Flood mitigation program for Gatun lake

Programa de mitigación de inundaciones del lago Gatún

Moffatt & Nichol Engineers

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Introducción y Recomendaciones

1 INTRODUCTION

1.1 Background

As part of the preparation of an overall Master Plan for expansion of the Panama Canal, the Panama Canal Authority (ACP) is studying a number of options to upgrade the Canal infrastructure and existing infrastructure limitations, including the current capacity of Gatun Spillway.

When the current spillway was designed in the early 1900's, very little information was available concerning the hydrology and hydraulics of the Rio Chagres. The current spillway capacity was designed based on discharges calculated from historical flood elevations along the river and a maximum operational lake level of 25.90 m (85 ft). In subsequent years, the maximum operating level was raised to 26.67 m (87.5 ft) to satisfy additional water demands and accommodate increasing vessel drafts. Now, after 90 years of operation, a significant amount of hydrologic data has been collected for both the river and climatology of the region. Studies since 1945 have found that the current spillway capacity is insufficient to safely handle maximum floods. The international standards for dams such as Gatun state that the spillway must be designed to meet the Probable Maximum Flood (PMF). Therefore, additional spillway capacity is needed in order to meet this criteria and to protect the Lake and the viability of the Canal system itself.

Increasing the spillway capacity will also allow the operation of the Lake at a higher elevation without compromising safety of structures and navigation. It would also increase the water yield from the Canal Lake system. Therefore, as part of the evaluation of a new spillway, consideration should also be made to evaluate the optimal maximum operating lake level (MOLL) for Gatun Lake with both the existing and proposed spillways.

As part of the evaluation of the optimal MOLL, numerous issues will have to considered including present and future water demands for navigation as well as for municipal and industrial uses. In addition to these impacts, potential flooding impacts on structures and facilities bordering the Lake will also require careful consideration as many ACP and third party structures border the lake. The imposition of higher lake elevations on the existing spillway also requires careful consideration in light of these concerns.

Finally, concerns have also been raised regarding the stability of the Gatun Dam and Spillway during a seismic event. ACP is currently undertaking an evaluation of the seismic stability of the existing locks and all other key structures as part of the long term Master Plan, and clearly the stability of the existing spillway must be included within this analysis.

1.2 Study Objectives

The primary objective of this study is to evaluate the stability and capacity of the existing Gatun Spillway and recommend alternatives for additional spillway capacity to mitigate the potential for flooding that might occur in the event of severe precipitation conditions.

The secondary and related objective is to examine the structural, environmental, hydraulic and cost implications of an increase in the existing MOLL as a result of the additional spillway capacity gained, in order to reduce the necessity of draft restrictions in the Canal during periods of prolonged dry weather.

1.3 Scope of this Report

This feasibility study first examines the existing Gatun Lake spillway and dam and assesses its hydraulic and structural capability to meet a Probable Maximum Flood (PMF) condition and also to respond to seismic events. Feasibility level design for the additional spillway capacity required is also presented.

The second component of the Flood Mitigation program then evaluates the impact of a series of incremental increases in the MOLL on the existing structures surrounding and impacted by the waters of Lake Gatun as a result of the additional spillway capacity gained. These include the existing spillway, the locks at Pedro Miguel and Gatun, a number of saddle dams, ACP installations at Gamboa and a number of third party facilities and structures located around the lake and downstream of the existing spillway.

Environmental and socio economic impacts are also evaluated, with recommendations for mitigation or avoidance of impacts where relevant. Cost estimates are provided for the modification or reconstruction of those structures that might be impacted by the incremental increases, based on conceptual designs or information available in previous reports.

Finally an economic benefits evaluation is provided in order to assist with the selection of the optimum MOLL.

6 SUMMARY AND RECOMMENDATIONS

6.1 Existing Spillway

Primary findings and recommendations arising from the analyses of the existing spillway are:

- Although Gatun Spillway has successfully operated for 91 years, it now requires upgrading to meet modern dam safety requirements. Modifications needed to accommodate a higher MOLL can be incorporated into these upgrades.
- Gatun Dam has been determined to be a “High Hazard” structure. Due to this designation and the potential economic consequences of a protracted outage of the canal due to dam failure, the recommended design flood is the Probable Maximum Flood.
- The hydraulic capacity of the spillway alone is insufficient to meet flood control requirements for Gatun Dam and other canal structures in the event of the Probable Maximum Flood. The present flood control plan envisages supplemental discharge of water through lock structures. Previous releases of spill through lock culverts have caused damage to the lock structures. Additional spillway capacity is required and could be best acquired by building an additional spillway.
- The inflow design flood and the ranges of headwater and tailwater elevations under which the spillway is now required to operate are considerably different than those that were anticipated when the structure was designed. It is recommended that the spillway be modeled over the full range of hydraulic conditions to ensure that it can safely perform as required
- The 1,000 and 5,000-year (Level I and Level II) return period earthquakes were selected for structural stability analyses. Stability analyses of the existing spillway ogee section under hydraulic and seismic loading indicate that it can satisfy overall sliding and overturning stability criteria under a maximum operating lake level of El. 27.44 m (90.0 ft) and a PMF reservoir level of El. 28.05 m (92.0 ft.).
- Previous structural analyses of the spillway piers by ACP have identified a lateral stability deficiency due to a lack of vertical steel reinforcement. Preliminary investigations indicate that this deficiency could be remedied by retrofitting vertical tendons in the piers and horizontal struts between the tops of the piers.

- The spillway gates have exceeded their expected service life and are due for replacement. It is recommended that the existing vertical lift Stoney gates be replaced with vertical lift fixed wheel gates with overhead electric hoists.
- For planning purposes, the estimated construction cost of rehabilitation of the spillway piers is $2,534,000. The estimated construction cost of replacement of the spillway gates and hoists is $27,331,000.
- Flood control operations are critical to the continued and safe operation of the Panama Canal so the proposed spillway improvement program should be implemented as soon as possible. Remediation work on the existing spillway could temporarily reduce spillway capacity while existing gates are removed and modifications are made to piers, gate guides and hoists. Factors that could mitigate this temporary loss of capacity include: Adding the new spillway prior to remediation work, scheduling remediation work for the dry season and scheduling the work so that only one gate is out of serivce at any time. Scheduling of the project should be refined relative to ACP's overall plan for upgrading the canal.
- Strengthening of the existing piers could be carried out without restricting spillway capacity.

6.2 New Spillway

Additional spillway capacity is required at Gatun Lake to meet modern dam safety requirements for Gatun Dam. This would also enable ACP to increase the maximum operating level of the lake and reduce the surcharge that must be maintained to pass large floods.

The capacity of the new spillway under the current operating regime is 5912 cms (208,780 cfs) at the current maximum operating level of El. 26.67 m (87.5 ft) PLD and the estimated maximum discharge at El. 27.43 (90 ft.) is 6693 cms (236,360 cfs). The estimated maximum flow under PMF routing assumptions El. 28.04 m. (92.0 ft) PLD is 7303 cms (257,910 cfs).

6.2.1 Establishment of PMF

The computations used for this report indicate that the current PMF flood appears to be only four times greater than a reported 15-year event. Given that the current PMF was developed in the early 1970's and over 30 years of additional hydrologic data is now available, it is recommended that the PMF be re-evaluated prior to the design stage, in order to verify its applicability.

6.2.2 Location Alternatives

Study of alternative locations for new spillway have determined that the most promising site is at the left (west) side of the dam where the embankment dam abuts a natural ridge that is comprised of Gatun series sedimentary rocks covered with a mantle of natural soil and embankment fill.

The proposed spillway arrangement is for a gated overflow spillway with seven crest gates that are twice as high as the gates on the existing spillway. The gates would be of the radial gate design instead of the present vertical lift gates on the existing spillway.

6.2.3 Recommended Spillway Configuration

Development of additional spillway capacity at the west abutment of Gatun dam appears to be feasible.The recommended project configuration is for a gated overflow surface spillway with a short approach channel, discharge channel and concrete lined stilling basin.

6.2.4 Site Investigation

The site investigation undertaken by ACP for this feasibility study was used to determine the optimum location and configuration of the new spillway structures. However, there are still some unresolved issues related to the competence and surface profile of the rock layers in the area of the proposed spillway and the stilling basin. More information is also required to map the location of the apparent fault line within the project site.

6.2.5 Hydraulic Modelling

Design of the approach channel, stilling basin and outflow channel would benefit from hydraulic modelling. In addition the potential effects of higher tailwater on the safety and operation of the existing spillway should be explored in conjunction with recommended hydraulic modeling of operation under existing conditions.

6.2.6 Potential Design Refinements

Design refinements that should be explored at the detailed design phase, when additional site investigation data is available include:

- Rotating the spillway counterclockwise to improve the approach conditions.
- Reduce the length of training wall on the left (west side of the spillway channel).
- Use of ground improvement techniques to improve the stability of embankment fill.
- Move the control structure upstream to reduce the cost of the training walls

- Trim down the size of gravity walls on the discharge chute immediately downstream of the control structure.
- Explore the use of secant pile walls on the discharge channel and stilling basin to reduce the need for temporary cofferdams and ground support.
- Optimize the hydraulic and structural design of the spillway gate structure.
- Optimize the size and number of spillway gates.
- Optimize the stilling basin design. If feasible, a sloping apron Type V Basin may prove to be superior to Type II design.

6.2.7 Construction Schedule & Costs

The spillway would take at least two years to construct and is estimated to cost approximately $US 91.0 million. The full project implementation schedule is currently estimated to be 52 months or 4.33 years including environmental studies, additional field investigations and final design. Raising of Mindi Dike is also recommended to limit impacts to navigation during the Canal Operational Flood. This construction is estimated to cost on the order of $US 3.1 million. Therefore, the total cost of the new spillway project is estimated to be $US 94.1 million. If a dike is required to protect Fort Sherman Road across Mojinga Swamp, this would incur an additional cost of $US 4.0 million.

6.2.8 Recommended MOLL

Given the need for further examination and discussion of the selection parameters used to identify the optimum MOLL, no firm conclusions are presented in this report. However, if it is considered that the current level of reliability must be provided in the future and water demands will eventually approach full-buildout conditions, an MOLL of at least 27.13 m (89.0 ft) and up to 28.04 m (90.0 ft) should be considered. While an MOLL of 28.04 m (90.0 ft) would be preferable as water demands approach full-buildout conditions, this significantly exceeds the ACP projections.

This then indicates that a reasonable target elevation for the MOLL will lie between these two elevations, with the exact determination of the optimum MOLL to be dependent on further analysis of the costs, transit projections and prioritization of evaluation criteria. Currently, the range of costs for the MOLL project is expected to range between $US 12.3 million and $US 31.6 million depending on the final MOLL selected.