600 | 480 | 48,669 | Wet | 3,362,314 |
| 6+700 | 334 | 40,712 | Wet | 3,403,026 |

| | |
|---|---|
| **Wet Excavation** | **3,403,026** |
| **Dry Excavation** | - |
| **Total** | **3,403,026** |

# Table C - 8

## Summary of Excavation Quantities

### Alignment P2 Phase 1 - Channel Bottom 184m Wide at El. 10.36

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 1+000 | 522 | - | Wet | - |
| 1+100 | 643 | 58,249 | Wet/Dry | 58,249 |
| 1+200 | 1258 | 95,037 | Wet/Dry | 153,286 |
| 1+300 | 2310 | 178,396 | Wet/Dry | 331,682 |
| 1+400* | 4427 | 251,966 | Dry | 583,647 |
| 1+500* | 10789 | 585,874 | Dry | 1,169,521 |
| 1+600* | 16724 | 1,020,764 | Dry | 2,190,285 |
| 1+700* | 22133 | 1,497,998 | Dry | 3,688,282 |
| 1+800* | 28778 | 2,010,694 | Dry | 5,698,976 |
| 1+900* | 22134 | 2,190,716 | Dry | 7,889,692 |
| 2+000* | 13466 | 1,605,097 | Dry | 9,494,789 |
| 2+100* | 6860 | 931,439 | Dry | 10,426,228 |
| 2+200 | 3217 | 503,857 | Dry | 10,930,085 |
| 2+300 | 3016 | 311,613 | Dry | 11,241,697 |
| 2+400 | 2831 | 292,307 | Dry | 11,534,004 |
| 2+500 | 2849 | 283,991 | Dry | 11,817,995 |
| 2+600 | 2607 | 272,829 | Dry | 12,090,824 |
| 2+700 | 2161 | 238,402 | Dry | 12,329,226 |
| 2+800 | 1938 | 204,941 | Dry | 12,534,166 |
| 2+900 | 1840 | 188,886 | Dry | 12,723,052 |
| 3+000 | 1791 | 181,523 | Dry | 12,904,575 |
| 3+100 | 1881 | 183,578 | Dry | 13,088,152 |
| 3+200 | 2399 | 213,990 | Dry | 13,302,142 |
| 3+300 | 3518 | 295,856 | Dry | 13,597,997 |
| 3+400 | 2939 | 322,850 | Dry | 13,920,847 |
| 3+500 | 2686 | 281,230 | Dry | 14,202,077 |
| 3+600 | 2843 | 276,440 | Dry | 14,478,517 |
| 3+700 | 2333 | 258,781 | Dry | 14,737,298 |
| 3+800 | 1981 | 215,661 | Dry | 14,952,959 |
| 3+900 | 2068 | 202,430 | Dry | 15,155,389 |
| 4+000 | 1499 | 178,356 | Dry | 15,333,745 |
| 4+100 | 2426 | 196,251 | Dry | 15,529,996 |
| 4+200 | 3431 | 292,831 | Dry | 15,822,826 |
| 4+300 | 3290 | 336,053 | Dry | 16,158,879 |
| 4+400 | 2821 | 305,559 | Dry | 16,464,438 |
| 4+500 | 3895 | 335,810 | Dry | 16,800,248 |
| 4+600 | 3137 | 351,589 | Dry | 17,151,836 |
| 4+700 | 3026 | 308,148 | Dry | 17,459,984 |

* Modified volume to reflect Gaillard Cut Widening Program

# Table C - 8

## Summary of Excavation Quantities

## Alignment P2 Phase 1 - Channel Bottom 184m Wide at El. 10.36

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 4+800 | 3170 | 309,799 | Dry | 17,769,783 |
| 4+900 | 3208 | 318,854 | Dry | 18,088,637 |
| 5+000 | 2830 | 301,873 | Dry | 18,390,510 |
| 5+100 | 938 | 188,394 | Dry | 18,578,904 |
| 5+138 | 612 | 29,458 | Dry | 18,608,362 |
| 5+200 | 536 | 35,613 | Dry | 18,643,975 |
| 5+300 | 699 | 61,749 | Dry | 18,705,724 |
| 5+400 | 462 | 58,019 | Dry | 18,763,743 |
| 5+500 | 524 | 49,307 | Dry | 18,813,049 |
| 5+600 | 2984 | 175,394 | Dry | 18,988,443 |
| 5+700 | 2695 | 283,949 | Dry | 19,272,391 |
| 5+800 | 1803 | 224,901 | Dry | 19,497,292 |
| 5+900 | 1705 | 175,357 | Dry | 19,672,648 |
| 6+000 | 847 | 127,563 | Dry | 19,800,211 |
| 6+100 | 2487 | 166,662 | Dry | 19,966,873 |
| 6+200 | 2595 | 254,074 | Dry | 20,220,947 |
| 6+300 | 2587 | 259,096 | Dry | 20,480,043 |
| 6+400 | 2661 | 262,421 | Dry | 20,742,464 |
| 6+500 | 4030 | 334,572 | Dry | 21,077,035 |
| 6+600 | 4020 | 402,522 | Dry | 21,479,557 |
| 6+700 | 1693 | 285,660 | Dry | 21,765,217 |
| 6+800 | 1265 | 147,893 | Dry | 21,913,110 |
| 6+900 | 2826 | 204,576 | Dry | 22,117,685 |
| 7+000 | 2191 | 250,870 | Dry | 22,368,555 |
| 7+100 | 2253 | 222,206 | Dry | 22,590,761 |
| 7+200 | 2485 | 236,931 | Dry | 22,827,692 |
| 7+300 | 4100 | 329,277 | Dry | 23,156,969 |
| 7+400 | 6057 | 507,859 | Dry | 23,664,827 |
| 7+500 | 4872 | 546,435 | Dry | 24,211,262 |
| 7+600 | 4907 | 488,925 | Dry | 24,700,187 |
| 7+700 | 3908 | 440,754 | Dry | 25,140,941 |
| 7+800 | 3602 | 375,505 | Dry | 25,516,446 |
| 7+900 | 3346 | 347,416 | Dry | 25,863,862 |
| 8+000 | 2635 | 299,086 | Dry | 26,162,948 |
| 8+100 | 5191 | 391,318 | Dry | 26,554,266 |
| 8+200 | 2398 | 379,459 | Dry | 26,933,724 |
| 8+300 | 6353 | 437,550 | Wet | 27,371,274 |
| 8+400 | 6479 | 641,601 | Wet | 28,012,875 |
| 8+500 | 7007 | 674,285 | Wet | 28,687,160 |
| 8+600 | 6454 | 673,005 | Wet | 29,360,165 |

# Table C - 8

## Summary of Excavation Quantities

## Alignment P2 Phase 1 - Channel Bottom 184m Wide at El. 10.36

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 8+700 | 5614 | 603,373 | Wet | 29,963,538 |
| 8+800 | 5305 | 545,949 | Wet | 30,509,487 |
| 8+900 | 4953 | 512,905 | Wet | 31,022,391 |
| 9+000 | 6076 | 551,453 | Wet | 31,573,844 |
| 9+100 | 5953 | 601,479 | Wet | 32,175,323 |
| 9+200 | 5750 | 585,155 | Wet | 32,760,478 |
| 9+300 | 5326 | 553,761 | Wet | 33,314,238 |
| 9+400 | 5220 | 527,287 | Wet | 33,841,525 |
| 9+500 | 4855 | 503,770 | Wet | 34,345,295 |
| 9+600 | 4528 | 469,188 | Wet | 34,814,483 |
| 9+700 | 3839 | 418,371 | Wet | 35,232,854 |
| 9+800 | 3450 | 364,423 | Wet | 35,597,276 |
| 9+900 | 3275 | 336,201 | Wet | 35,933,477 |
| 10+000 | 3058 | 316,609 | Wet | 36,250,086 |
| 10+100 | 2921 | 298,909 | Wet | 36,548,995 |
| 10+200 | 2658 | 278,935 | Wet | 36,827,929 |
| 10+300 | 2417 | 253,766 | Wet | 37,081,695 |
| 10+400 | 2164 | 229,047 | Wet | 37,310,742 |
| 10+453 | 1962 | 109,341 | Wet | 37,420,083 |
| | **Wet Excavation** | **10,625,659** | | |
| | **Dry Excavation** | **26,794,424** | | |
| | **Total** | **37,420,083** | | |

# Table C - 9

## Summary of Excavation Quantities

## Alignment P2 Phase 2 - Channel Bottom 184m Wide at El. 7.16

Computed: LEG
Checked : BMR

| Station Number | Cut Area (m²) | Station Volume (m³) | Excavation Type | Cumulative Volume (m³) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 1+000 | 644 | - | Wet | - |
| 1+100 | 625 | 63,445 | Wet | 63,445 |
| 1+200 | 628 | 62,663 | Wet | 126,108 |
| 1+300 | 673 | 65,071 | Wet | 191,180 |
| 1+400* | 791 | 68,093 | Wet | 259,272 |
| 1+500* | 1220 | 95,439 | Wet | 354,711 |
| 1+600* | 1403 | 126,070 | Wet | 480,781 |
| 1+700* | 1426 | 136,333 | Wet | 617,114 |
| 1+800* | 1445 | 138,421 | Wet | 755,535 |
| 1+900* | 1380 | 136,151 | Wet | 891,686 |
| 2+000* | 1259 | 126,819 | Wet | 1,018,506 |
| 2+100* | 791 | 97,344 | Wet | 1,115,850 |
| 2+200 | 648 | 71,945 | Wet | 1,187,795 |
| 2+300 | 648 | 64,834 | Wet | 1,252,629 |
| 2+400 | 645 | 64,655 | Wet | 1,317,284 |
| 2+500 | 645 | 64,508 | Wet | 1,381,791 |
| 2+600 | 642 | 64,365 | Wet | 1,446,156 |
| 2+700 | 637 | 63,925 | Wet | 1,510,082 |
| 2+800 | 633 | 63,485 | Wet | 1,573,567 |
| 2+900 | 624 | 62,868 | Wet | 1,636,435 |
| 3+000 | 624 | 62,438 | Wet | 1,698,873 |
| 3+100 | 636 | 63,020 | Wet | 1,761,893 |
| 3+200 | 628 | 63,220 | Wet | 1,825,113 |
| 3+300 | 649 | 63,851 | Wet | 1,888,965 |
| 3+400 | 652 | 65,034 | Wet | 1,953,998 |
| 3+500 | 656 | 65,380 | Wet | 2,019,378 |
| 3+600 | 624 | 63,975 | Wet | 2,083,353 |
| 3+700 | 622 | 62,295 | Wet | 2,145,648 |
| 3+800 | 634 | 62,797 | Wet | 2,208,445 |
| 3+900 | 636 | 63,476 | Wet | 2,271,921 |
| 4+000 | 629 | 63,250 | Wet | 2,335,171 |
| 4+100 | 633 | 63,100 | Wet | 2,398,271 |
| 4+200 | 641 | 63,662 | Wet | 2,461,932 |
| 4+300 | 670 | 65,523 | Wet | 2,527,455 |
| 4+400 | 627 | 64,851 | Wet | 2,592,306 |
| 4+500 | 639 | 63,331 | Wet | 2,655,637 |
| 4+600 | 628 | 63,369 | Wet | 2,719,006 |
| 4+700 | 625 | 62,649 | Wet | 2,781,655 |

* Modified volume to reflect Gaillard Cut Widening Program

# Table C - 9

## Summary of Excavation Quantities
## Alignment P2 Phase 2 - Channel Bottom 184m Wide at El. 7.16

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 4+800 | 631 | 62,788 | Wet | 2,844,443 |
| 4+900 | 665 | 64,775 | Wet | 2,909,218 |
| 5+000 | 697 | 68,062 | Wet | 2,977,280 |
| 5+100 | 685 | 69,096 | Wet | 3,046,376 |
| 5+200 | 650 | 66,762 | Wet | 3,113,138 |
| 5+300 | 668 | 65,881 | Wet | 3,179,019 |
| 5+400 | 628 | 64,808 | Wet | 3,243,827 |
| 5+500 | 623 | 62,558 | Wet | 3,306,385 |
| 5+600 | 629 | 62,578 | Wet | 3,368,963 |
| 5+700 | 639 | 63,370 | Wet | 3,432,333 |
| 5+800 | 639 | 63,882 | Wet | 3,496,215 |
| 5+900 | 624 | 63,134 | Wet | 3,559,349 |
| 6+000 | 586 | 60,502 | Wet | 3,619,851 |
| 6+100 | 328 | 45,703 | Wet | 3,665,553 |
| | **Wet Excavation** | **3,665,553** | | |
| | **Dry Excavation** | **-** | | |
| | **Total** | **3,665,553** | | |

# Table C - 10

## Summary of Excavation Quantities

## Alignment P2 Phase 2a - Channel Bottom 184m Wide at El. 8.08

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 1+000 | 457 | - | Wet | - |
| 1+100 | 444 | 45,079 | Wet | 45,079 |
| 1+200 | 446 | 44,543 | Wet | 89,622 |
| 1+300 | 474 | 46,016 | Wet | 135,639 |
| 1+400* | 557 | 46,406 | Wet | 182,045 |
| 1+500* | 863 | 65,885 | Wet | 247,930 |
| 1+600* | 992 | 87,657 | Wet | 335,586 |
| 1+700* | 1015 | 95,223 | Wet | 430,810 |
| 1+800* | 1029 | 97,063 | Wet | 527,873 |
| 1+900* | 982 | 95,439 | Wet | 623,312 |
| 2+000* | 895 | 88,733 | Wet | 712,044 |
| 2+100* | 562 | 67,734 | Wet | 779,779 |
| 2+200 | 461 | 51,158 | Wet | 830,937 |
| 2+300 | 461 | 46,088 | Wet | 877,025 |
| 2+400 | 458 | 45,963 | Wet | 922,988 |
| 2+500 | 459 | 45,856 | Wet | 968,844 |
| 2+600 | 456 | 45,753 | Wet | 1,014,597 |
| 2+700 | 453 | 45,439 | Wet | 1,060,036 |
| 2+800 | 450 | 45,125 | Wet | 1,105,161 |
| 2+900 | 444 | 44,688 | Wet | 1,149,849 |
| 3+000 | 444 | 44,382 | Wet | 1,194,231 |
| 3+100 | 452 | 44,792 | Wet | 1,239,023 |
| 3+200 | 447 | 44,933 | Wet | 1,283,956 |
| 3+300 | 461 | 45,388 | Wet | 1,329,344 |
| 3+400 | 463 | 46,228 | Wet | 1,375,572 |
| 3+500 | 466 | 46,465 | Wet | 1,422,037 |
| 3+600 | 443 | 45,466 | Wet | 1,467,503 |
| 3+700 | 442 | 44,280 | Wet | 1,511,784 |
| 3+800 | 451 | 44,639 | Wet | 1,556,423 |
| 3+900 | 452 | 45,123 | Wet | 1,601,546 |
| 4+000 | 447 | 44,962 | Wet | 1,646,508 |
| 4+100 | 450 | 44,859 | Wet | 1,691,367 |
| 4+200 | 455 | 45,260 | Wet | 1,736,628 |
| 4+300 | 476 | 46,579 | Wet | 1,783,207 |
| 4+400 | 446 | 46,102 | Wet | 1,829,309 |
| 4+500 | 455 | 45,026 | Wet | 1,874,336 |
| 4+600 | 447 | 45,082 | Wet | 1,919,417 |
| 4+700 | 445 | 44,597 | Wet | 1,964,014 |

* Modified volume to reflect Gaillard Cut Widening Program

# Table C - 10

## Summary of Excavation Quantities

## Alignment P2 Phase 2a - Channel Bottom 184m Wide at El. 8.08

Computed: LEG
Checked : BMR

| Station Number | Cut Area ($m^2$) | Station Volume ($m^3$) | Excavation Type | Cumulative Volume ($m^3$) |
|---|---|---|---|---|
| 4+800 | 449 | 44,690 | Wet | 2,008,704 |
| 4+900 | 473 | 46,100 | Wet | 2,054,804 |
| 5+000 | 495 | 48,411 | Wet | 2,103,215 |
| 5+100 | 475 | 48,519 | Wet | 2,151,735 |
| 5+200 | 452 | 46,354 | Wet | 2,198,089 |
| 5+300 | 477 | 46,423 | Wet | 2,244,511 |
| 5+400 | 447 | 46,188 | Wet | 2,290,700 |
| 5+500 | 443 | 44,518 | Wet | 2,335,217 |
| 5+600 | 447 | 44,503 | Wet | 2,379,720 |
| 5+700 | 454 | 45,046 | Wet | 2,424,766 |
| 5+800 | 454 | 45,416 | Wet | 2,470,182 |
| 5+900 | 443 | 44,878 | Wet | 2,515,059 |
| 6+000 | 417 | 43,002 | Wet | 2,558,061 |
| 6+100 | 232 | 32,458 | Wet | 2,590,520 |
| | **Wet Excavation** | **2,590,520** | | |
| | **Dry Excavation** | **-** | | |
| | **Total** | **2,590,520** | | |

# THE PANAMA CANAL
# EVALUATION OF LOCK CHANNEL ALIGNMENTS
# PART 3 - FINAL EVALUATION AND OPTIMIZATION

# APPENDIX D

# REFERENCES

# THE PANAMA CANAL
# EVALUATION OF LOCK CHANNEL ALIGNMENTS
# PART 3 - FINAL EVALUATION AND OPTIMIZATION

## APPENDIX D
## REFERENCES

Delgado V., Rigoberto. Alignments of the Panama Canal Studies Review, 1999.

Japan International Cooperation Agency. Final Report for the Study of Alternatives to the Panama Canal (Canal Alternative Study (CAS)), by Yachiyo Engineering Co., LTD. 1993.

McCarville, James R. and Haydee F. McCarville. Definitional Mission Report on Projects of the Panama Canal and a Crossing of the Panama Canal, 1998.

Panama Canal Commission. Concepts Study for Canal Alternatives, by USACE Pittsburgh District. 1997.

The Panama Canal Commission (PCC) and HARZA Engineering Company. Delivery Order for Evaluation of Lock Channel Alignments (Scope of Work), 1999.