US Army Corps of Engineers
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PANAMA CANAL

Reconnaissance Study

Identification, Definition and Evaluation of Water Supply Projects

Volume II

31 December 1999

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Volume 2

Panama Canal

Reconnaissance Study

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TABLE OF CONTENTS

SECTION 17

Upper Rio Trinidad

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein would include a dam and lake on the Upper Rio Trinidad passing water directly to Gatun Lake via the Rio Trinidad. Water impounded in Upper Rio Trinidad Lake would be transferred to the Gatun Lake as needed to support canal operations.

The Upper Rio Trinidad watershed is a portion of the southwestern side of the Panama Canal watershed. The proposed Upper Trinidad dam site would be on Rio Trinidad approximately 5 km upstream from Gatun Lake. Plate 17 - 1 shows the location of the proposed Upper Rio Trinidad project. Since the Upper Trinidad Lake is within the Panama Canal watershed, it would only provide additional storage. The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, a hydropower plant at the dam, and outlet works.

The proposed Upper Rio Trinidad project would contribute only slightly to the hydrologic reliability of the Panama Canal to serve its customers and minimally alter the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent (46.42 lockages) of the current level would be 98.8 percent. These figures would be virtually unaffected by installation of the Upper Rio Trinidad project.

The amount of hydropower energy that could be produced by the hydropower plants in the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water increase. With the inclusion of the hydropower plants at the proposed Upper Rio Trinidad project, the system could produce some additional megawatt hours of hydropower.

The proposed Rio Upper Trinidad Project was weighed against the technical objectives stated in Section 4 of this report and was found to be lacking in the fundamental purpose for which these alternatives are intended. The volume of water produced by this project would not be enough to significantly affect the reliability of the Panama Canal water supply. The additional storage allows demands on the system to increase by only 2.5 percent before the reliability of the system drops below the current level of 99.60 percent. This would equate to approximately 0.97 lockages. Criteria set forth in Section 4 requires that a project provide at least one additional lockage. Upper Trinidad falls short of that goal. The only apparent benefit to be derived by installation of this project would be the small amount of incidental hydropower that could be produced.

Since the plan for the development of the Rio Upper Trinidad does not meet the first criterion set forth in Section 4, it will not be pursued further and will be eliminated from the list of technically viable projects to be subjected to further scrutiny in this report. No formal cost estimate, economic analysis or environmental analyses will be made of this alternative.

Site Selection

The proposed Upper Rio Trinidad dam site was chosen with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Upper Rio Trinidad watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and where the valley was relatively narrow. The portion of the Upper Rio Trinidad watershed immediately above Gatun Lake contains several sites that meet these criteria.

The site chosen for the proposed Upper Rio Trinidad Dam would be approximately 5 km upstream from Gatun Lake. This site would accommodate construction of a dam with a normal operating lake level at elevation 100 m MSL and a maximum flood lake level at elevation 104 m MSL.

Hydrologic Considerations

The Upper Rio Trinidad flows northward from the Continental Divide to Gatun Lake. The headwater of the watershed begins at approximate elevation 1,000 m MSL approximately 30 km south of the point where the Rio Trinidad enters Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 3,200 mm in the upper basin areas near the Continental Divide to 2,600 mm at Gatun Lake. The proposed Upper Trinidad Lake would receive runoff from approximately 168 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 7 CMS at the proposed dam site.

The discharge at the Rio Trinidad dam site was obtained by extrapolating the recorded and correlated stream flow data of the El Chorro hydrologic station.

This station began operation in 1948 and is still in operation. In order to complete missing data and to increase the period of record, a significant statistical correlation using standard hydrologic techniques was established with the discharge data of the Rio Ciri Grande at Los Cañones. The consistency of the data measured and correlated was verified using the double mass curve method with satisfactory results.

Because of the proximity of Upper Rio Trinidad to Gatun Lake, and because of the absence of site specific information, the monthly evaporation rates established for Gatun Lake were considered appropriate for the evaporation rates of Upper Trinidad Lake.

Geologic Considerations

The proposed Upper Trinidad project is located in an area of the Isthmus of Panama where Pleistocene aged extrusive igneous rocks (basalts, andesites, amygdaloids, and vitrophyres) of the Cerro Viejo Formation are encountered at the surface. A visit was made during the preparation of this report to the site of the PCC gauging station located approximate 1.5 km downstream from the proposed dam location. At the gauging station the river flows through a narrow gorge eroded in columnar jointed basalt. The basalt columns averaged about 2 m in diameter and, along the river bank, were separated by joints open to at least .33 m. The rock at the gauging station was hard and appeared to be high quality. If the rock at the proposed site is similar, it is expected to be adequate for either rock fill or concrete aggregate.

In the absence of detailed geologic information for the proposed Upper Rio Trinidad dam site, a degree of extrapolation was necessary. It was predicted that rock, at the site, would be encountered at a shallow depth and would be of sufficient quality to serve as foundation material for the dam and appurtenant structures. Furthermore, it was assumed that sufficient rock for fill and concrete aggregate would be available from the required excavation and that impervious materials would be available within the immediate area for use in the construction of the project.

Lake Operation

Two operating options were considered in this study for periods when water would be transferred from Indio Lake to the Panama Canal watershed for canal operations. Operating Option 1 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 100 m MSL down to the minimum operating lake level at elevation 80 m MSL with 80 MCM of useable storage. Operating Option 2 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 100 m MSL down to the minimum operating lake level at elevation 90 m MSL with 51 MCM of usable storage. The maximum flood lake level would be at elevation 104 m MSL. The volume between the maximum flood lake level and the normal operating lake level would be used to store floodwaters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Upper Rio Trinidad downstream of the dam, and flood flow impacts on Gatun Lake would be lessened to some degree. Table 17 - 1 shows the lake levels for the two operating options.

Table 17 - 1 Lake Operating Options

Lake Level (m MSL)	Operating Option 1	Operating Option 2
Normal Operating Lake Level	100	100
Minimum Operating Lake Level	80	90
Maximum Flood Lake Level	104	104

Project Features

GENERAL

The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, a hydropower plant at the dam, and outlet works. The following paragraphs provide a description of the proposed structures and improvements for the Upper Rio Trinidad Lake project. The major structural components indicated here are configured for Operating Option 1. In some instances, the proposed structures and improvements for Operating Option 1 and Operating Option 2 would be slightly different. Plate 17 - 2 depicts the dam site in downstream left bank perspective view.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the PCC that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The dam would be an embankment with the top at elevation 105 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercado Grid, Zone 17, Clark 1866 Spheroid Coordinates 990,882 north and 610,011 east. The right abutment would be 990,547 north and 610,532 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam at its highest point would be approximately 45 m high, and the overall length would be 620 m. The actual side slopes and crest width would be determined during further study and would be contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. The embankment would be constructed as shown for the Rio Indio project, Section 5 of this report.

Foundation grouting might be required across the entire base of the dam and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

SPILLWAY

An uncontrolled ogee spillway with a length of 41.1 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 636 CMS at a maximum flood lake level at elevation 104 m MSL. The spillway design discharge was equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway would be located within the abutment some distance from the right end of the dam and would consist of a mass concrete sill section embedded in the natural rock. A sloped and / or stepped, natural rock cut tailrace channel would return flow to the existing stream. The tailrace channel would extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. The spillway would be similar to that shown for the Rio Indio project, Section 5 of this report.

IMPOUNDMENT

The lake formed by the proposed Upper Rio Trinidad Dam would have a normal operating lake level at elevation 100 m MSL. The surface area at the normal operating lake level would be approximately 694 ha. At the maximum flood lake level, elevation 104 m MSL, the surface area would be approximately 870 ha. With the minimum operating lake level at elevation 80 m MSL (Operating Option 1), the surface area would be approximately 165 ha. With the minimum operating lake level at elevation 90 m MSL (Operating Option 2), the surface area would be approximately 366 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas required for construction of the dam (embankments and spillway), outlet works, hydropower plant, access roads, and disposal and staging areas. Under Operating Option 1, clearing only would be required for the 529 ha in the lake area between the normal operating lake level at elevation 100 m MSL and the minimum operating lake level at elevation 80 m MSL, and for the transmission line. Under Operating Option 2, clearing only would be required for the 328 ha in the lake area between the normal operating lake level at elevation 100 m MSL and the minimum operating lake level at elevation 90 m MSL, and for the transmission line.

HYDROPOWER PLANT

The flows, excess to the needs of the Panama Canal operation, at the proposed Upper Rio Trinidad Dam would support installation of a 4.8 MW hydropower plant with a plant factor of 0.5 at the dam. This plant would consist of a single power generating unit designed and configured to function as part of the national power grid. A transmission line would be required to carry the energy to a connection with the grid near La Chorrera.

OUTLET WORKS

An outlet works system would be required to provide for diversion of the Upper Rio Trinidad flows during construction, to supply flows for production of hydropower, to allow for emergency drawdown of the lake, to pass water to Gatun Lake for navigation, and to allow minimum flow to pass through the dam.

This outlet works system would be served by a single intake structure. This structure would be configured to allow passage of channel flows up to the required level of protection during construction. Once diversion was no longer needed for construction, the structure would be used to control the flows for hydropower and for navigation releases, and for emergency drawdown. It would also have separate controlled water intakes at various elevations to allow flows to be withdrawn from the lake to optimize the quality of the water passed as minimum flow. The hydropower intake would also be elevated to prevent silt from entering the power units.

This system would consist of a 6.1 by 6.1 m horseshoe shaped tunnel passing through the left dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits. The diversion tunnel would be 710 m in length; it would have an inlet invert at elevation 60 m MSL and an outlet invert at elevation 58 m MSL. The diversion tunnel would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of approximately 307 CMS at the site without regulation from the dam. The cofferdam would measure 8.2 m above the upstream invert of the tunnel. A separate 410 mm diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be 710 m in length; it would have an inlet invert at elevation 58 m MSL and an outlet invert at elevation 56 m MSL. The capacity of the minimum flow conduit would be 0.7 CMS. A gated / stoplog structure would be required at the tunnel outlet to close the construction diversion for maintenance and to divert flows from the lake into the hydropower conduit. The closure would be configured so that it could be removed in the event that the Upper Trinidad Lake had to be drawn down.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from the main population centers on the Atlantic and Pacific coasts, Colon and Panama City, respectively.

Roadway access from the south and east exists as far as the village of Arosemena. From this point, a new roadway would be constructed to the dam site and lake area some 1.5 km to the west.

In addition to providing construction access, this new corridor into the interior of the country west of the Panama Canal will be of benefit to those living in that region. It would provide ready access to the main centers of commerce in the southern part of the country, La Chorrera and Panama City.

Sources of Construction Material

Rock removed from the spillway site would be used as fill in the embankment portion of the dam. Impervious materials for the core section might have to be obtained from outside the project area. For this study, it was assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that insufficient impervious materials are available, then other materials such as roller compacted concrete should be considered for the construction of the dam.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Upper Rio Trinidad project would be located in the Cocle, Colon and Panama Provinces. Construction of this proposed project would require acquisition of approximately 1,920 ha. Table 17 - 2 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 17 - 2 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	920
Dam Site	200
Staging Area	200
Disposal Area	400
Total	1,920

Relocations

The lake would be located in a sparsely populated region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. The few structures and individuals located in the lake area below elevation 105 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations.

Hydrologic Reliability

This alternative did not pass the first criterion in the initial assessment process described in Section 4. The first criterion requires that the project provide a constant firm yield equivalent to at least one lockage per day.

To determine the potential water yield for the Upper Trinidad Lake, the proposed project was added to the existing conditions model of the Panama Canal watershed, which was developed by the Hydrologic Engineering Center (HEC) under a separate work order. Monthly discharge data, as described in the section titled Hydrologic Conditions were used as input to the simulation models. Elevation-volume values at the proposed Upper Trinidad dam sites were developed from existing 1:50,000 scale topographic mapping. Model simulations were conducted for the 50.5-year period (January 1948 through July 1998) for the options described in Table 17 - 3 below, with the reservoir fluctuating between the normal operating lake level and the minimum operating lake level.

Table 17 - 3 Modeled Options

Operating Option	Normal Operating Lake Level Elevation (m MSL).	Minimum Operating Lake Level Elevation (m MSL).
Option 1	100	80
Option 2	100	90

Special operating procedures were applied to Upper Trinidad Lake to allow up to 80 percent of the conservation storage to be held until Gatun Lake reached levels that threatened shortages of water for navigation and M&I withdrawals. This permitted use of the additional storage provided by Upper Trinidad Lake at the most needed times. The HEC-5 model allows upstream reservoirs to be operated to provide water for operation of reservoirs or points downstream. When this simulation technique is applied, the model balances the reservoir storages based on criteria specified by the modeler. This criterion is provided in the operating rule curves and flow limitations in channels downstream of the reservoirs that are input by the modeler.

Table 17 - 4 shows a summary of the reliability for current demands and for 120 percent of the current demands. The demands were based on the average demands for 1993 through 1997. Based model simulations, the Upper Rio Trinidad project would provide up to 0.7 additional lockages under option 1 and 0.97 additional lockages with option 2 before the hydrologic reliability would drop below 99.6 percent. Since the reliability for both options dropped below 99.6 percent before the demand level reach 120 percent, higher demand levels were not simulated.

Table 17 - 4 Hydrologic Reliability

Percent of Demands	Lockages Provided at 99.6 Percent Reliability		
	Existing Conditions	With Option 1	With Option 2
100.0	99.60	99.68	99.68
101.9		99.60	
102.5			99.60
120.0	98.76	98.92	98.83

Hydropower

Hydropower energy that could be generated from discharges at the dam is estimated with the HEC-5 model. The plant capacities listed in Table 17 - 5 were coded into the models with energy generated when flows were released at the dam. Water quality and minimum flows were met through the minimum flow structure when the hydropower plant was not operating.

Table 17 - 5 Hydropower at Proposed Upper Trinidad Dam

Option	Lake Range (m)	Capacity (MW)	Average Annual Generation (MWH)	Effective Head (m)	Leakage (CMS)	Average Plant Factor
Upper Trinidad 1	100-80	4.8	21,164	55	0.3	0.50
Upper Trinidad 2	100-90	4.8	21,236	55	0.3	0.50

The minimum flow conduit bypasses the turbines with no resulting hydropower production. Consequently, leakage was counted toward minimum flow when the hydropower plant was not operating.

Table 17 - 6 shows the change in hydropower production at Gatun Hydropower Plant with the Upper Trinidad Plant in operation. A slight reduction in power generation at Gatun Lake is realized because more water is used for lockage and M&I water supply.

Table 17 - 6 Generation at Gatun Hydropower Plant

Percent of Demands	Average Annual Generation (MWh)		
	Existing Conditions	With Option 1	With Option 2
100	97,438	96,573	96,252
120	73,256	72,232	72,114

This alternative does not meet the minimum criterion of providing at least one lockage; therefore it should not be recommended for further consideration.

Pertinent Data

Table 17 - 7 presents pertinent data for Operating Option 1 of the proposed Upper Rio Trinidad project.

Table 17 - 7 Pertinent Data for Upper Trinidad

GENERAL		
Dam site, above Gatun Lake	5 km	
Drainage area above dam site	168 km^2	
Average annual flow at dam site	7 CMS	
LAKE	**Option 1**	**Option 2**
Elevation of normal operating lake level	100 m MSL	100 m MSL
Elevation of maximum flood lake level	104 m MSL	104 m MSL
Elevation of minimum operating lake level	80 m MSL	90 m MSL
Useable Storage between Max and Min levels	80 MCM	51 MCM
Area at normal operating lake level	694 ha	694 ha
Area at maximum flood lake level	870 ha	870 ha
Area at minimum operating lake level	165 ha	366 ha
Top clearing elevation	100 m MSL	100 m MSL
Lower clearing elevation	80 m MSL	90 m MSL
EMBANKMENTS		
Dam		
Type of dam	Rock fill embankment	
Top elevation of dam	105 m	
Fixed crest width	13 m	
Height	45 m	
Overall length of dam	620 m	
SPILLWAY		
Type of Spillway	Uncontrolled ogee	
Total length	41.1 m	
Elevation of spillway	100 m MSL	
Maximum discharge	636 CMS	

Table 17 - 7 Pertinent Data for Upper Trinidad (continued)

HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of each unit	4.8 MW
CONSTRUCTION / POWERHOUSE DIVERSION /WATER SUPPLY TUNNEL	
Diversion length	710 m
Horseshoe tunnel dimensions	6.1 by 6.1 m
Inlet invert	60 m MSL
Outlet invert	58 m MSL
Maximum Outlet Flow	307 CMS
Cofferdam Height above tunnel inlet invert	8.2 m
MINIMUM FLOW CONDUIT	
Conduit diameter	410 mm
Conduit length	710 m
Inlet invert	58 m
Outlet invert	56 m
Conduit capacity	0.7 CMS

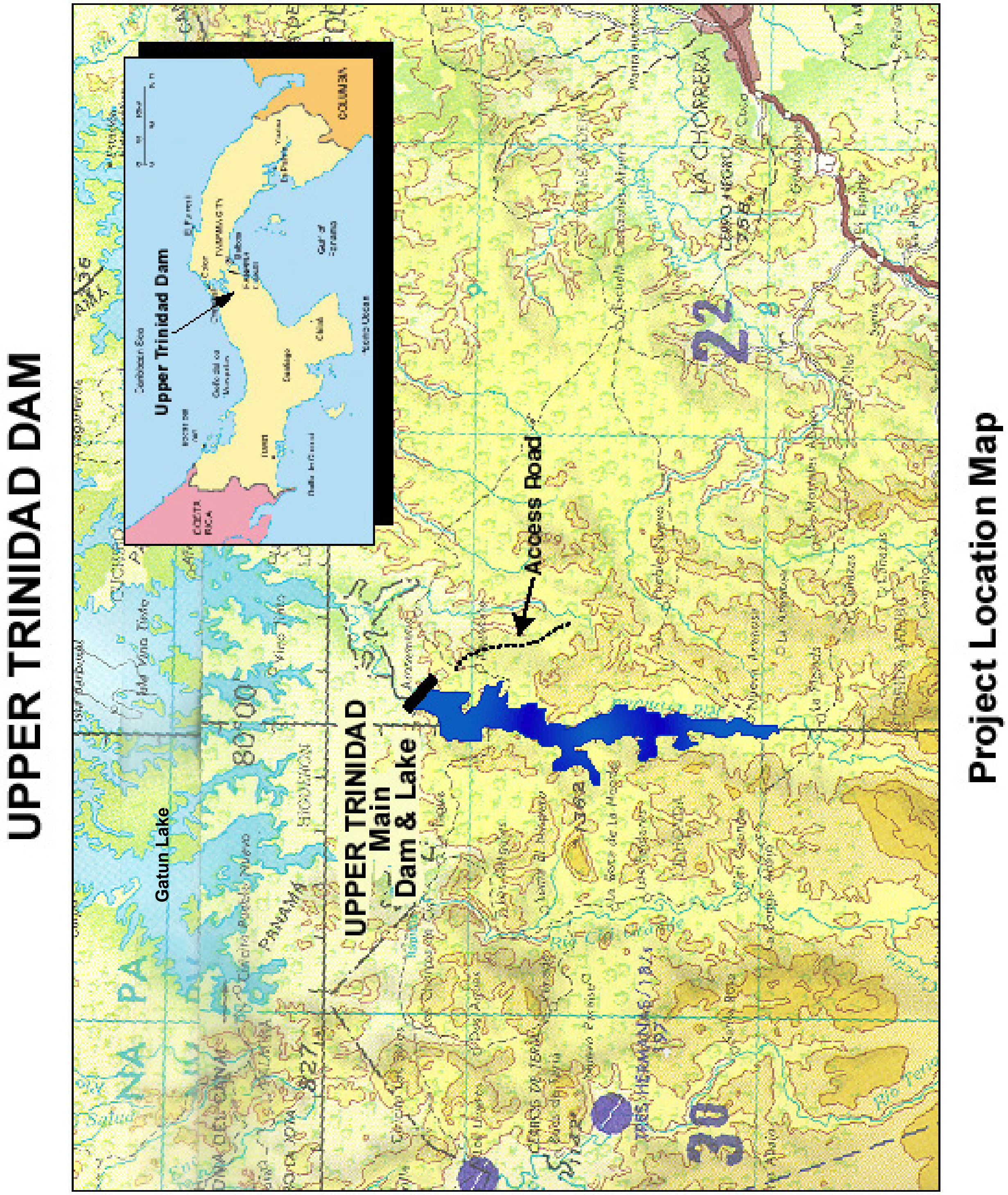


Plate 17 - 1   Project Location Map

UPPER TRINIDAD

Site Plan

Plate 17 - 2   Site Plan

SECTION 18

Rio Chagres

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein would include a dam and lake on the Rio Chagres above Madden Lake of the Panama Canal watershed. Water impounded in Chagres Lake would be transferred to the Panama Canal watershed as needed to support canal operations. The Rio Chagres comprises a portion of the eastern side of the Panama Canal watershed that feeds into Madden Lake. The proposed Rio Chagres dam site would be approximately 15 km Northeast of Buenos Aires and 1 mile downstream of the confluence of Rio Chico and Rio Chagres. Plate 18 - 1 shows the location of the proposed Rio Chagres project. The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, a hydropower plant, and outlet works. The project would transfer water through Madden Lake to Gatun Lake as needed for canal operations. The total project first costs of the proposed Rio Chagres project are estimated to be $318,975,000.

The proposed Rio Chagres project would contribute to the hydrologic reliability of the Panama Canal to serve its customers and would reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent (46.42 lockages) of the current level would be 98.8 percent. With construction of the proposed Rio Chagres project, the existing high hydrologic reliability could be continued as demand for lockages increases up to 20.45 percent (7.91 lockages) above current demand levels.

The amount of hydropower energy that could be produced by the hydropower plants in the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water increase. With the inclusion of the hydropower plants at the proposed Rio Chagres project, the system could produce additional megawatt hours of hydropower through the Chagres and Madden Dams.

Site Selection

The proposed Rio Chagres dam site was chosen with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Chagres watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow.

The site chosen for the proposed Rio Chagres Dam would be approximately 15 km Northeast of Buenos Aires and 1.6 km downstream of the Rio Chico and Rio Chagres confluence. This site would accommodate the construction of a dam with a normal operating lake level at elevation 200 m MSL and a maximum flood lake level at elevation 204 m MSL for Option 1 and a normal operating lake level at elevation 220 m MSL and a maximum flood lake level at elevation 224 m MSL for Option 2.

Hydrologic Considerations

The Rio Chagres flows southwestward into Madden Lake from the mountains of the Panama and Colon Province border. The headwater of the watershed begins at elevation 700 m MSL approximately 45 km above Madden Dam and falls to elevation 76.8 m MSL, normal pool level at Madden Lake. The distribution of the average annual rainfall over the Rio Chagres watershed varies from a high of 3,050 mm at the middle watershed area and decrease to a low of 2,800 mm on the east and west edges of the watershed. The proposed Chagres Lake would receive runoff from approximately 414 km^2 of the watershed. Rainfall runoff produces an average annual flow of 50 CMS at the proposed dam site.

The discharge at the Rio Chagres dam site was obtained from the recorded and correlated stream flow data of the Chico hydrologic gaging station. This station began operation in 1933 and is located on the Rio Chagres approximately 150 m upstream from the dam site. In order to complete missing data, a statistical correlation was established with the discharge data of the Rio Pequeni at Candelaria using standard hydrologic techniques. The consistency of the data measured and correlated was satisfactorily verified using the double mass curve method.

Because of the proximity of Rio Chagres to Madden Lake, and because of the absence of site specific information, the monthly evaporation rates established for Madden Lake were considered appropriate for the evaporation rates of Chagres Lake.

Geologic Considerations

The proposed Rio Chagres project is located in an area of the Isthmus of Panama where the geologic map shows that pillow basalts occur. A geological reconnaissance investigation of the Rio Chagres conducted during the spring of 1944 by Randolph Thompson, Chief of the Geology Section for the Panama Canal, found only andesites and diorites, occasionally cut by dams of light colored material (syenites, felsites, rhyolites, etc.), exposed in the lower portion of the Chagres River. In the area of the proposed dam site, the survey found andesite that was closely and tightly jointed. A site visit made during the preparation of this report agreed with the presence of andesite at the project location. The andesite exposed in the river channel was hard, unweathered, and of high quality. It is expected that this rock would make both a good foundation for a dam and a good source for either rock fill or concrete aggregate.

In the absence of detailed geologic information at the site, a degree of extrapolation was necessary. It was predicted that rock would be encountered at a shallow depth and would be of sufficient quality to serve as foundation material for the dam and appurtenant structures. Furthermore, it was assumed that sufficient rock for fill and concrete aggregate would be available from the required excavation and that impervious materials would be available within the immediate area for use in the construction of the project.

Lake Operation

Two operating options were considered in this study for periods when water would be transferred from Chagres Lake to the Panama Canal watershed for canal operations. Operating Option 1 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 200 m MSL down to the minimum operating lake level at elevation 180 m MSL with 207,587,000 M^3 of useable storage. Operating Option 2 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 220 m MSL down to the minimum operating lake level at elevation 180 m MSL with 518,722,000 M^3 of usable storage. The maximum flood lake level would be at elevation 204 m MSL for Option 1 and 224 m MSL for Option 2. The volume between the maximum flood lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Chagres downstream of the dam. Table 18 - 1 shows the lake levels for the two operating options.

Table 18 - 1 Lake Operating Options

Lake Level (m MSL)	Operating Option 1	Operating Option 2
Normal Operating Lake Level	200	220
Minimum Operating Lake Level	180	180
Maximum Flood Lake Level	204	224

Project Features

GENERAL

The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, a hydropower plant, and outlet works. The following paragraphs provide a description of the proposed structures and improvements for the Rio Chagres Lake project. The major structural components indicated here are configured for Operating Option 2. In some instances, the proposed structures and improvements for Operating Option 1 and Operating Option 2 would be slightly different. Plate 18 - 2 depicts the dam site.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the PCC that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The dam would be an embankment with the top at elevation 225 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1024422 north and 663611 east. The right abutment would be 1024295 north and 664280 east coordinates. The embankment would be constructed with an impervious earthen core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam at its highest point would be approximately 135 m high, and the overall length would be 680 m. The actual side slopes and crest width would be determined during further study and would be contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. The composition of the dam would be as shown for the Rio Indio Dam, Section 5 of this report.

Foundation grouting could be required across the entire base of the dam and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

SPILLWAY

An uncontrolled ogee spillway with a length of 286.5 m and a crest at elevation 220 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 4,430 CMS at a maximum flood lake level at elevation 224 m MSL. The spillway design discharge was equivalent to a 1 in 1000 frequency unregulated flow at the dam site. The spillway would be located within the abutment adjacent to the right end of the dam and would consist of a mass concrete sill section embedded in the natural rock. A sloped and / or stepped, natural rock cut tailrace channel would return flow to the existing stream. The tailrace channel would extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. See Plate 18 - 2 for the location of the spillway. The spillway profile would be similar to that shown for the Rio Indio Dam, Section 5 of this report.

IMPOUNDMENT

The lake formed by the proposed Rio Chagres Dam would have a normal operating lake level at elevation 220 m MSL. The surface area at the normal operating lake level would be approximately 1,850 ha. At the maximum flood lake level, elevation 224 m MSL, the surface area would be approximately 1,990 ha. With the minimum operating lake level at elevation 180 m MSL, the surface area would be approximately 794 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas required for construction of the dam (embankments and spillway), outlet works, hydropower plant, access roads, and disposal and staging areas. Under Operating Option 2, clearing only would be required for the 1,060 ha in the lake area between the normal operating lake level at elevation 220 m MSL and the minimum operating lake level at elevation 180 m MSL, and for the transmission lines.

HYDROPOWER PLANT

The flows released from the proposed Rio Chagres Dam would support installation of a 34.5 MW hydropower plant with a plant factor of 0.5 at the dam. The 34.5 MW hydropower plant would have two 17.25 MW units. These facilities would be designed and configured to function as part of the national power grid. A 115 kV transmission line would be required to carry the energy to a connection with the grid near Panama City. See Plate 18 - 3 for the hydropower plant details.

Model simulations indicate that the operation of the proposed Rio Chagres Lake impacts the delivery times of water to Madden. This causes a slight decrease (<1 percent) on hydropower production at Madden at current demand levels. When demand levels are increase to 180 percent of current levels, Madden experiences a net decrease in hydropower production of almost 8 percent. On the other hand, the added power production from Chagres results in an approximate 60 percent increase in total power production for the system with current demand levels for canal operation and M&I water supply.

OUTLET WORKS

An outlet works system would be required to provide for diversion of the Rio Chagres flows during construction, to supply flows for production of hydropower, allow for emergency drawdown of the lake, provide downstream minimum releases and to pass water from the Upper Chagres Lake downstream for canal operation.

This outlet works system would be included in a single intake structure. This structure would be configured to allow passage of channel flows up to the required level of protection during construction. Once diversion was no longer needed for construction, the structure would be used to control the flows for hydropower, navigation water releases, and emergency drawdown. The hydropower intake would be elevated to prevent silt from entering the power units.

This system would consist of two 7.2 by 7.2 m horseshoe shaped tunnels passing through the right abutment, an intake structure located in the lake, an outlet channel downstream and a headwall / stoplog structure at the downstream end of each tunnel. The tunnels would be 500 m in length; they would have an inlet invert at elevation 90 m MSL and an outlet invert at elevation 88 m MSL. The tunnels would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of approximately 1,882 CMS at the site without regulation from the dam. The cofferdam would measure 8.8 m above the upstream invert of the tunnel. A gate structure would be required at the tunnel outlet to close the construction diversion and to divert flows from the lake into the hydropower conduit(s). See Plate 18 - 4 for a diagram of the diversion intake structure.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from the main population centers on the Atlantic and Pacific coasts, Colon and Panama City, respectively.

The route from Colon would be southeastward following Panama Routes 3, 81 and 727 to a point immediately southeast of the village of Caimitillo. From this point, a system of improved and new roadways would be constructed to the dam site. The length of the new and improved roadway would be approximately 10 km in length and would require two stream crossings, the Rio Las Cascadas and the Rio Las Palmas.

The route from Panama City would travel northeastward following Panama Routes 3 and 727 to the point near the village of Caimitillo described above. From this point, the access to the dam site would be the same.

The route around the north side of Madden Lake would require construction of many kilometers of new roadway and would require major stream crossings at the Rio Boqueron and Rio

Pequeni. Plate 18 - 1 shows the portion of the proposed access road from Panama Route 727 to the construction site.

In providing construction access, it is noted that this new corridor into the interior of the country east of the Panama Canal would open up an heretofore undisturbed area of virgin jungle and would be deleterious to the ecology of the area.

Sources of Construction Material

Rock removed from the spillway site would be used as fill in the embankment portion of the dam. Impervious materials for the core section could have to be obtained from outside the project area. For this study, it was assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that insufficient impervious materials are available, then other materials such as roller compacted concrete should be considered for construction of the dam.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Chagres project would be located in the Colon and Panama Provinces. Construction of this proposed project would require acquisition of approximately 3,030 ha. Table 18 - 2 shows the amount of land required for the various project features.
Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 18 - 2 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	2,030
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	3,030

Relocations

The lake would be located in a sparsely populated region having no roads or utilities. This area is very rugged and covered with pristine rain forest. The few structures and individuals that might be located in the lake area below elevation 225 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising and award phase, and on through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, including the access roads, would be acquired initially. Lands for the dam site, staging area, disposal area, and lake would then be acquired.

Access roads would be constructed to the dam site and the lake area. Once highway access to the sites has been established, a camp would be built to house workers during construction.

Socio-economic programs would begin shortly before construction of the dam. The relocation of the small communities and isolated structures would be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project would continue throughout the construction phase.

Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the intake structure and construction of the diversion tunnels at the dam site and the spillway would follow. Where possible, materials removed from the excavations would be placed directly into the earth and rock fill cofferdams. Once the intake structure and diversion tunnels were completed, the dam construction site would be isolated using upstream and downstream cofferdams. These would eventually become part of the main dam, and the stream would be diverted through the tunnels. The dam foundation would then be excavated and grouted, and the dam constructed. Concurrently with construction of the dam, the hydropower plant site downstream of the dam would be excavated, and the powerhouse construction would be started. The power transmission lines would also be constructed during this time frame. Upon completion of the dam and appurtenant structures, the diversion would be stopped by closing the intake structure gates, and lake filling would begin. Simultaneously with this operation, the downstream gate and flow separation structure would be completed to provide for closure of the diversion tunnel and diversion of the tunnel flows to the hydropower penstock(s). The minimum flow conduit would also be installed through the diversion tunnel at this time. Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 10 years, from initial planning to lake filling. Figure 18 - 1 depicts the development sequence of the various project features.

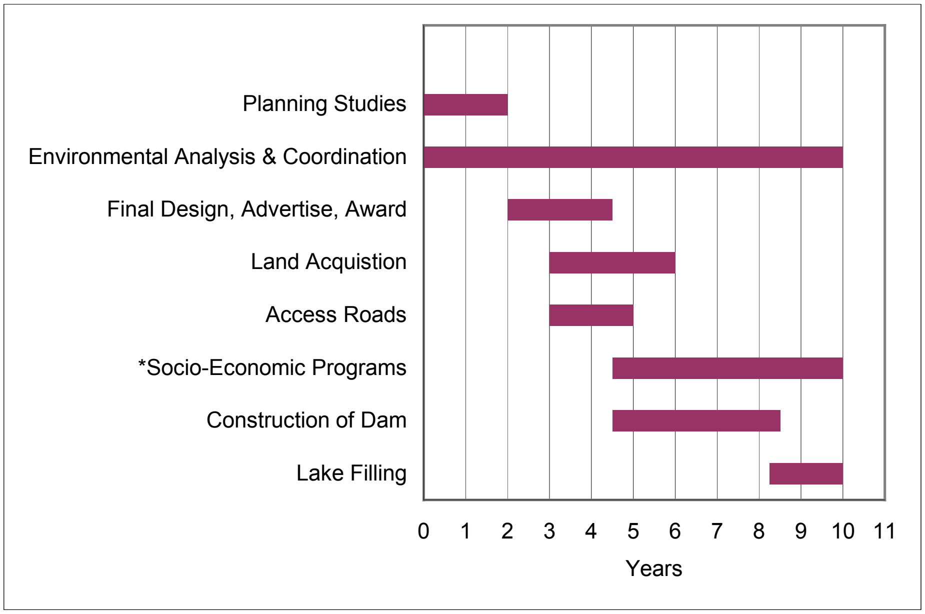


Figure 18 - 1 Development Sequence

*Socio-Economic Programs would be very limited for this project.

Hydrologic Reliability

In order to determine the effect of the proposed Rio Chagres Lake on the hydrologic reliability of the Panama Canal, the existing HEC-5 model was modified to include the Rio Chagres Lake. The Rio Chagres Lake was modeled to release flows into Madden Lake and local inflows to Madden Lake were reduced by the amount that the Rio Chagres Lake would capture.

HEC-5 model simulations were conducted for both the existing Panama Canal system and the system operating with the proposed Chagres Lake providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record. Figure 18 - 2 presents the resulting hydrologic reliability for three configurations with demands increasing up to 180 percent of current demands. These configurations were:

- Existing system,
- Operating Option 1 (Rio Chagres Lake fluctuating between the normal operating lake level at elevation 200 m MSL and the minimum operating lake level at elevation 180 m MSL), and

- Operating Option 2 (Rio Chagres Lake fluctuating between the normal operating lake level at elevation 220 m MSL and the minimum operating lake level at elevation 180 m MSL).

The horizontal axis along the bottom of Figure 18 - 2 reflects demands as a ratio of the five-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 18 - 2, the existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability with a demand ratio of 1.0 would be 99.90 percent for Operating Option 1, and the hydrologic reliability with a demand ratio of 1.8 would be 87.48 percent. With Operating Option 2, the hydrologic reliability with a demand ratio of 1.0 would be 99.99 percent, and the hydrologic reliability with a demand ratio of 1.8 would be 88.70 percent. Table 18 - 6 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the Panama Canal system would decrease. With the construction of the proposed Rio Chagres project, the existing high hydrologic reliability could be continued as demand for lockages increases up to 108.3 percent (3.21 lockages) with Option 1 and 120.45 percent (7.91 lockages) with Option 2 of current demand levels.

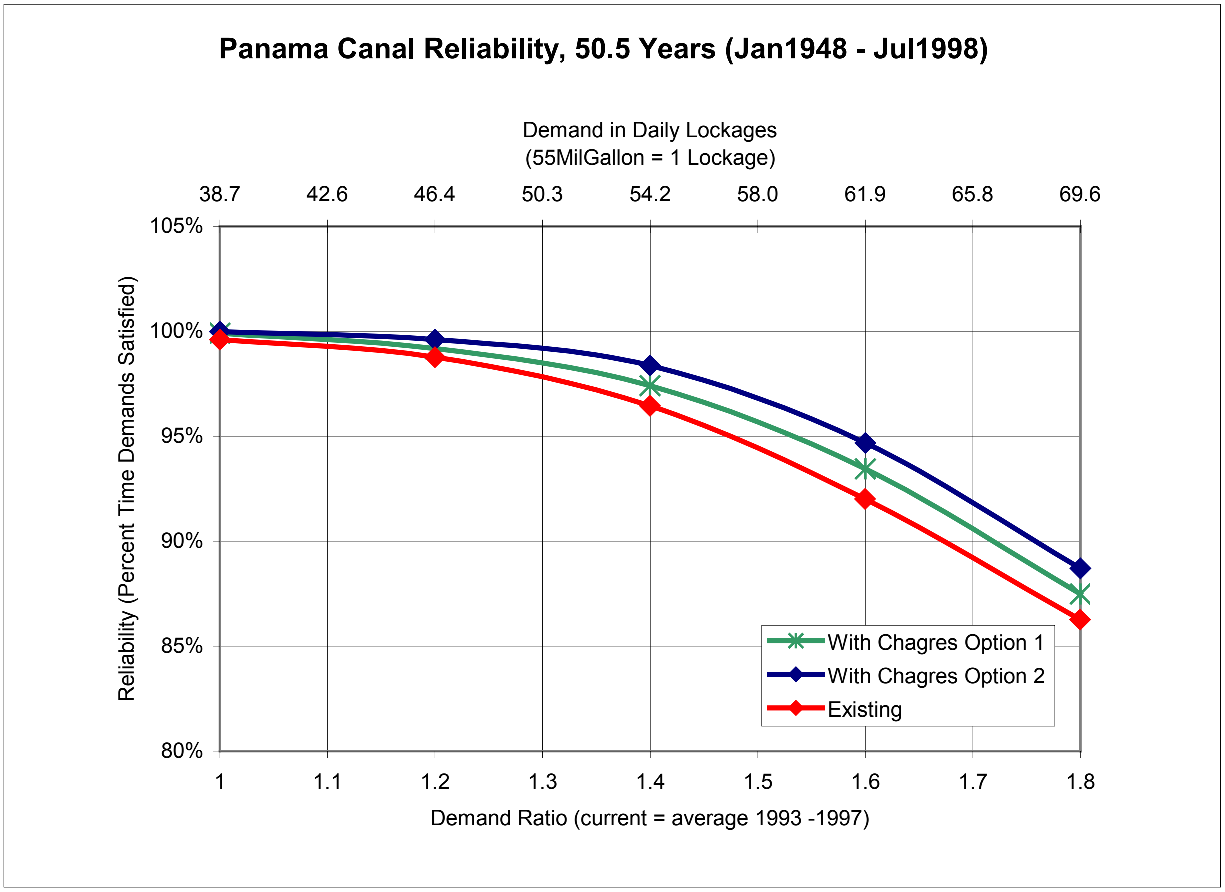


Figure 18 - 2 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts shown on Plates 18 - 1 and 18 - 2 and details provided separately. The unit prices applied to these quantities were based on historical information from previous estimates prepared for similar construction in the Republic of Panama, previous estimates for similar construction in the Southeastern United States, information gathered from Mobile District Construction Division personnel in the Republic of Panama, and the publication, Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1979.

Engineering and design is estimated to be 12 percent and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent was included for contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $318,975,000. Table 18 - 3 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 18 - 3 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	7,575,000
Access Roads	4,600,000
Clearing and / or Grubbing	23,216,250
Diversion Tunnel	19,095,910
Intake for By-pass Tunnel	10,242,135
Cofferdam	8,730,248
Dam	45,044,051
Spillway	82,143,480
Hydropower Plants	10,353,075
Transmission Lines	1,650,000
Subtotal	212,650,149
E&D, S&A, Field Overhead	42,530,030
Contingencies	63,795,045
Total Project First Costs	318,975,224 **Approximately** 318,975,000

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Chagres project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 11 who would include a station manager, a multi-skilled supervisor, 3 leaders (Electronics / Instrumentation, Electrical and Mechanical), 5 craftsmen, and one laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the proposed project. The part-time staff would consist of three mechanics and three electricians. The annual costs of the staff are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $300,000 per year for the main project facilities.

Major Replacements

The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 100 years. To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it was assumed that specific items would cost the same as at present. No allowance was made for salvageable fixed parts. Table 18 - 4 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements would be $343,000 and the average annual replacement costs would be $41,000.

Table 18 - 4 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	5,280,000	18,300
Bridges	50	1	1,575,000	5,400
Intake				
Head Gates	50	1	360,000	1,200
Stoplogs	50	1	156,750	500
Trashracks	50	1	60,000	200
Access Stairs	50	1	93,750	300
Downstream Bulkhead / Gate	50	1	382,500	1,300
Hydropower Plant				
Turbines and Generators	33	1	9,900,000	235,200
Station Electrical Equipment	33	1	1,290,000	30,600
Switchyard Equipment	33	1	1,050,000	24,900
Miscellaneous Plant Equipment	33	1	697,500	16,600
Transmission Lines	50	1	2,475,000	8,600
Total			23,320,500	343,000
Average Annual Replacement Costs				41,000

Annual Costs

The total project first costs are estimated to be $318,975,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the total project first costs was computed from mid-year throughout the 10-year period from initiation of Planning and Design until the lake was filled. The interest during construction at 12 percent would be $165,362,000 and it was added to the total project first costs for total project investment costs of $484,337,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $58,322,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to the present worth as of completion of reservoir filling. Table 18 - 5 contains a summary of the annual costs.

Table 18 - 5 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	318,975,000
Interest During Construction	165,362,000
Total Project Investment Costs	484,337,000
Annual Average Investment Costs	58,322,000
Operation and Maintenance Costs	
Staff Costs	500,000
Ordinary Maintenance Costs	320,000
Major Replacement Costs	41,000
Total Average Annual Costs	59,183,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Section 4. The following paragraphs present the results of the economic investigations for the proposed Rio Chagres project. The 50-year planning period for this proposal is 2010 to 2060.

The proposed Rio Chagres project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 18 - 6 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages were obtained from the data used to develop Figure 18 - 2. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 18 - 6 Panama Canal Hydrologic Reliability

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability		
			Existing System (%)	Operating Option 1[1/] (%)	Operating Option 2 [2/] (%)
1	2000	38.68 [3/]	99.60	99.90	99.99
	2010	45.11	98.91	99.29	99.67
1.2		46.42	98.76	99.17	99.61
	2020	47.61	98.41	98.90	99.42
	2030	49.55	97.83	98.46	99.11
	2040	52.02	97.09	97.89	98.71
1.4		54.15	96.45	97.41	98.37
	2050	55.13	95.89	96.91	97.90
	2060	59.05	94.49	95.65	96.73
1.6		61.89	92.02	93.44	94.68
	2070	63.97	90.47	91.84	93.07
1.8		69.63	86.27	87.48	88.70

[1/] Operating Option 1 (Chagres Lake fluctuating between the normal operating lake level at elevations 200 m MSL and the minimum operating lake level at elevation 180 m MSL).

[2/] Operating Option 2 (Chagres Lake fluctuating between the normal operating lake level at elevations 220 m MSL and the minimum operating lake level at elevation 180 m MSL).

[3/] 2000 Daily Demand is Average of 1993-1997

Regardless of the operating option, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands grow, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Rio Chagres project, these shortages would be less than they would be under the existing system. With a hydrologic reliability of 99.6 percent, Operating Option 1 would increase the amount of water supplied for navigation by approximately 3.21 equivalent lockages, and Operating Option 2 would increase that amount by 7.91 equivalent lockages. For Operating Option 1, the 99.6 percent hydrologic reliability would occur in the year 2009 with an equivalent daily average number of lockages set to 41.89. For Operating Option 2, the 99.6 percent hydrologic reliability level would occur in the year 2012 with an equivalent daily average number of lockages of 46.59. Benefits for these amounts of additional water would be attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages provided by each option. The average annual benefits for water supply would be $65,225,000 for Operating Option 1 and $156,098,000 for Operating Option 2. Table 18 - 7 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Rio Chagres project in operation, the annual benefits for meeting shortages and the average annual benefits for both options.

Table 18 - 7 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages With Operating Option 1	Remaining Daily Shortages With Operating Option 2	Annual Benefits for Operating Option 1 ($)	Annual Benefits For Operating Option 2 ($)
2010	6.43	3.22	0	62,707,000	125,610,000
2020	8.93	5.72	1.02	66,205,000	163,161,000
2030	10.87	7.66	2.96	66,205,000	163,161,000
2040	13.34	10.13	5.43	66,205,000	163,161,000
2050	16.45	13.24	8.54	66,205,000	163,161,000
2060	20.37	17.15	12.45	66,205,000	163,161,000
Average Annual Benefits				65,225,000	156,098,000

With Option 1, the system will provide a total of 41.89 equivalent lockages at the 99.6 percent level of reliability or 3.21 more lockages than the existing system.

With Option 2, the system will provide a total of 46.59 equivalent lockages at the 99.6 percent level of reliability or 7.91 more lockages than the existing system.

With either operating option, the reliability of the system to provide all of the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Rio Chagres project would be $3,933,000 for Operating Option 1 and $7,936,000 for Operating Option 2. Table 18 - 8 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits for each operating option.

Table 18 - 8 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Daily Lockage ($)	Annual Navigation Benefits For Operating Option 1 ($)	Annual Navigation Benefits For Operating Option 2 ($)
2010	39.0	2,086,000	2,956,000	5,836,000
2020	40.0	2,260,000	4,046,000	8,318,000
2030	40.0	2,260,000	5,185,000	10,531,000
2040	40.0	2,260,000	6,632,000	13,342,000
2050	40.0	2,260,000	8,370,000	16,554,000
2060	40.0	2,260,000	9,594,000	18,521,000
Average Annual Benefits			3,933,000	7,936,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was based upon the growth in population. The PCC provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day. An equivalent lockage is 55 million gallons of water. One equivalent lockage was added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Rio Chagres project, the current costs to the PCC to process finished water at $0.69 per 1,000 gallons, the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability would be $531,000 for Operating Option 1 and $1,072,000 for Operating Option 2. Table 18 - 9 displays the population forecast, the resulting number of equivalent lockages demanded per day, and the benefits for M&I water supply.

Table 18 - 9 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits for Operating Option 1 ($)	Annual M&I Water Supply Benefits for Operating Option 2 ($)
2010	1,724,000	6.1	330,000	652,000
2020	2,141,000	7.6	517,000	1,064,000
2030	2,688,000	9.6	833,000	1,691,000
2040	3,384,000	12.0	1,338,000	2,692,000
2050	4,259,000	15.1	2,126,000	4,204,000
2060	5,360,000	19.0	3,069,000	5,925,000
Average Annual Benefits			531,000	1,072,000
The value of a daily lockage for M&I is $0.69 X 55,000 = $37,950				

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for canal operation and M&I water supply increase. With the inclusion of the proposed Rio Chagres project, the system could produce net additional megawatt hours of hydropower. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, Operating Option 1 would have benefits of $12,460,000 and Operating Option 2 would have benefits of $12,021,000. Table 18 - 10 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 18 - 10 Average Annual Benefits For Hydropower Generation

Year	Net Generation for Operating Option 1 [1/] (MWh)	Net Generation for Operating Option 2 [1/] (MWh)	Annual Hydropower Benefits for Operating Option 1 ($)	Annual Hydropower Benefits for Operating Option 2 ($)
2010	182,074	180,659	12,745,000	12,646,000
2020	177,121	169,873	12,398,000	11,891,000
2030	173,261	160,895	12,128,000	11,263,000
2040	168,402	149,595	11,788,000	10,472,000
2050	164,731	143,013	11,531,000	10,011,000
2060	157,538	134,101	11,028,000	9,387,000
Average Annual Benefits			12,460,000	12,021,000

[1/] Net generation of Gatun, Madden, and Chagres hydropower plants above generation of Gatun and Madden hydropower plants.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 18 - 11, total average annual benefits for Operating Option 1 and Operating Option 2 of the proposed Rio Chagres project would be $82,149,000 and $177,127,000, respectively.

Table 18 - 11 Summary of Annual Benefits

Benefit Category	Average Annual Benefits: Operating Option 1 ($)	Average Annual Benefits: Operating Option 2 ($)
Navigation – Water Supply	65,225,000	156,098,000
Navigation – Reliability	3,933,000	7,936,000
M&I - Reliability	531,000	1,072,000
Hydropower	12,460,000	12,021,000
Total	82,149,000	177,127,000

Once average annual benefits and costs are estimated, the ratio of benefits to costs and the net benefits (net of costs) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. While there would be small differences in some project features between Operating Option 1 and Operating Option 2, the differences would not have any impact on total project first costs at this level of investigation. The same facilities would be constructed for each operating option. Table 18 - 12 provides the benefit to cost ratios for Operating Option 1 and Operating Option 2 and the net benefits for both.

Table 18 - 12 Economic Evaluation

Item	Operating Option 1 ($)	Operating Option 2 ($)
Average Annual Benefits	82,149,000	177,127,000
Average Annual Costs	59,183,000	59,183,000
Benefit to Cost Ratio	1.4	3.0
Net Benefits	22,966,000	117,944,000

Internal Rate of Return

An internal rate of return analysis for each operating option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For Operating Option 1, the internal rate of return would be 15.7 percent, and for Operating Option 2, the internal rate of return would be 25.0 percent.

Incremental Evaluation of Hydropower

Since the generation of hydropower energy would be provided through the conjunctive use of storage, an analysis of the incremental benefits and costs for this purpose was accomplished. The first costs of the Lands and Relocations and the Clearing and / or Grubbing, which were associated with hydropower, as well as the costs of the Hydropower Plants and the Transmission Lines were taken from Table 18 - 3. The portion of annual operation and maintenance costs associated with hydropower generation were derived from the data included in Table 18 - 5. The construction costs are estimated to be approximately $18,483,000. Interest during a two-year construction period is estimated to be $2,251,000 for a total hydropower investment costs of $20,734,000. The portion of annual operation and maintenance costs for hydropower were assumed to be $350,000 for staff, $250,000 for ordinary maintenance and $38,000 for major replacement. The total average annual costs for hydropower would be $3,135,000. The average annual benefits for operating Option 1 and Operating Option 2 are estimated to range between $12,460,000 and $12,021,000. The average annual benefits exceed the average annual costs for both operating options yielding benefit to cost ratios of 4.0 and 3.8. It should be noted, however, that hydropower was valued at the current costs of production of the PCC. This value might underestimate the economic value of any additional hydropower generating capacity. Additional effort should be expended in any future planning studies to determine the economic value of added hydroelectric power generation.

Socio-Economic Impacts

The socio-economic impacts of the project would be limited, because the impoundment area is only sparsely populated with no roads or utilities. The area to be impacted by the project is home to the indigenous Embera tribe. Land use would be impacted by the inundation of any agricultural land used for subsistence farming; however, the relocation of agricultural land would be minimal because the area is so sparsely populated. The impoundment area covers approximately 1,990 ha with an additional 800 ha required for the dam and construction activities including permanent disposal areas.

Currently, access from the project area to public schools and health centers is limited. After construction is completed, these services would be more accessible to the local residents, and new facilities could be constructed.

To construct the dam and the associated hydropower plant, a new road, 10 km in length, would be built. Some dirt trails within the impoundment area would be eliminated, which could cause some small settlements to lose overland transportation, communication, cohesion, and commerce with other settlements. Noise levels would increase during construction of the project and during operation of the hydropower plant and could negatively impact noise-sensitive receptors; however, after construction, the only noise would be that generated by the hydropower plant.

Construction of the dam would permanently displace indigenous people and disrupt community cohesion through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including fishing and ecotourism, could increase. Project implementation would also provide better access to the major centers for commerce in the northern and southern parts of the country.

Environmental Setting

The Rio Chagres project will produce hydroelectric power and provide for 7.9 additional lockages per day on a continual basis. The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, a hydropower plant, and outlet works. The project encompasses the area to be flooded as well as the area downstream from the dam site. This area is very sparsely populated and is characterized by primary forests. The Rio Chagres is located east of the Panama Canal and flows northward from the Continental Divide into the Atlantic Ocean. The Rio Chagres watershed above the dam is approximately 414 km^2. The impoundment area covers approximately 1,990 ha composed of mostly forested land. The lake water elevation will fluctuate from elevation 180 to 224 m MSL. The transmission lines and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The Rio Chagres project area encompasses the area to be flooded as well as the area downstream from the dam site to Madden Lake. The project area is located in the Parque Nacional Chagres and is sparsely populated with settlements of the indigenous Embera tribe. Rio Chagres is used for subsistence fishing. A primary rainforest ecosystem, including rare, elfin forests, occupies almost the entire project area.

INFRASTRUCTURE

There are no roads or utilities in the project area. The Chico stream gauge station is located about 150 m upstream from the dam site. Travel routes consist of trails and Rio Chagres. Because of the isolated location of the project area, these trails are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities. Schools and medical facilities are available in settlements on Madden Lake downstream from the dam site. Water is obtained from Rio Chagres. No treatment of community waste is provided. All domestic wastewater is discharged into the environment; some of it most likely reaches Rio Chagres and its tributaries. There are some known health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses attributed to the present waste disposal methods. No major industries or poultry or beef processing plants are located in the project area.

TERRESTRIAL HABITAT

The primary forests, which cover almost 100 percent of the land along the upper reaches of the Rio Chagres and its tributaries, and the surrounding watershed, could support diverse wildlife populations.

ANIMALS ON ENDANGERED LIST

ANAM by its Resolution 002-80 on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although none have been identified to date, some or all of the animals and other species of concern may be found in the project area.

AQUATIC HABITAT

The portion of Rio Chagres in the impoundment area displays traits characteristic of streams in mountainous regions. Substrate in the upper reaches of the river ranges from bedrock to gravel and is dominated by sand and silt along the last few kilometers before it empties into Madden Lake. The width of the river ranges from less than 1 m at the headwaters during the dry season to 30 m at the dam site. Rio Chagres and its tributaries serve as habitat for fish communities that support subsistence fishing; however, currently available information about fish communities within the project area is limited.

WETLANDS

Areas which contain hydric soils and hydrophytic plant communities, and which are subject to hydrologic conditions are termed wetlands. The wetlands in the project area consist of forested riparian habitat along Rio Chagres and its tributaries, and are limited in some areas by the narrow river valley and rocky substrate. Most of Rio Chagres and its tributaries both above and below the dam are bordered by forested riparian habitat.

AIR QUALITY

Although no applicable data are available, air quality in the project area appears to be excellent. There may a few small, isolated tracts of land subjected to slash and burn agricultural activities for use in subsistence farming. Air quality monitoring has not been implemented in the project area. The natural environment may provide indicators that could be useful in evaluating air quality.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The impoundment area is located within the boundaries of the Parque Nacional Chagres and is protected as a national park. Only limited investigations into cultural resources have been conducted in the project area; therefore, impacts to cultural resources cannot be determined. It should be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in the project area could be substantial, since almost the entire impoundment area and dam site are covered with high quality terrestrial habitat of primary forests. Construction of the lake could adversely affect migration routes of some species as a result of fragmentation of the continuous tract of primary forest. Genetic drift among populations of some species would increase as forest fragmentation separates populations, thus decreasing genetic variability. The only forests that would remain near the Rio Chagres reservoir and its drainage basin would be confined to the higher elevations above the proposed maximum lake level of 224 m MSL.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered animals cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Some endangered and / or threatened species may use Rio Chagres for some or all parts of their life cycle. The significance of the Parque Nacional Chagres may increase if animals on the endangered list are found in the region. Species indigenous to primary rainforest can be expected to occur within the project area and could be negatively impacted. The Mesoamerican Biological Corridor is promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions, in addition to those governing the Panama National Parks, on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity should be positive, because construction of the dam will result in an increase in the volume of stored fresh water during the dry season. Approximately 80 percent of the water needed for Panama Canal operations and all of the drinking water for Panama City originate in the Rio Chagres watershed. The impacts downstream should be minimal because the dam site is approximately 1 km above the headwaters of Madden Lake.

WATER QUALITY

Impacts of the project on water quality have not been determined. Clearing and grubbing associated with practices in the project area should increase the amount of nutrients and debris flowing into the river. The rate at which nutrients and debris enter the river will determine the severity of impact on water quality. Project implementation could cause an increase in turbidity and interfere with photosynthesis. The increased in turbidity could deprive plants and other aquatic species from necessary sunlight. Species at specific depths could be impacted when the river becomes a lake. The velocity of water should decrease with dam construction while sedimentation should increase. Downstream from the dam, erosional forces between the dam and Madden Lake may increase and the ecology of the river could change as flow, sediment load, and species are impacted.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts on downstream aquatic faunal communities could be substantial, depending on the seasonal migration patterns of fishes and invertebrates and on the water demands of the new hydropower plant. Large fluctuations in temperature, flow rate, and turbidity resulting from periodic releases of water could substantially impact the reproductive cycle of downstream fauna. Alteration of the normal flow patterns during the construction could also substantially impact downstream fauna. The Rio Chagres dam should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation should not be a problem. Streambed degradation below the dam should be minimal, provided that water release rates are low enough not to cause excessive erosion and scouring.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed lake will depend on water levels, which are anticipated to range from 180 to 224 m MSL. Since the water levels would fluctuate widely, much of the lakeshore would become mud slopes where neither aquatic nor terrestrial plant communities could thrive. However, rooted aquatic plants, which tend to grow at depths where light penetration allows photosynthesis to occur, may flourish.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Chagres and its upstream tributaries could be considerable. Since Rio Chagres in the project area is bordered by primary forests, it is likely to provide high quality aquatic habitat that is no longer available in other drainage systems because of agricultural practices. The reservoir could support species that thrive in lentic systems. Species that require highly oxygenated lotic systems could be extirpated from the reach of Rio Chagres that will be covered by the reservoir. The dam could also create a barrier to the seasonal migration crucial to the reproductive cycle of some fishes and aquatic invertebrates. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. The new reservoir could provide opportunities for recreational and subsistence fishing if it is responsibly managed and stocked with gamefish by the Aquaculture Department. An increase in fish population could cause an increase in piscivorous predators, such as crocodiles, caimans, otters, herons, etc. Other manmade lakes in the Republic of Panama have been stocked with exotic fish such as peacock bass and tilapia, both of which are efficient predators, which may have led to the extirpation of several native riverine fishes that formerly occupied the impoundments.

WETLANDS

The impacts to wetlands could be significant, although wetlands in the impoundment area are limited to the riparian corridor. The riparian wetlands inundated by the new impoundment would be destroyed; however, new wetlands could form in shallow water areas along the shoreline of the newly created reservoir depending on water level fluctuation. Wetlands downstream from the dam site could also be impacted. A decrease in the total amount of water flowing through the downstream floodplain and the corresponding reduction in seasonal flooding could result in narrowing of the floodplain and a loss of wetlands.

AIR QUALITY

During construction of the dam and hydropower plant, dust and emissions from equipment could impact the air quality in the project area. After construction, air quality should return to pre-construction conditions.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The project area is within the boundaries of the Parque Nacional Chagres and the indigenous Embera tribe resides in and around the project area. Information regarding other Cultural Resources and Historic Properties is incomplete. Additional evaluation studies need to be completed to identify Cultural Resources and Historic Properties. Prior to construction, surveys would be conducted to locate cultural resources and historic properties, and the important sites would be preserved or salvaged as appropriate.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Rio Chagres alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an SIA. The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities.
  - Employment.
  - Land Use.
  - Property Values.
  - Public and Community Facilities and Services (including utilities and schools).
  - Community and Regional Growth.
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population - Indigenous.
  - Community Cohesion.
  - Recreational Resources.
  - Mineral Resources

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major types of terrestrial and aquatic habitat are identified and quantified.
- Conduct field studies to locate special habitat features, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migratory flyways.
- Determine the present quality and ecosystem value of existing habitats within the project area.
- Coordinate with local experts regarding these habitats.
- Provide species inventory lists for each site area identifying their status as native or exotic and whether they are threatened or endangered.
- Cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to identify the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts to determine the presence of these species.

WATER QUALITY

- As limited water quality data are available for the Rio Chagres area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources is incomplete. Additional evaluation studies need to be completed to identify cultural resources and historic properties.

Evaluation Matrices

In accordance with evaluation procedures described in Section 4, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Section 35. Tables 18 - 13 through 18 - 15 present the evaluation of the proposed Rio Chagres project as related to developmental effects, environmental effects, and socio-economic effects.

Table 18 - 13 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I demands	8	10	80
	Supplements Existing System	0	10	0
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	3	5	15
Technical Viability	Design Constraints	8	6	48
	Feasibility of Concept	8	6	48
Operational Issues	Compatibility	10	6	60
	Maintenance Requirements	10	2	20
	Operational resources required	8	2	16
Economic feasibility	Net Benefits	3	9	27
	Total			314

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 18 - 14 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	1	8	8
Animals on Extinction List	1	10	10
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts -- Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	4	8	32
Future Lake Aquatic Plant Community	4	8	32
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	6	6	36
Wetlands	5	4	20
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			381

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 18 - 15 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	4	7	28
Relocation of People	5	10	50
Relocation of Agricultural/Ranching Activities	5	6	30
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	5	5	25
Property Values During Construction	5	4	20
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	6	8	48
Traffic Volumes over Existing Roadway System During Construction	4	5	20
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	5	8	40
Community Cohesion	5	8	40
Tourism	7	5	35
Total			456

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 18 - 16 presents pertinent data for Operating Option 1 and 2 of the proposed Rio Chagres project.

Table 18 - 16 Pertinent Data

GENERAL		
Dam site, below Chico stream gage	150 m	
Drainage area above dam site	414 km^2	
Average annual flow at dam site	50 CMS	
LAKE	**Option 1**	**Option 2**
Elevation of normal operating lake level	200 m MSL	220 m MSL
Elevation of maximum flood lake level	204 m MSL	224 m MSL
Elevation of minimum operating lake level	180 m MSL	180 m MSL
Useable Storage between Max and Min levels	207.6 MCM	518.7 MCM
Area at normal operating lake level	7,618 ha	11,315 ha
Area at maximum flood lake level	8,278 ha	12,177 ha
Area at minimum operating lake level	4,846 ha	4,846 ha
Top clearing elevation	200 m MSL	220 m MSL
Lower clearing elevation	180 m MSL	180 m MSL
EMBANKMENTS		
Dam		
Type of dam	Rock fill embankment	
Top elevation of dam	205 m MSL	225 m MSL
Fixed crest width	13 m	13 m
Height above lowest foundation	115 m	135 m
Overall length of dam	497 m	680 m
SPILLWAY	**Option 1**	**Option 2**
Type of Spillway	Uncontrolled ogee	Uncontrolled ogee
Total length	286.5 m	286.5 m
Elevation of spillway	200 m MSL	220 m MSL
Maximum discharge	4,430 CMS	4,430 CMS
HYDROPOWER PLANTS		
Dam		
Type of hydropower plant construction	Reinforced concrete	
Number of units	2	
Capacity of each unit	17.25 MW	
CONSTRUCTION /POWERHOUSE DIVERSION		
Diversion length	500 m	
Horseshoe tunnel dimensions (2)	7.2 m by 7.2 m	
Inlet invert	100 m MSL	
Outlet invert	90 m MSL	
Cofferdam Height above tunnel inlet invert	8.8 m	

Table 18 - 16 Pertinent Data (continued)

MINIMUM FLOW CONDUIT	
Conduit diameter	0.6 m
Conduit length	500 m
Inlet invert	100 m MSL
Outlet invert	90 m MSL
Conduit capacity	5.0 CMS

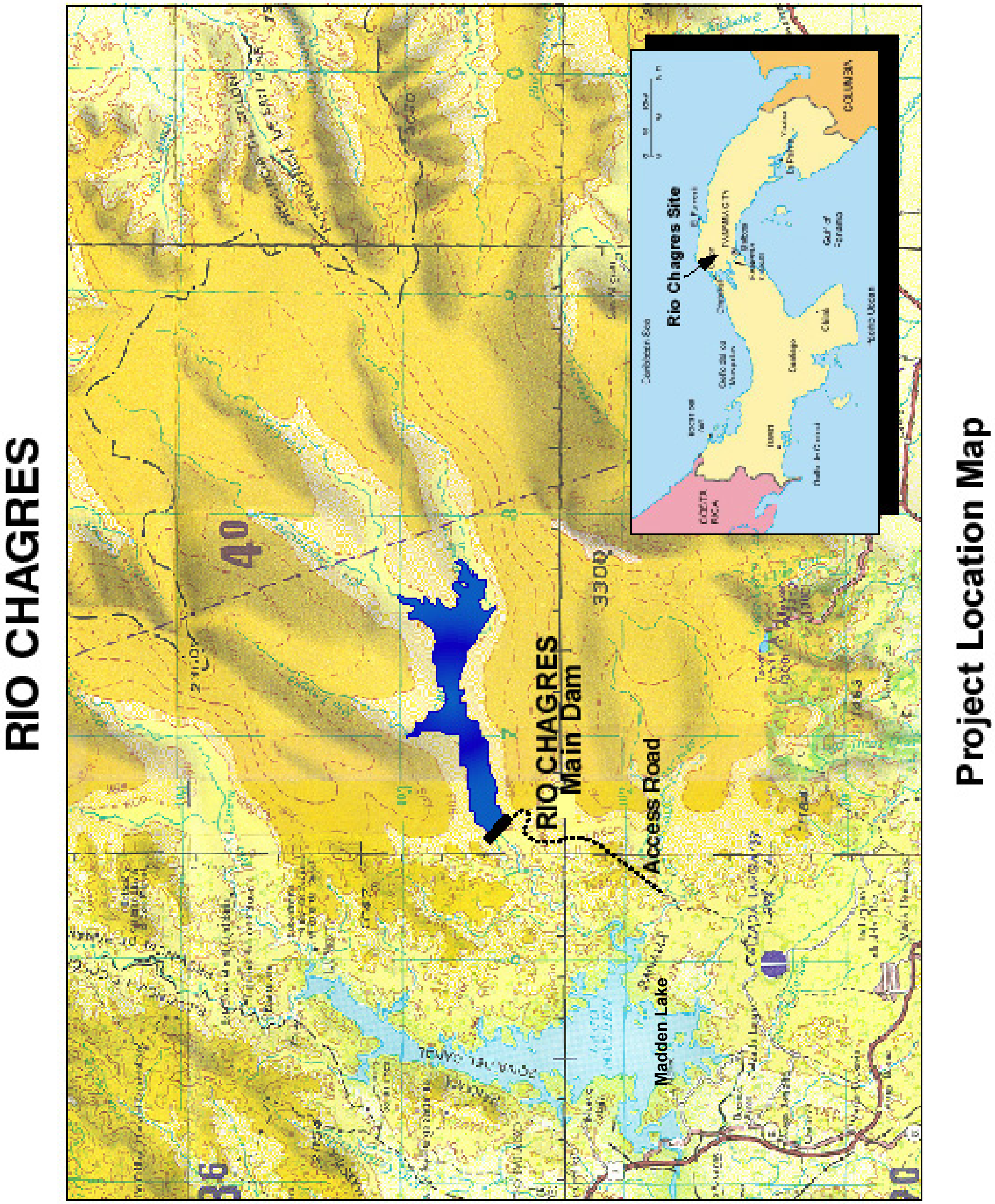
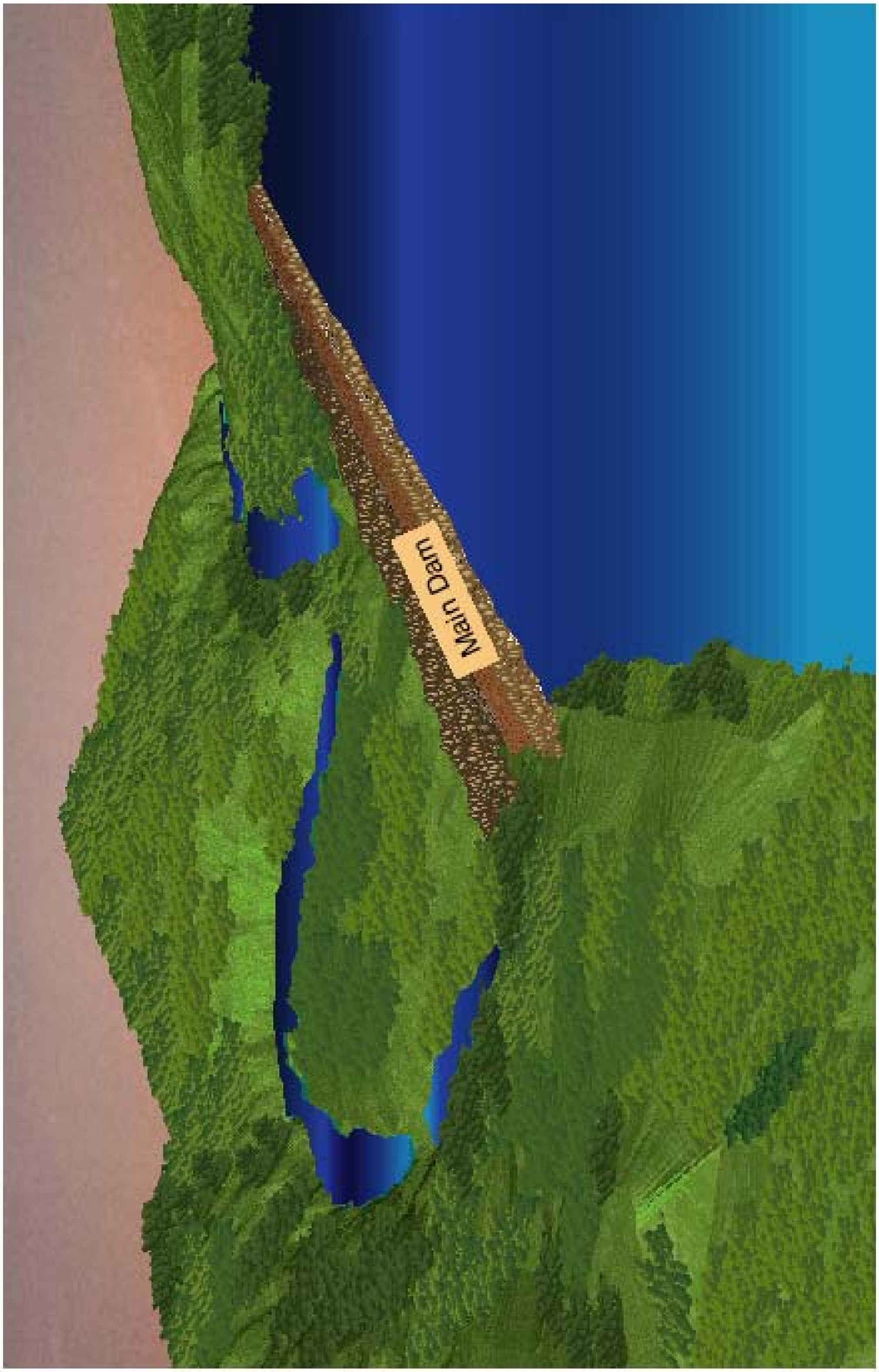


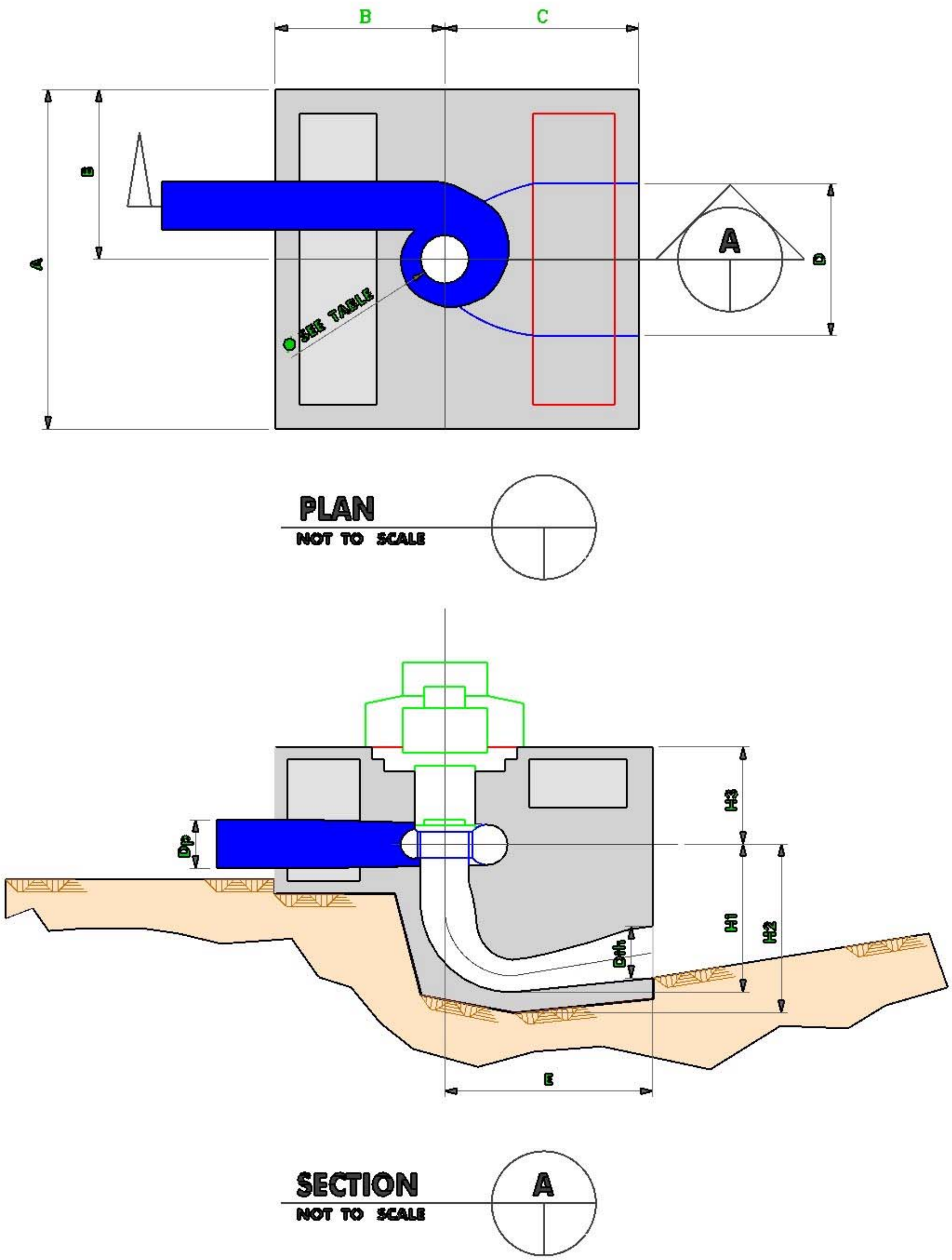
Plate 18 - 1 Project Location Map

RIO CHAGRES



Site Plan

Plate 18 - 2 Site Plan



RIO CHAGRES DAM POWER FACILITIES									
UNIT	A	B	C	D	E	Dp	H1	H2	H3
Dth					(Meters)				
UNITS 1 & 2									
	1.83	12.5	4.88	7.32	5.85	7.32	2.74	5.73	2.44

Plate 18 - 3 Hydropower Plant Details

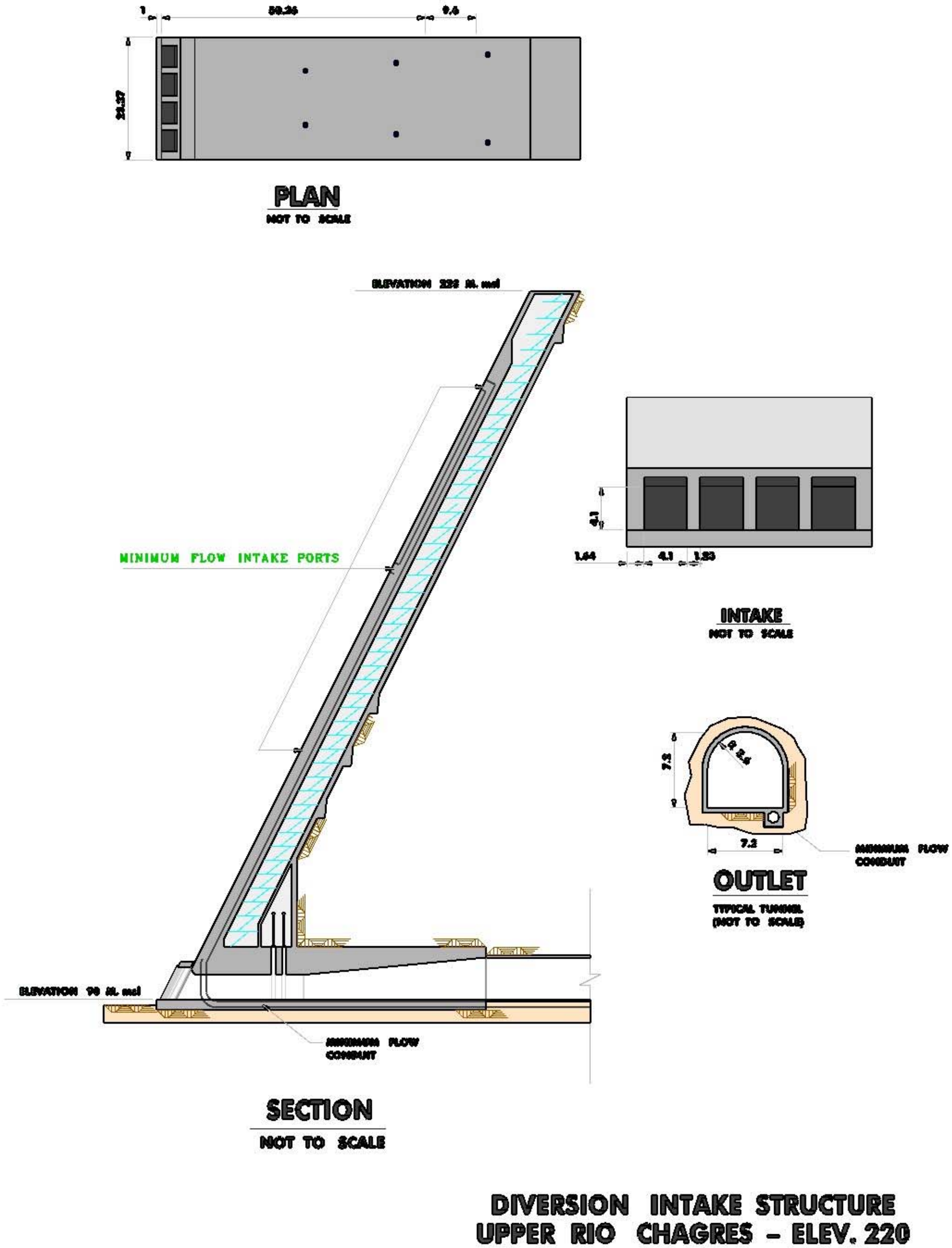


Plate 18 - 4 Diversion Intake Structure

SECTION 19

Rio Pequeni

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The Rio Pequeni watershed comprises a portion of the eastern side of the Panama Canal watershed that feeds into Madden Lake. The proposed Rio Pequeni dam site would be approximately 3 km above Madden Lake measured along the Rio Pequeni. The proposed project would include a 35 m high rock fill dam with an outlet system allowing stored water to be passed to the Panama Canal watershed via Madden Lake. The system would transfer water from Pequeni Lake to the Panama Canal watershed as required for navigation purposes.

The proposed Rio Pequeni project would not significantly contribute to maintaining the hydrologic reliability of the Panama Canal. It would only minimally help the Panama Canal to serve its customers, and reduce the need for imposing draft restrictions and light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the 50.5-year period of record from January 1948 through July 1998, is approximately 99.6 percent. The hydrologic reliability with a demand ratio of 1.2 (46.42 lockages) of current levels would be 98.8 percent. These figures would be virtually unaffected by the installation of the Rio Pequeni project. The project is not recommended for further consideration.

The amount of hydropower production expected from the facilities at Gatun Lake and Madden Lake will decline over time as the demands for navigation and M&I water increase. With the inclusion of the proposed Rio Pequeni project, the system could produce net additional megawatt hours of hydropower because Pequeni would provide additional storage for M&I water withdrawn from Madden Lake.

The proposed Rio Pequeni Project was weighed against the technical objectives stated in Section 4 of this report and was found to be lacking in the fundamental purpose for which these alternatives are intended. The volume of water produced by this project would not be enough to significantly impact the reliability of the Panama Canal water supply. The additional storage allows demands on the system to increase only 0.73 percent before the reliability of the system drops below current level of 99.60 percent. This would equate to approximately 0.28 lockages.

The proposed Rio Pequeni Project was weighed against the technical objectives stated in Section 4 of this report and found to be lacking in the following areas:

The volume of water produced by this project would not be enough to significantly impact the reliability of the operation of the Panama Canal. The only apparent benefit to be derived by installation of this project would be the small amount of incidental hydropower that might be produced.

Therefore, the plan for development of the Rio Pequeni was not pursued further and was eliminated from the list of technically viable projects to be subjected to further scrutiny in this report. No formal cost, economic, or environmental analyses will be made of this alternative.

Site Selection

The proposed Rio Pequeni dam site was chosen with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. To maximize the water impounded, it was desirable to locate the dam downstream in the Rio Pequeni watershed as far as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow. The downstream portion of the Rio Pequeni watershed contains sites that adequately meet these criteria.

The site chosen for the proposed Rio Pequeni Dam would accommodate construction of a dam with a normal operating lake level at elevation 100 m MSL and a maximum flood storage lake level at elevation 104 m MSL. Plate 19 - 1 shows the location of the proposed Rio Pequeni project.

Hydrologic Considerations

The Rio Pequeni flows southwestward into Madden Lake from the mountains east of the Panama Canal watershed. The headwaters of the watershed begin at elevation 581 m MSL approximately 20 km above Madden Dam, and fall to approximately elevation 72 m MSL at Madden Lake. The distribution of the average annual rainfall over the Rio Pequeni watershed varies from approximately 3,000 mm at Madden Lake to approximately 4,000 mm in the upper watershed area. The proposed Pequeni Lake would receive runoff from approximately 153 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 13.8 CMS at the proposed dam site.

The discharge at the Rio Pequeni damsite was obtained by extrapolating the recorded and correlated streamflow data of the Candelaria hydrologic station.

This station began operation in 1933 and is still in operation. In order to complete missing data, a significant statistical correlation using standard hydrologic techniques was established with the discharge data of the Rio Boqueron at Peluca. The consistencies of the measured and correlated data were verified using the double mass curve method with satisfactory results.

Because of the proximity and in the absence of additional information, the monthly evaporation rates recorded at Madden Lake were used to establish the evaporation of Pequeni Lake.

Geologic Considerations

The proposed Rio Pequeni project is located in an area of the Isthmus of Panama where the geologic map shows that pillow basalts occur. A geological reconnaissance investigation of the Rio Pequeni conducted during the spring of 1944 by Randolph Thompson, Chief of the Geology Section for the Panama Canal, found only andesites, diorites, and granites exposed in the lower portion of the Pequeni River. In the area of the proposed Pequeni Dam the survey found andesite that was closely but tightly jointed. A site visit made during the preparation of this report agreed with the presence of andesite at the proposed dam location. The andesite exposed in the river channel was hard, unweathered, and of high quality. It is expected that this rock would make both a good foundation for a dam and a good source for either rock fill or concrete aggregate.

In the absence of detailed geologic information at the site, a degree of extrapolation was necessary. It was predicted that rock would be encountered at a shallow depth and would be of sufficient quality to serve as foundation material for the dam and appurtenant structures. Furthermore, it was assumed that sufficient rock for fill and concrete aggregate would be available from the required excavation and that impervious materials would be available within the immediate area for use in the construction of the project.

Lake Operation

Pequeni Lake would be operated to supply navigation water through Madden Lake to the Panama Canal watershed. Two operating options were considered for this study. Under Operating Option 1 the water surface of the lake would be allowed to fluctuate from the normal operating lake level at elevation 100 m MSL down to the minimum operating lake level at elevation 90 m MSL. This would provide approximately 28,270,000 M^3 of usable storage. Under Operating Option 2 the water surface of the lake would be allowed to fluctuate from the normal operating lake level at elevation 100 m MSL down to the minimum operating lake level at elevation 95 m MSL. This would provide approximately 16,600,000 M^3 of usable storage. The maximum lake level, during flood conditions, would be elevation 104 m MSL. The volume between elevation 104 m MSL and 100 m MSL would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in Madden Lake because of this additional regulation. Table 19 - 1 below summarizes the operating options considered for this alternative.

Table 19 - 1 Pequeni Lake Operating Options

Lake Level (m MSL)	Operating Option 1	Operating Option 2
Normal Operating Lake Level	100	100
Minimum Operating Lake Level	90	95
Maximum Flood Storage Lake Level	104	104

Project Features

GENERAL

The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, and other outlet works as required to pass stored waters to Madden Lake. The following paragraphs provide a description of the proposed structures and improvements for Option 1. Basic features for Option 2 would differ only slightly. Plate 19 - 2 depicts the location of the dam.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the PCC containing assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The dam would be an embankment with the top at elevation 105 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1035182 north and 660882 east. The right abutment would be 1035230 north and 661097 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam at its highest point would be approximately 35 m high, and the overall length would be 221 m. The total fill volume required to complete the embankment would be 371,200 M^3 The actual side slopes and crest width would be determined during further study. Final design would be contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment.

SPILLWAY

An uncontrolled ogee spillway with a length of 132 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 2,044 CMS at a maximum lake elevation, during flood conditions, of 104 m MSL. The spillway design discharge was equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway would be located within the abutment adjacent to the dam and would include a mass concrete sill section embedded in the natural rock. A sloped and / or stepped, natural rock cut tailrace channel would return flow to the existing stream. The tailrace channel would extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation.

IMPOUNDMENT

The lake formed by the proposed Rio Pequeni Dam for Operating Option 1 would have a normal operating lake level at elevation 100 m MSL. The surface area at the normal operating lake level would be approximately 415 ha. With the minimum operating lake level at elevation 90 m MSL, the surface area would be approximately 198 ha. At the maximum lake level, elevation 104 m MSL, the surface area would be approximately 505 ha. Rio Pequeni Dam for Operating Option 2 would also have a normal operating lake level at elevation 100 m MSL. With the minimum operating lake level at elevation 95 m MSL, the surface area would be approximately 305 ha. The maximum lake level during flood conditions for Operating Option 2 would also be elevation 104 m MSL.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas necessary for the construction of the dam (embankments and spillway), other outlet works, access roads, and disposal and staging areas. For Operating Option 1, clearing only would be required for the 215 ha in the lake area between the maximum operating lake level at elevation 104 m MSL and the minimum operating lake level at elevation 90 m MSL. For Operating Option 2, clearing only would be required for the 147 ha in the lake area between the maximum operating lake level at elevation 104 m MSL and the minimum operating lake level at elevation 95 m MSL.

HYDROPOWER PLANTS

The hydropower plant at the dam was sized as a run-of-the-river plant with a power factor near 0.5. All controlled releases from the dam were assumed to be available for hydropower production. Hydropower plant capacities for the ranges of energy head investigated and resulting energy production of the hydropower plants in the system are tabulated in the section entitled Simulation Model. These investigations indicated that the proposed Rio Pequeni Dam would support a 6 MW hydropower plant at the dam. These facilities would be designed and configured to function as part of the national power grid. A transmission line would be required to carry the energy to a connection at the Madden Dam.

OUTLET WORKS

An outlet works system would be required to provide for diversion of the Rio Pequeni River during construction, to pass water downstream for navigation purposes, to supply water for hydropower production, to allow for emergency drawdown of the lake, and to pass minimum flow through the dam.

This outlet works system would include a single intake structure. This structure would be configured to allow passage of channel flows up to the required level of protection during construction. Once diversion was no longer needed for construction, the structure would be used to control the flows for hydropower, controlled releases and emergency drawdown. It would also have separate, controlled water intakes at various elevations to allow flows to be withdrawn from the lake to optimize the quality of the water passed as minimum flow.

This system would consist of an 7.6 by 7.6 m horseshoe shaped tunnel passing through the dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits. The diversion tunnel would be 240 m in length. The intake structure would have an inlet invert at elevation 72 m MSL and the outlet invert elevation of the tunnel would be at 70 m MSL. The diversion tunnel would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of 988 CMS at the site without regulation from the dam. The cofferdam would measure 8.9 m above the upstream invert of the tunnel. The details of the intake structure would be similar to those shown for the Rio Indio Intake Structure in Section 5. Because of the proximity of the dam to the head of Madden Lake no separate minimum flow conduit was provided. All flow would either pass through the main tunnel or the powerhouse.

ACCESS ROADS

Access to the Rio Pequeni dam site and the lake construction area would be provided using the existing road, which follows the west edge of Madden Lake to a point on Rio Boqueron at the extreme north end of the lake. From this point, a new access road would be required, crossing the Rio Boqueron, and traversing approximately 6 km across the land area between Rio Boqueron and the Rio Pequeni dam site.

The existing roadways leading to the general area of Madden Dam from the major population centers, Colon to the north and Panama City to the south, would provide ample access for materials and equipment.

Plate 19 - 1 shows the portion of the proposed access road from the vicinity of Madden Dam to the construction site.

Sources of Construction Material

Rock removed from the spillway site would be used as fill in the embankment portion of the dam. Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Pequeni project would be located in the Panama Province. Construction of this proposed project would require 1,330 ha. Table 19 - 2 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 19 - 2 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	530
Dam Site	200
Staging Area	200
Disposal Area	400
Total	1,330

Relocations

The lake would be located in a sparsely populated region with few roads and utilities. This area is practically primary forest. Structures and individuals located in the lake area below elevation 105 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. However, there are no settlements of any size within the lake impoundment area. Relocations required would include only isolated structures and a few small settlements (Indian Villages).

Hydrologic Reliability

In order to determine the effect of the proposed Rio Pequeni Lake on the hydrologic reliability of the Panama Canal, the existing HEC-5 model was modified to include the Rio Pequeni Lake. The Rio Pequeni Lake was modeled to release flows into Madden Lake and local inflows to Madden Lake were reduced by the amount that the Rio Pequeni Lake would capture.

HEC-5 model simulations were conducted for the existing Panama Canal system using the model developed by the Corps of Engineers Hydrologic Engineering Center (HEC). The simulations considered proportionally increasing demands beginning with current demand levels. The designated period considered a 50.5-year hydrologic record (January 1948 to July 1998). A separate HEC-5 model with the Pequeni Lake included was also developed. This model was used to determine the contribution that the Pequeni Lake would provide for the same period of record. Figure 19 - 1 presents the resulting hydrologic reliability for three configurations with demands increasing up to 180 percent of current demands. These configurations were:

- Existing system,
- Operating Option 1 (Pequeni Lake fluctuating between the normal operating lake level at elevation 100 m MSL and the minimum operating lake level at elevation 90 m MSL), and
- Operating Option 2 (Pequeni Lake fluctuating between the normal operating lake level at elevation 100 m MSL and the minimum operating lake level at elevation 95 m MSL).

The horizontal axis along the bottom of Figure 19 - 1 reflects demands as a ratio of the five-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 19 - 1, the existing hydrologic reliability of the Panama Canal, based on the 50.5-year period of record, is approximately 99.60 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.30 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability with a demand ratio of 1.0 would be 99.63 percent for Operating Option 1, and the hydrologic reliability with a demand ratio of 1.8 would be 86.39 percent. With Operating Option 2, the hydrologic reliability with a demand ratio of 99.62 would be 100 percent, and the hydrologic reliability with a demand ratio of 1.8 would be 86.36 percent. With the construction of the proposed Rio Pequeni project, the hydrologic reliability of the canal system would increase only slightly. The existing high hydrologic reliability could be maintained as demand for lockages increases up to only 0.73 percent above current demand levels which is equivalent to 0.28 lockages per day with Option 1 and 0.42 percent or .16 lockages with Option 2. Therefore, the proposed Rio Pequeni project would not provide significant help to offset increasing M&I and navigation demands on the system.

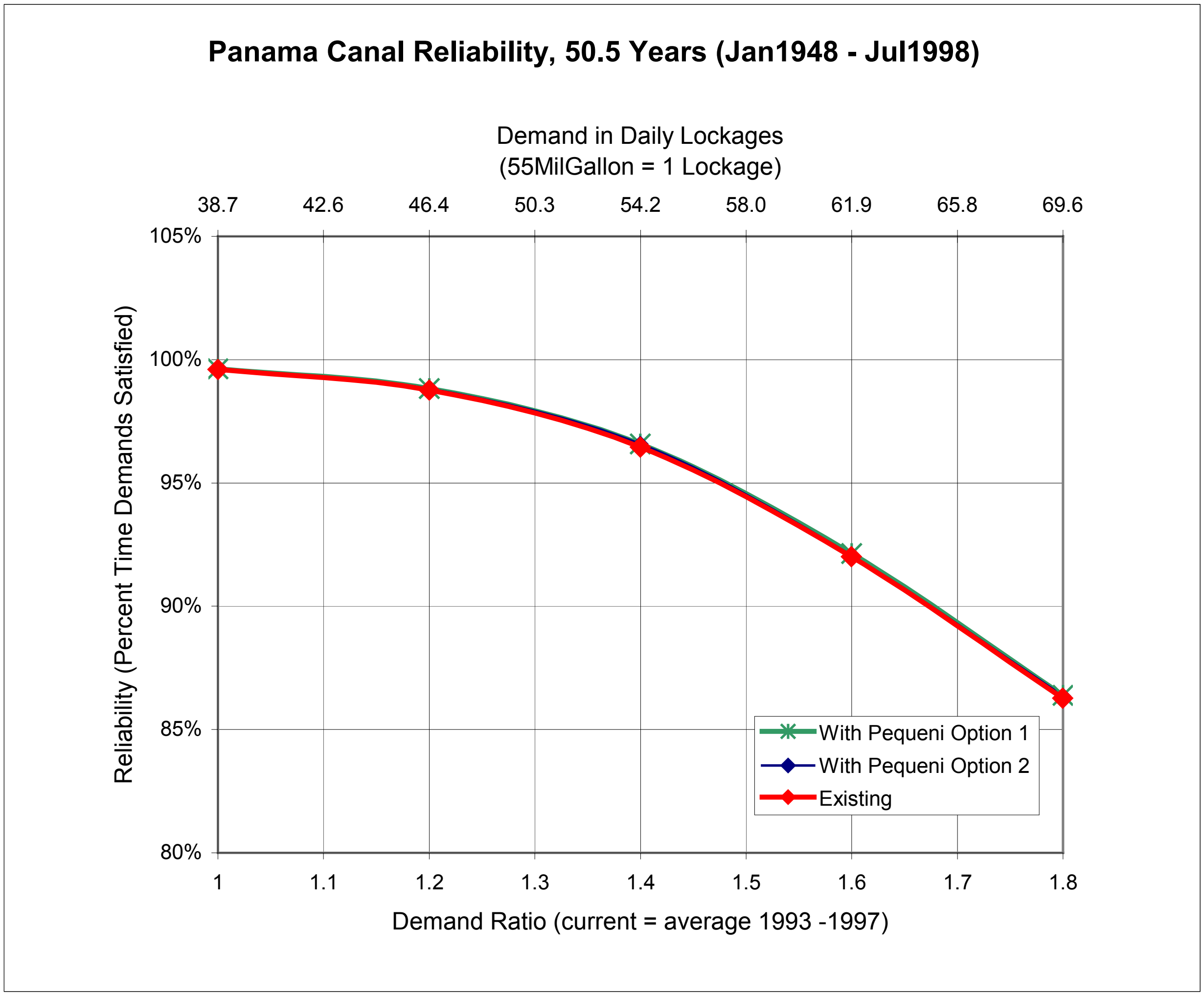


Figure 19 - 1   Panama Canal Hydrologic Reliability

This alternative does not meet the first assessment criterion, which is to provide at least one lockage per day. Therefore, further consideration of this alternative is not recommended.

Pertinent Data

Table 19 - 3 presents pertinent data for a maximum operating pool at elevation 100 m MSL for the proposed Rio Pequeni project.

Table 19 - 3 Pertinent Data - for Operating Options 1 and 2

GENERAL		
Dam site, above mouth of Rio Pequeni	3 km	
Drainage area above dam site	153 km^2	
Average annual flow at dam site	13.8 CMS	
LAKE	**Option 1**	**Option 2**
Elevation of normal operating lake level	100 m MSL	100 m MSL
Elevation of maximum flood storage lake level	104 m MSL	104 m MSL
Elevation of minimum operating lake level	90 m MSL	95 m MSL
Useable Storage between Max and Min levels	28.3 MCM	16.6 MCM
Area at normal operating lake level	266 ha	266 ha
Area at maximum flood storage lake level	336 ha	336 ha
Area at minimum operating lake level	125 ha	189 ha
Top clearing elevation	104 m MSL	104 m MSL
Lower clearing elevation	90 m MSL	95 m MSL
EMBANKMENTS		
Dam		
Type of dam	Rock fill embankment	
Top elevation of dam	105 m	
Fixed crest width	13 m	
Height	35 m	
Overall length of dam	203 m	
SPILLWAY		
Type of Spillway	Uncontrolled ogee	
Total length	132 m	
Elevation of spillway	100 m MSL	
Maximum Design Discharge	2,044 CMS	
Sluce Gate Option 1		
Conduit diameter	1.22 m	
Outlet invert	77 m	
Design flow	13.7 CMS	
Sluce Gate Option 2		
Conduit dimension	0.91 by 1.21 m	
Outlet invert	77 m	
Design flow	13.7 CMS	
Power Plant		
Option 1	6,000 kW	
Option 2	6,000 kW	

Table 19 - 3 Pertinent Data - for Operating Options 1 and 2 (continued)

CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	240 m
Horseshoe tunnel dimensions	(2) 7.6 by 7.6 m
Inlet invert	72 m MSL
Outlet invert	70 m MSL
Cofferdam Height above tunnel inlet invert	8.9 m
MINIMUM FLOW CONDUIT	
Conduit diameter	500 mm
Conduit length	240 m
Inlet invert	71 m MSL
Outlet invert	69 m MSL
Conduit capacity	1.4 CMS

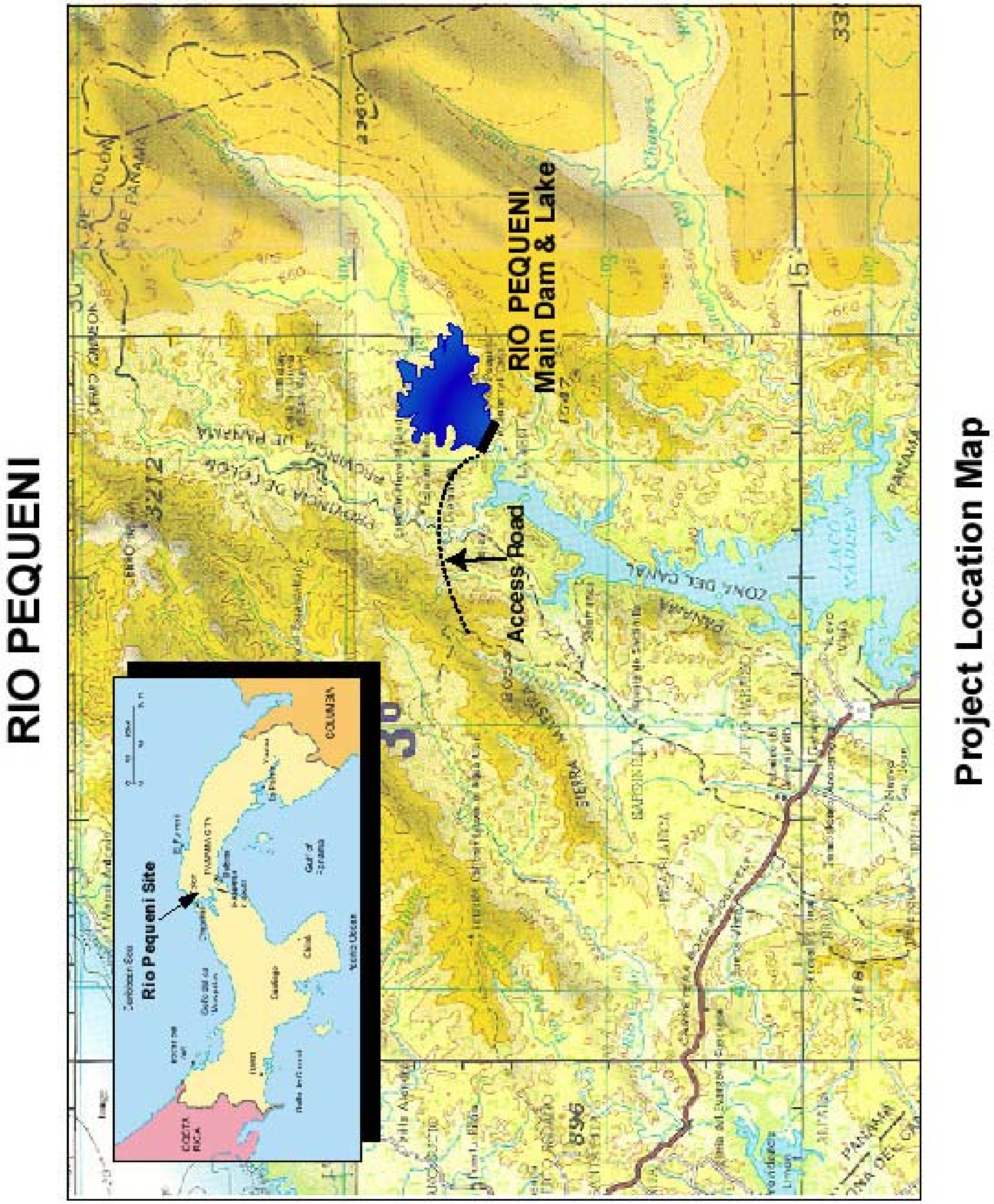


Plate 19 - 1   Project Location Map

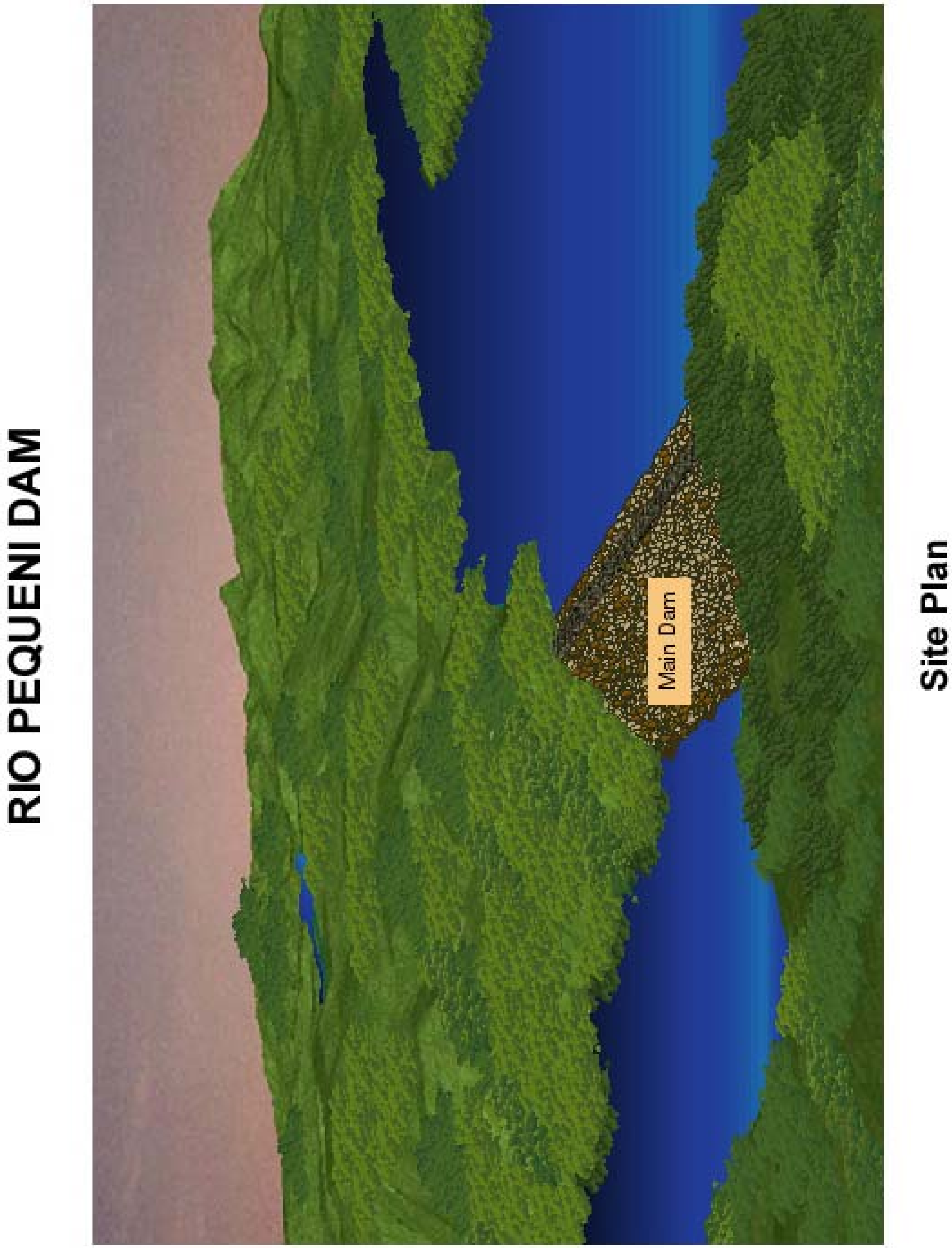


Plate 19 - 2 Site Plan

SECTION 20

Rio Ciri Grande

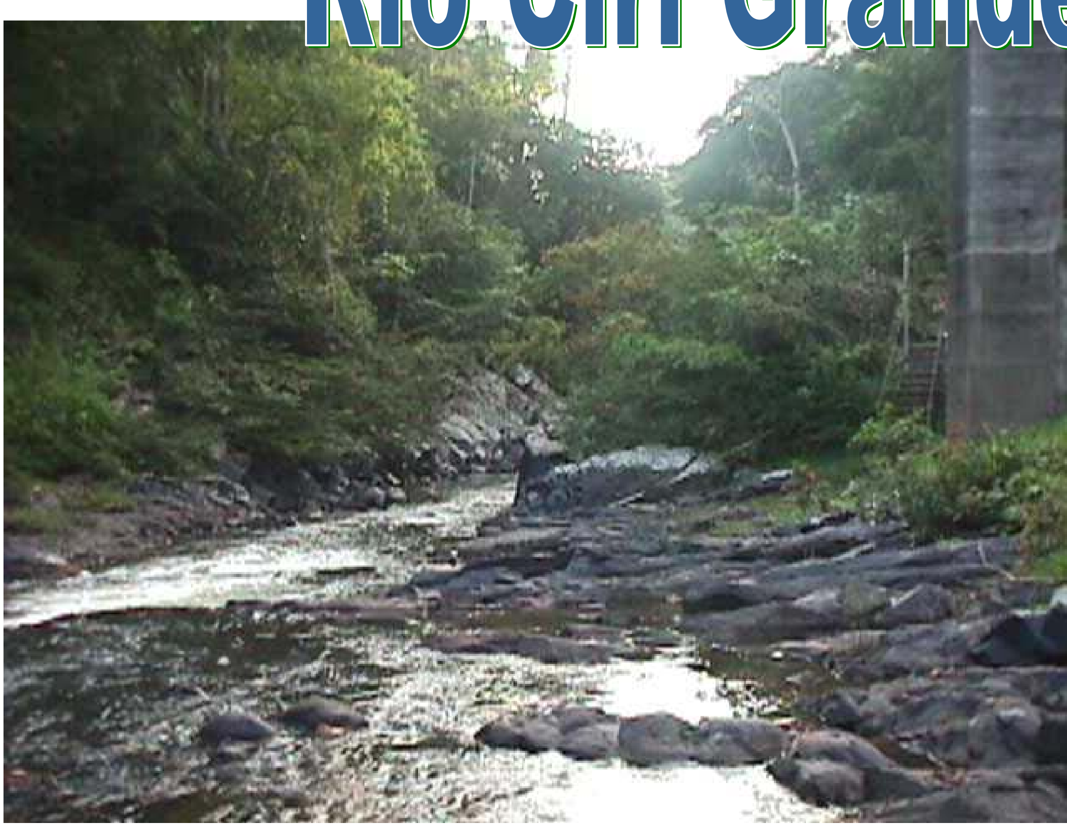


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein would include a dam and lake on the Rio Ciri Grande in the western part of the Panama Canal watershed above Gatun Lake. Water impounded in Ciri Grande Lake would be released to the Panama Canal watershed as needed to support canal operations.

The Rio Ciri Grande watershed is within the Panama Canal watershed above the Gatun Lake in the District of Capira. The proposed Ciri Grande dam site would be on Rio Ciri Grande approximately 3.5 km upstream from the point were the Rio Ciri Grande enters Gatun Lake. The structures for this proposed project would consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, a hydropower plant, and other outlet works. The total project first costs of the proposed Rio Ciri Grande project are estimated to be $71,856,000.

The proposed Rio Ciri Grande project would contribute positively to the hydrologic reliability of the Panama Canal to serve its customers and would reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.2 (46.42 lockages) would be 98.8 percent. With construction of the proposed Rio Ciri Grande project, the existing high hydrologic reliability could be continued as demand for lockages increases up to 8.0 percent above current demand levels. This would equate to approximately 3.1 lockages.

The amount of hydropower that could be produced by the hydropower plants in the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water increase. With the inclusion of the hydropower plants at the proposed Rio Ciri Grande project, the system could produce net additional megawatt hours of hydropower.

Site Selection

The proposed Rio Ciri Grande dam site was chosen with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Ciri Grande watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow.

The site chosen for the proposed Ciri Grande Dam would be approximately 3.5 km upstream from the point were the Rio Ciri Grande enters Gatun Lake. This site would accommodate construction of a dam with a normal operating lake level at elevation 140 m MSL and a maximum flood storage lake level at elevation 144 m MSL. Plate 20 - 1 shows the location of the proposed Rio Ciri Grande project.

Hydrologic Considerations

The Rio Ciri Grande flows northward from the Continental Divide to the Gatun Lake. The headwaters of the watershed begin at approximate elevation 1,000 m MSL approximately 36 km south of the point where Rio Ciri Grande enters Gatun Lake. The distribution of the average annual rainfall over the Rio Ciri Grande watershed varies from a high of 3,200 mm in the upper basin areas near the Continental Divide to 2,600 mm at Gatun Lake. The average rainfall over the entire basin is estimated to be 2,700 mm. The proposed Ciri Grande Lake would receive runoff from approximately 186 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 9.3 CMS at the proposed dam site.

The discharge at the Rio Ciri Grande dam site was obtained by using the recorded and correlated stream flow data of the Los Cañones hydrologic station.

This station began operation in 1948, was discontinued in 1959 and was placed in operation again in 1978. In order to complete missing data, a significant statistical correlation using standard hydrologic techniques was established with the discharge data of the Rio Trinidad at El Chorro. The consistencies of the measured and correlated data were verified using the double mass curve method.

Because of the proximity of Rio Ciri Grande to Gatun Lake, and because of the absence of site specific information, the monthly evaporation rates established for Gatun Lake were considered appropriate for the evaporation rates of Ciri Grande Lake.

Geologic Considerations

The proposed Rio Ciri Grande project is located in an area of the Isthmus of Panama where Miocene aged volcanic rocks (andesites, basalts, breccias, and tuffs) of the Tucue Formation are encountered at the surface. A visit was made during the preparation of this report to the Ciri Grande hydrographic station, located at the proposed dam site. The river flows over basalt rock at the hydrographic station, just prior to entering a narrow gorge. The rock at the gauging station was hard and appeared to be of high quality. It is expected that the rock in the gorge is similar in type and quality, and would be suitable for either rock fill or concrete aggregate.

In the absence of detailed geologic information for the proposed Ciri Grande dam site, a degree of extrapolation was necessary. It was predicted that rock, at the site, would be encountered at a shallow depth and would be of sufficient quality to serve as foundation material for the dam and appurtenant structures. Furthermore, it was assumed that sufficient rock for fill and concrete aggregate would be available from the required excavation and that impervious materials would be available within the immediate area for use in the construction of the project.

Lake Operation

Two operating options were considered in this study for periods when water would be transferred from Ciri Grande Lake to Gatun Lake for Panama Canal operations. Option 1 consists of the water surface of the lake fluctuating from the maximum lake operating level at elevation 140 m MSL down to the minimum lake operating level at elevation 120 m MSL. The maximum flood lake level would be at elevation 144 m MSL. Approximately 360 MCM of storage would be provided under Option 1. Option 2 consists of the water surface of the lake fluctuating from the maximum lake operating level at elevation 130 m MSL down to the minimum lake operating level at elevation 120 m MSL. Approximately 136 MCM of storage would be provided under Option 2. The maximum flood lake level would be at elevation 124 m MSL. The volume between the maximum flood storage lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Ciri Grande downstream of the dam, and flood flow impacts on Gatun Lake would be lessened somewhat. Table 20 - 1 shows the lake levels for the two operating options.

Table 20 - 1 Lake Operating Options

Lake Level (m MSL)	Operating Option 1	Operating Option 2
Normal Operating Lake Level	140	130
Minimum Operating Lake Level	120	120
Maximum Flood Storage Lake Level	144	134

Project Features

GENERAL

The structures for this proposed project would consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, a hydropower plant, and outlet works of sufficient size to release stored water to Gatun Lake for supplementing water for canal operations. The following paragraphs provide a description of the proposed structures and improvements for the Rio Ciri Grande project. The major structural components indicated here are configured for Operating Option 1. In some instances, the proposed structures and improvements for Operating Option 1 and Operating Option 2 would be slightly different. Plate 20 - 2 depicts the dam in downstream left bank perspective view.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the PCC that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The dam would be an embankment with the top at elevation 145 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 989363 north and 603224 east. The right abutment would be 989243 north and 603330 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam at its highest point would be approximately 55 m high, and the overall length would be 161 m. The actual side slopes and crest width would be determined during further study and would be contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. The embankment section at the dam would be similar to that shown for the Rio Indio project, Section 5 of this report.

Foundation grouting might be required across the entire base of the dam and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

Saddle Dams

Two saddle dams would be required to complete the lake impoundment for Operating Option 1. The saddle dams would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The top of the saddle dams would be set at elevation 145 m MSL, and they would have a crest width of 13 m. The length of the north saddle dam would be 350 m, and that of the south saddle dam, 322 m. The actual side slopes and crest widths would be determined during further study and would be contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. The cross section of the main dam and saddle dams would be similar to that shown for Rio Indio project, Section 5 of this report.

SPILLWAY

An uncontrolled ogee spillway with a length of 48.7 m and a crest at elevation 140 m MSL would be required to release flood flows. The spillway crest elevation would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 673 CMS at a maximum lake elevation, during flood conditions, of 144 m MSL. The spillway would be located within the abutment adjacent to the right end of the dam and would consist of a mass concrete sill section embedded in the natural rock. A sloped and / or stepped, natural rock cut tailrace channel would return flow to the existing stream. The tailrace channel would extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. The spillway profile would be similar to that shown for the Rio Indio project, Section 5 of this report.

IMPOUNDMENT

The lake formed by the proposed Rio Ciri Grande Dam would have a normal operating lake level at elevation 140 m MSL. The surface area at the normal operating lake level would be approximately 2,610 ha. At the maximum flood storage lake level, elevation 144 m MSL, the surface area would be approximately 2,920 ha. With the minimum operating lake level at elevation 120 m MSL, the surface area would be approximately 1,100 ha. The area at the elevation of the top of the dam elevation 145 m MSL, would be approximately 3,000 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas required for construction of the dam (embankments and spillway), outlet works, hydropower plant, access roads, and disposal and staging areas. Clearing only would be required for the 1,510 ha in the lake area between the normal operating lake level at elevation 140 m MSL and the minimum operating lake level at elevation 120 m MSL, and for the transmission lines.

HYDROPOWER PLANT

The flows, excess to the needs of the Panama Canal operation, at the proposed Rio Ciri Grande Dam would support installation of a 2.2 MW hydropower plant, assuming a 0.5 plant factor. This facility would be designed and configured to function as part of the national power grid. A transmission line would be required to carry the energy to a connection with the grid near La Chorrera. Plate 5 – 6 shows a similar location of the hydropower plant at the dam.

OUTLET WORKS

An outlet works system would be required to provide for passage of stored water to Gatun Lake as required for navigation. This system would also provide for diversion of the Rio Ciri Grande during construction, supply water for production of hydropower, allow for emergency drawdown of the lake, and allow minimum flows to be released to the downstream river channel.

This outlet works system would include a single intake structure. This structure would be configured to allow passage of channel flows up to the required level of protection during construction. Once diversion was no longer needed for construction, the structure would be used to control the flows for navigation, hydropower and emergency drawdown of the reservoir. It would also have separate controlled water intakes at various elevations to allow flows to be withdrawn from the lake to optimize the quality of the water passed as minimum flow. The hydropower intake would also be elevated to prevent silt from entering the power units.

This system would consist of an 6 m diameter tunnel passing through the land mass to the left of the dam abutment, an intake structure with redundant sluice gates located in the lake, an outlet channel downstream, and various gate structures and water conduits. The diversion tunnel would be 540 m in length; it would have an inlet invert at elevation 82 m MSL and an outlet invert at elevation 81 m MSL. The diversion tunnel would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of 325.3 CMS at the site without regulation from the dam. The cofferdam would measure 9 m above the upstream invert of the tunnel. A control structure would be required at the tunnel outlet to provide free flow of water or to divert flows from the lake into the hydropower conduit. The closure would be configured with stoplogs to provide for periodic maintenance of the control gates.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from the main population centers on the Atlantic and Pacific coasts, Colon and Panama City, respectively.

Roadway access from the south and east exists as far as the village of Arosemena. From this point a new roadway would be constructed to the dam site and lake area some 12 km to the west. This route would require crossing the Rio Quebrado Grande and the Rio Trinidad.

Another possible means of access might be a combined water and land route similar to that addressed for the Rio Lagarto alternative, Section 10 of this report, using the channel in the Rio Ciri Grande arm of Gatun Lake to ferry materials and equipment as far as possible and constructing new land access from that point. This route would require approximately 7 km of new road construction and would require that mooring and off loading facilities be constructed near the end of the Ciri Grande channel. This route may require some dredging of the existing small channel in order to be serviceable.

The land route from Arosemena Village was used in developing costs for this alternative. In addition to providing construction access to this new corridor into the interior of the country west of the Panama Canal will be of benefit to those living in that region. The new roads will provide ready access to the main centers of commerce in the southern part of the country, La Chorrera and Panama City.

Sources of Construction Material

Rock removed from the spillway site would be used as fill in the embankment portion of the dam. Impervious materials for the core section might have to be obtained from outside the project area. For this study, it was assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that insufficient impervious materials are available, then other materials such as roller compacted concrete should be considered for construction of the dam.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Ciri Grande project would be located in the District of Capira. Construction of this proposed project would require 4,000 ha. Table 20 – 2 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 20 – 2 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	3,000
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	4,000

Relocations

The lake would be located in a moderately populated region with a local network of vehicle paths and utilities. This area is devoted primarily to subsistence farming and ranching. Structures and individuals located in the lake area below elevation 145 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. Relocations required would include at least seven (7) small villages in the lake area (La Bonga Abajo, Ciri Grande, Los Faldares, La Boca de La Honda, La Sonadora, Nuevo Paraiso, Loma El Nispero), several other small settlements (just a few structures), and numerous isolated structures. Many of the villages have elementary schools, churches, electricity, and limited telephone service.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising and award phase, and on through the construction of the project. Environmental coordination would begin with planning studies and would continue through completion of construction. The final design would be accomplished for the recommended project. Upon completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, would be acquired initially. Lands for the dam site, staging area, disposal area, and lake would then be acquired.

Access roads would be constructed to the dam site. Once access to the sites has been established, a camp would be built to house workers during construction.

Socio-economic programs would begin shortly before construction of the dam. The relocation of the seven villages, small settlements and isolated structures would be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project would continue throughout the construction phase.

Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the construction diversion tunnel and the intake and outlet structures near the dam site and the spillway would follow with work being done simultaneously. Where possible, materials removed from the these sites would be placed directly into the earth and rock fill portions of the dam. Once the intake structure and diversion tunnel were completed, the dam construction site would be isolated using upstream and downstream cofferdams. These would eventually become part of the main dam, and the stream would be diverted through the tunnel. The dam foundation would then be excavated and grouted, and the dam constructed. Concurrently with construction of the dam, the hydropower plant site downstream of the dam would be excavated, and the powerhouse construction would be started. The power transmission lines would be constructed during this time frame also. Upon completion of the dam and the inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped using the intake structure gates, and lake filling would begin. Simultaneously, the downstream gate and flow separation structure would be constructed to provide for redirection of flows passing through the diversion tunnel to the hydropower penstock(s). The minimum flow conduit would also be installed through the diversion tunnel. Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 10 years from initial planning to lake filling. Figure 20 – 1 depicts the development sequence of the various project features.

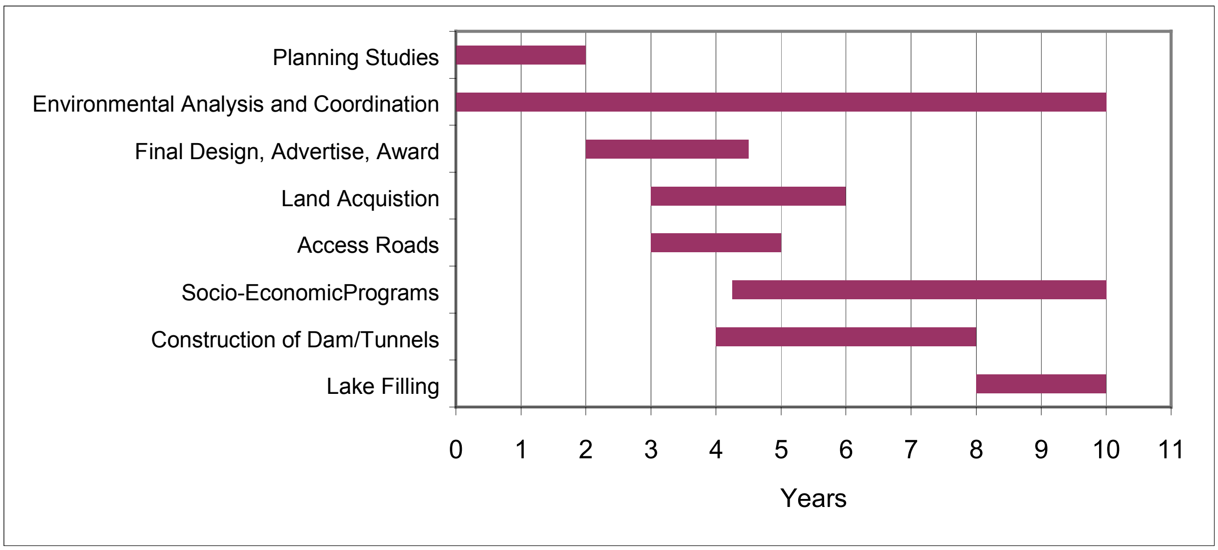


Figure 20 – 1 Development Sequence

Hydrologic Reliability

In order to determine the effect of the proposed Ciri Grande Lake on the hydrologic reliability of the Panama Canal, the existing HEC-5 model was modified to include the Rio Ciri Grande Lake. The Ciri Grande Lake was modeled to release flows into Gatun Lake and local inflows to Gatun Lake were reduced by the amount that the Ciri Grande Lake would capture.

HEC-5 model simulations were conducted for both the existing Panama Canal system and the system operating with the proposed Indio Lake providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record. Figure 20 - 2 presents the resulting hydrologic reliability for three configurations with demands increasing up to 180 percent of current demands. These configurations were:

- Existing system,
- Operating Option 1 (Ciri Grande Lake fluctuating between the normal operating lake level at elevation 140 m MSL and the minimum operating lake level at elevation 120 m MSL), and
- Operating Option 2 (Ciri Grande Lake fluctuating between the normal operating lake level at elevation 130 m MSL and the minimum operating lake level at elevation 120 m MSL).

The horizontal axis along the bottom Figure 20 - 2 reflects demands as a ratio of the five-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 20 - 2, the existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability with a demand ratio of 1.0 would be 99.83 percent for Operating Option 1, and the hydrologic reliability with a demand ratio of 1.8 would be 97.96 percent. With Operating Option 2, the hydrologic reliability with a demand ratio of 99.67 would be 100 percent, and the hydrologic reliability with a demand ratio of 1.8 would be 87.25 percent. Table 20 – 6 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the Panama Canal system would decrease. With the construction of the proposed Rio Ciri Grande project, the existing high hydrologic reliability could be continued as demand for lockages increases up to 8 percent above current demand levels for Option 1 and 2.1 percent for Option 2. This equates to 3.1 and .82 lockages respectively.

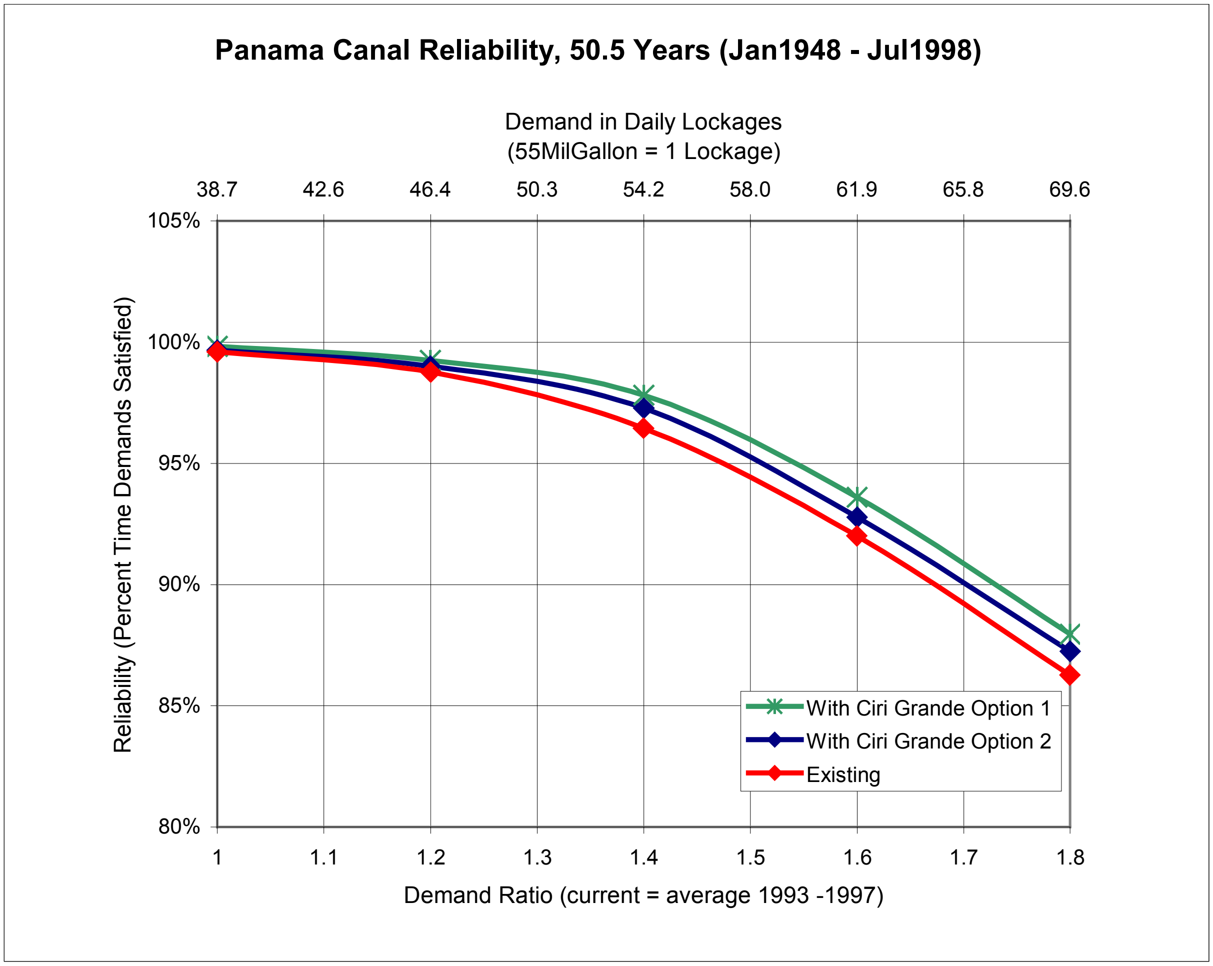


Figure 20 – 2 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts shown on Plates 20 – 1 and 20 – 2 and detailed in data provided under separate cover. The unit prices applied to these quantities were based on historical information from previous estimates prepared for similar construction in the Republic of Panama, previous estimates for similar construction in the Southeastern United States, information gathered from U.S. Army Corps of Engineers, Mobile District, Construction Division personnel in the Republic of Panama, and the publication, Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1979.

Engineering and design is estimated to be 12 percent and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.).

An allowance of 25 percent was included for contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $71,856,000. Table 20 – 3 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 20 – 3 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	10,000,000
Access Roads	11,870,000
Clearing and / or Grubbing	2,585,000
Diversion Tunnel	3,814,950
Cofferdam	498,297
Dam	2,644,304
Spillway	1,422,720
Intake	3,286,524
Downstream Bulkhead / Gate Structure	299,800
Hydropower Plants	1,617,725
Transmission Lines	7,700,000
North Saddle Dam	1,886,475
South Saddle Dam	277,892
Subtotal	47,903,687
E&D, S&A, Field Overhead	9,580,737
Contingencies	14,371,106
Total Project First Costs	71,855,530 **approximately** 71,856,000

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Ciri Grande project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 11 who would include a station manager, a multi-skilled supervisor, 3 leaders (Electronics / Instrumentation, Electrical and Mechanical), 5 craftsmen, and one laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the proposed project. The part-time staff would consist of three mechanics and three electricians. The annual costs of the staff are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $300,000 per year for the main project facilities.

Major Replacements

The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 100 years. To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it was assumed that specific items would cost the same as at present. No allowance was made for salvageable fixed parts. Table 20 – 4 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements would be $144,000 and the average annual replacement costs would be $17,000.

Table 20 – 4 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	16,500,000	57,100
Bridges	50	1	1,125,000	3,900
Intake				
Head Gates	50	1	375,000	1,300
Minimum Flow Gates	50	1	45,000	200
Stoplogs	50	1	205,500	700
Trashracks	50	1	66,000	200
Access Stairs	50	1	48,750	200
Downstream Bulkhead				
Bulkhead / Gate	50	1	155,150	500
Hydropower Plant				
Turbines and Generators	33	1	900,000	21,400
Station Electrical Equipment	33	1	375,000	8,900
Switchyard Equipment	33	1	240,000	5,700
Miscellaneous Plant Equipment	33	1	93,000	2,200
Slide Gates	50	1	30,000	100
Stoplogs	50	1	321,000	1,100
Transmission Lines	50	1	11,550,000	40,000
Total			32,029,400	144,000
Average Annual Replacement Costs				17,000

Annual Costs

The total project first costs are estimated to be $71,856,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the total project first costs was computed from mid-year throughout the 10-year period from initiation of Planning and Design until the lake was filled. The interest during construction at 12 percent would be $49,184,000 and it was added to the total project first costs for total project investment costs of $121,040,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $14,575,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to the present worth as of completion of reservoir filling. Table 20 – 5 contains a summary of the annual costs.

Table 20 – 5 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	71,856,000
Interest During Construction	49,184,000
Total Project Investment Costs	121,040,000
Annual Average Investment Costs	14,575,000
Operation and Maintenance Costs	
Staff Costs	500,000
Ordinary Maintenance Costs	320,000
Major Replacement Costs	17,000
Total Average Annual Costs	15,412,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Section 4. The following paragraphs present the results of the economic investigations for the proposed Rio Ciri Grande project. The 50-year planning period for this proposal is 2010 to 2060.

The proposed Rio Ciri Grande project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 20 – 6 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages were obtained from the data used to develop Figure 20 - 2. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 20 – 6 Panama Canal Hydrologic Reliability

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability		
			Existing System (%)	Operating Option 1[1/] (%)	Operating Option 2 [2/] (%)
1	2000	38.68 [3/]	99.60	99.83	99.67
	2010	45.11	98.91	99.35	99.13
1.2		46.42	98.76	99.25	99.02
	2020	47.61	98.41	99.03	98.75
	2030	49.55	97.83	98.67	98.31
	2040	52.02	97.09	98.21	97.76
1.4		54.15	96.45	97.82	97.28
	2050	55.13	95.89	97.28	96.71
	2060	59.05	93.65	95.95	95.29
1.6		61.89	92.02	93.60	92.78
	2070	63.97	90.47	92.08	91.29
1.8		69.63	86.27	87.96	87.25

[1/] Operating Option 1 (Ciri Grande Lake fluctuating between the normal operating lake level at elevations 140 m MSL and the minimum operating lake level at elevation 120 m MSL).

[2/] Operating Option 2 (Ciri Grande Lake fluctuating between the normal operating lake level at elevations 130 m MSL and the minimum operating lake level at elevation 120 m MSL).

[3/] 2000 Daily Demand is Average of 1993-1997

Regardless of the operating option, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands grow, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Rio Ciri Grande project, these shortages would be less than they would be under the existing system. With a hydrologic reliability of 99.6 percent, Operating Option 1 would increase the amount of water supplied for navigation by approximately 3.10 equivalent lockages, and Operating Option 2 would increase that amount by 0.82 equivalent lockage. For Operating Option 1, the 99.6 percent hydrologic reliability would occur in the year 2005 with an equivalent daily average number of lockages set to 41.78. For Operating Option 2, the 99.6 percent hydrologic reliability level would occur in the year 2001 with an equivalent daily average number of lockages of 39.50. Benefits for these amounts of additional water would be attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages provided by each option. The average annual benefits for water supply would be $63,020,000 for Operating Option 1 and $16,639,000 for Operating Option 2. Table 20 – 7 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Rio Ciri Grande project in operation, the annual benefits for meeting shortages, and the average annual benefits for both options.

Table 20 – 7 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages With Operating Option 1	Remaining Daily Shortages With Operating Option 2	Annual Benefits for Operating Option 1 ($)	Annual Benefits For Operating Option 2 ($)
2010	6.43	3.33	5.61	60,587,000	15,997,000
2020	8.93	5.83	8.11	63,966,000	16,889,000
2030	10.87	7.77	10.05	63,966,000	16,889,000
2040	13.34	10.24	12.52	63,966,000	16,889,000
2050	16.45	13.35	15.63	63,966,000	16,889,000
2060	20.37	17.26	19.55	63,966,000	16,889,000
Average Annual Benefits				63,020,000	16,639,000

With Option 1, the system will provide a total of 41.78 equivalent lockages at the 99.6 percent level of reliability or 3.10 more lockages than the existing system.

With Option 2, the system will provide a total of 39.50 equivalent lockages at the 99.6 percent level of reliability or 0.82 more lockages than the existing system.

With either operating option, the reliability of the system to provide all of the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Rio Ciri Grande project would be $4,941,000 for Operating Option 1 and $2,668,000 for Operating Option 2.
Table 20 – 8 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits for each operating option.

Table 20 – 8 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Daily Lockage ($)	Annual Navigation Benefits For Operating Option 1 ($)	Annual Navigation Benefits For Operating Option 2 ($)
2010	39.0	2,086,000	3,393,000	1,673,000
2020	40.0	2,260,000	5,148,000	2,799,000
2030	40.0	2,260,000	6,955,000	3,989,000
2040	40.0	2,260,000	9,252,000	5,502,000
2050	40.0	2,260,000	11,469,000	6,745,000
2060	40.0	2,260,000	19,004,000	13,535,000
Average Annual Benefits			4,941,000	2,668,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was based upon the growth in population. The PCC provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day. An equivalent lockage is 55 million gallons of water. One equivalent lockage was added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Rio Ciri Grande project, the current costs to the PCC to process finished water at $0.69 per 1,000 gallons, the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability would be $679,000 for Operating Option 1 and $373,000 for Operating Option 2. Table 20 – 9 displays the population forecast, the resulting number of equivalent lockages demanded per day, the annual benefits for increased reliability, and the average annual benefits for M&I water supply.

Table 20 – 9 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits for Operating Option 1 ($)	Annual M&I Water Supply Benefits for Operating Option 2 ($)
2010	1,724,000	6.1	379,000	187,000
2020	2,141,000	7.6	658,000	358,000
2030	2,688,000	9.6	1,117,000	641,000
2040	3,384,000	12.0	1,867,000	1,110,000
2050	4,259,000	15.1	2,913,000	1,713,000
2060	5,360,000	19.0	6,080,000	4,330,000
Average Annual Benefits			679,000	373,000
The value of a daily lockage for M&I is $0.69 X 55,000 = $37,950				

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Rio Ciri Grande project, the system could produce net additional megawatt hours of hydropower for the first few years. After that period, the amount of hydropower generation from the proposed Rio Ciri Grande project would not offset the lower amounts of generation available from the system of Gatun Lake and Madden Lake. This would result in a net loss of hydropower generation after 2020 for Operating Option 1 and after 2030 for Operating Option 2. The positive benefits during the early part of the planning period offset the negative benefits in the latter part of the planning period resulting in positive annual average benefits. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, Operating Option 1 would have benefits of $51,000 and Operating Option 2 would have benefits of $210,000. Table 20 – 9 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 20 – 10 Average Annual Benefits For Hydropower Generation

Year	Net Generation for Operating Option 1 [1/] (MWh)	Net Generation for Operating Option 2 [1/] (MWh)	Annual Hydropower Benefits for Operating Option 1 ($)	Annual Hydropower Benefits for Operating Option 2 ($)
2010	3,495	5,122	245,000	359,000
2020	209	2,571	15,000	180,000
2030	(2,779)	423	(195,000)	30,000
2040	(6,539)	(2,282)	(458,000)	(160,000)
2050	(8,845)	(4,095)	(619,000)	(287,000)
2060	(12,272)	(7,181)	(859,000)	(503,000)
Average Annual Benefits			51,000	210,000

[1/] Net generation of Gatun, Madden, and Ciri Grande hydropower plants above generation of Gatun and Madden hydropower plants.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 20 – 11, total average annual benefits for Operating Option 1 and Operating Option 2 of the proposed Rio Ciri Grande project would be $68,68,691,000 and $19,890,000, respectively.

Table 20 – 11 Summary of Annual Benefits

Benefit Category	Average Annual Benefits	
	Operating Option 1 ($)	Operating Option 2 ($)
Navigation – Water Supply	63,020,000	16,639,000
Navigation – Reliability	4,941,000	2,668,000
M&I - Reliability	679,000	373,000
Hydropower	51,000	210,000
Total	68,691,000	19,890,000

Once average annual benefits and costs are estimated, the ratio of benefits to costs and the net benefits (net of costs) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. While there would be small differences in some project features between Operating Option 1 and Operating Option 2, the differences would not have any impact on total project first costs at this level of investigation. The same facilities would be constructed for each operating option. Table 20 – 12 provides the benefit to cost ratios for Operating Option 1 and Operating Option 2 and the net benefits for both.

Table 20 – 12 Economic Evaluation

Item	Operating Option 1 ($)	Operating Option 2 ($)
Average Annual Benefits	68,691,000	19,890,000
Average Annual Costs	15,412,000	15,412,000
Benefit to Cost Ratio	4.5	1.3
Net Benefits	53,279,000	4,478,000

Internal Rate of Return

An internal rate of return analysis for each operating option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For Operating Option 1, the internal rate of return would be 29.6 percent, and for Operating Option 2, the internal rate of return would be 14.8 percent.

Incremental Evaluation of Hydropower

Since the generation of hydropower would be provided through the conjunctive use of storage, an analysis of the incremental benefits and costs for this purpose was accomplished. The first costs of the Lands and Relocations and the Clearing and / or Grubbing, which were associated with hydropower, as well as the costs of the Hydropower Plants and the Transmission Lines were taken from Table 20 – 3. The portion of annual operation and maintenance costs associated with hydropower generation were derived from the data included in Table 20 – 5. The construction costs are estimated to be approximately $14,361,000. Interest during a two-year construction period is estimated to be $1,749,000 for a total hydropower investment costs of $16,110,000. The portion of annual operation and maintenance costs for hydropower were assumed to be $350,000 for staff, $250,000 for ordinary maintenance and $10,000 for major replacement. The total average annual costs for hydropower would be $2,550,000. The average annual benefits are estimated to range between $51,000 and $210,000. Since the average annual benefits do not exceed the average annual costs, the addition of hydropower at the proposed Rio Ciri Grande project would not be feasible. It should be noted, however, that hydropower was valued at the current costs of production for the PCC. This value might underestimate the economic value of any additional hydropower generating capacity. Additional effort should be expended in any future planning studies to determine the economic value of added hydroelectric power generation.

Socio-Economic Impacts

The socio-economic impacts of the project could be substantial. The relocation of the towns of La Bonga Abajo (population – 164), Ciri Grande (332), Los Chorros de Ciri (244), Los Faldares (90), La Boca de La Honda (22), La Sonadora (170), and Nuevo Paraiso (120) and their approximately 1,200 residents would be an important issue. The average monthly income of families in the project area ranges from less than $100 to $200 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to create the Ciri Grande Lake. The relocation of agricultural and ranching activities would be a substantial issue because approximately 60 percent of the land in the impoundment area is used for farming and ranching. The impoundment would also substantially impact mineral ore resources. The surface area of the proposed lake is 2,920 ha with another 600 ha for the dam and construction areas including permanent disposal areas.

Post-construction revenues generated for the nation would be greater, because the project will create electric power generating potential. On a per hectare basis, the revenues from power generation would be greater than those produced by the current agricultural activity. It is estimated that after construction, 11 persons would be employed to operate and maintain the new facilities. During construction, the influx of workers could create a temporary demand for additional housing, which could result in an increase in housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands and the housing values could drop to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available and additional public and community services may be offered.

To construct the dam, some existing roads would be improved and some new roads and bridges would be built; however, some unpaved roads within the impoundment area would be eliminated, which would change the traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads would increase; however following completion of construction, the traffic volumes would decline. Noise levels would increase during construction and could negatively impact noise-sensitive receptors; however, after construction, noise levels should return to pre-construction levels.

The communities that would receive the people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the dam would permanently displace people and disrupt community cohesion through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including fishing and ecotourism, could increase.

Environmental Setting

The Rio Ciri Grande project would produce hydroelectric power and provide for 3.1 additional lockages per day on a continual basis. The structures for this proposed project would consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, a hydropower plant, and outlet works of sufficient size to release stored water to Gatun for supplementing water for canal operations. The project encompasses the area to be flooded as well as the area downstream from the dam site. This area is sparsely populated and has rolling hills as well as low regions near Gatun Lake. The Rio Ciri Grande is located west of the Panama Canal, is used for navigation, and flows northward from the Continental Divide into Gatun Lake. The Rio Ciri Grande watershed above the dam is approximately 186 km^2. The impoundment area covers approximately 2,920 ha and consists of approximately 25 percent of forested land, 30 percent of pastureland (used by ranchers), 30 percent of cropland, and 15 percent of newly slashed and burned land. The lake water elevation will fluctuate from elevation 120 to 144 m MSL. The transmission lines, and roads associated with the project would also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The Rio Ciri Grande project area encompasses the area to be flooded as well as the area downstream from the dam site and the construction areas which includes a permanent disposal area. It is inhabited by about 1,200 people, dispersed throughout the area, with concentrations in the towns of La Bonga Abajo (population – 164), Ciri Grande (population – 332), Los Faldares (population – 90), La Boca de La Honda (population – 22), La Sonadora (population – 170), and Nuevo Paraiso (population – 120) and several smaller settlements. Downstream from the dam site, Los Chorros de Ciri with a population of 244, is the only town.

Approximately 60 percent of the land in the project area is occupied by farms and ranches of various sizes as well as some teak plantations. Major farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranchers raise cows, horses, chickens, and hogs. Some of the farmers and ranchers operate commercial enterprises, others rely on cash crops and subsistence farming.

INFRASTRUCTURE

The towns of La Bonga Abajo, Ciri Grande, Los Faldares, La Boca de La Honda, La Sonadora, Nuevo Paraiso, and Loma El Nispero have elementary schools. Most of these towns have cemeteries, churches, and medical centers. Towns depend on the Rio Ciri Grande and its tributaries or groundwater wells for their water supply. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Rio Ciri Grande and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners: each home has an outdoor latrine (a hole in the ground). Some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses are attributable to the present waste disposal methods. The project area is transversed by unpaved horseback riding trails that link the various communities. No major industries or poultry or beef processing plants are located in the project area. The only roads in the project area are poorly maintained dirt roads that are usable only in the dry season. The roads are rarely graded and receive little attention by either the Ministry of Public Works or the local government. Because of the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

About 80 percent of the land along Rio Ciri Grande and its tributaries is covered with forests that could support diverse wildlife populations. The forests extend to the upper mountainous areas above the Rio Ciri Grande impoundment area; however, as a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations.

ANIMALS ON ENDANGERED LIST

ANAM by its Resolution 002-80 on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although none have been identified to date some or all of the listed animals and other species of concern may be found in the project area.

AQUATIC HABITAT

Rio Ciri Grande in the project area has characteristics typical of streams in mountainous regions. Its water is clear and cool, and its bed ranges from sand to boulders, with numerous riffles, runs, and pools, and with accumulations of large boulders and rocks downstream from the dam site. Rio Ciri Grande has two major tributaries: Rio Ciri, and Rio Ciricito; approximately 15 smaller creeks also flow into Rio Ciri Grande. The river is approximately 36 km long; its width ranges from 5 m (in the dry season) to 20 m, and its depth ranges from less than 1 m to 15 m. Rio Ciri Grande and its tributaries support some fish communities; however, information about fish communities in the project area is limited.

WETLANDS

The wetlands consist of forested riparian habitat, and are limited by the relatively steep topography of the project area to the immediate vicinity of the stream banks. The width of the riparian habitat within the impoundment area varies from approximately 5 to 75 m. Approximately 80 percent of the streams above and below the dam site along Rio Ciri Grande and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during slash and burn activities. At the end of the dry season in March or early April, sizable areas of established forests and secondary growth are burned and cleared to prepare the land for agricultural use. Based on observations in the Rio Ciri Grande project area, the amount of forested land burned varies annually.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

No parks or other government-protected lands are known to be located in the Rio Ciri Grande impoundment area. Some Pre-Columbian cultural resources that have been identified by archaeological surveys are located in the impoundment area. It should be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in the impoundment area would be scattered, since approximately 730 ha, or 25 percent of the impoundment area is covered by patches of forest, which constitutes a relatively high-quality terrestrial habitat. With the creation of the lake, migration routes of some species could be adversely affected. The only forests that would remain near the Ciri Grande Lake and its drainage basin would be confined to the higher elevations.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered animals cannot be determined at this time, because it is not known which, if any, of the listed species occur within the proposed project area. The significance of the forested riparian corridor along area streams may increase if animals on the endangered list are found in the region. The Mesoamerican Biological Corridor is also promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity could be positive, because construction of the dam will result in an increase in the volume of stored fresh water in surrounding areas during the dry season. The impacts downstream from the dam site should be minimal, although the water should be released at lower rates, and seasonal extremes should be significantly reduced. The releases should be made at appropriate intervals and in amounts that should help reduce problems with water quality and temperature downstream. The cumulative impacts downstream of the dam site over time should also be minor.

WATER QUALITY

The impacts of the project on water quality downstream from the dam site could be positive. The water should contain less silt due to minimum normal flow and should provide people downstream a higher quality supply. The proposed Ciri Grande Lake should also serve as a dependable high-quality water supply for the people living around the lake.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on downstream aquatic faunal communities should be minimal, because the dam would be designed to allow releases of water from different lake levels which should help avoid problems with water quality and temperature downstream. The Rio Ciri Grande dam should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation should not be a problem. The impacts of interference with the migratory movements of natural stream fishes are unknown. Streambed degradation below the dam should be minimal.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed lake should depend on water level fluctuations, which are anticipated to vary seasonally from 120 to more than 144 m. Such fluctuations would cause much of the shore to be covered with mud, where neither aquatic nor terrestrial plant communities could thrive. Rooted aquatic plants tend to grow as deep as light penetration allows.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting Rio Ciri Grande and its upstream tributaries could be important. The reservoir could support species that thrive in lentic systems.

Species that require highly oxygenated lotic systems could be extirpated from the reach of Rio Ciri Grande that will be covered by the reservoir. If aquatic fauna are able to thrive in the new reservoir, they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur, these impacts should be identified, and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. If the new reservoir is responsibly managed and stocked with game fish by the Aquaculture Department, it could provide good opportunities for recreational and subsistence fishing. An increase in fish population could cause a corresponding increase in piscivorous predators, such as crocodiles, caimans, otters, and herons, among others. Some manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well, but several riverine native species that formerly occupied the impoundments have disappeared.

WETLANDS

The impacts to upstream and downstream wetlands could be significant. Owing to the topography of the project area, a number of wetlands could be impacted by the project. It is possible that even though the reservoir water levels will fluctuate, new wetlands could develop in the littoral zones. Due to minimum normal flow, the cumulative effects downstream of the dam site are expected to be minor.

AIR QUALITY

During construction of the dam, dust and emissions from equipment could impact the air quality in the project area. After construction, the air quality could improve because the Panamanian government currently discourages slash and burn activities.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The impacts of the project on cultural resources and historic properties could be minor. The project area is relatively large and is known to contain Pre-Columbian sites; therefore, the presence of cultural resources and historic properties is highly probable. Prior to construction, surveys would be conducted to locate cultural resources and historic properties, and the important sites would be preserved or salvaged as appropriate.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Rio Ciri Grande alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an SIA. The SIA would consist of three tasks: cooping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities.
  - Employment.
  - Land Use.
  - Property Values.

- Public and Community Facilities and Services (including utilities and schools).
- Community and Regional Growth.
- Transportation.
- Housing.
- Health (vector routes).
- Population.
- Community Cohesion.
- Recreational Resources.
- Mineral Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major types of terrestrial and aquatic habitat are identified and quantified upstream and downstream of the project.
- Conduct field studies to locate special habitat features, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Rio Ciri Grande project area.
- Coordinate with local experts regarding terrestrial and aquatic habitats.
- Provide species inventory lists for each area, identifying their status as native or exotic and whether they are threatened and / or endangered species.
- Cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.

WATER QUALITY

- As only limited water quality data are available for the Rio Ciri Grande area, additional information should be completed on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria content of the water.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and / or properties.

Evaluation Matrices

In accordance with evaluation procedures described in Section 4, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Section 35.

Tables 20 – 13 through 20 – 15 present the evaluation of the proposed Rio Ciri Grande project as related to developmental effects, environmental effects, and socio-economic effects.

Table 20 – 13 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I demands	4	10	40
	Supplements Existing System	0	10	0
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	9	6	54
	Feasibility of Concept	10	6	60
Operational Issues	Compatibility	10	6	60
	Maintenance Requirements	10	2	20
	Operational resources required	8	2	16
Economic feasibility	Net Benefits	1	9	9
	Total			259

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 20 – 14 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	4	8	32
Animals on Extinction List	4	10	40
Water Quantity Impacts – Lake	9	10	90
Water Quantity Impacts -- Downstream	5	7	35
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	5	8	40
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	5	5	25
Potential for Fishing on Lake	6	6	36
Wetlands	4	4	16
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			477

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 20 – 15 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	3	7	21
Relocation of People	3	10	30
Relocation of Agricultural/Ranching Activities	3	6	18
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	3	5	15
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	3	8	24
Community Cohesion	3	8	24
Tourism	6	5	30
Total			380

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 20 – 16 presents pertinent data for Operating Option 1 of the proposed Rio Ciri Grande project.

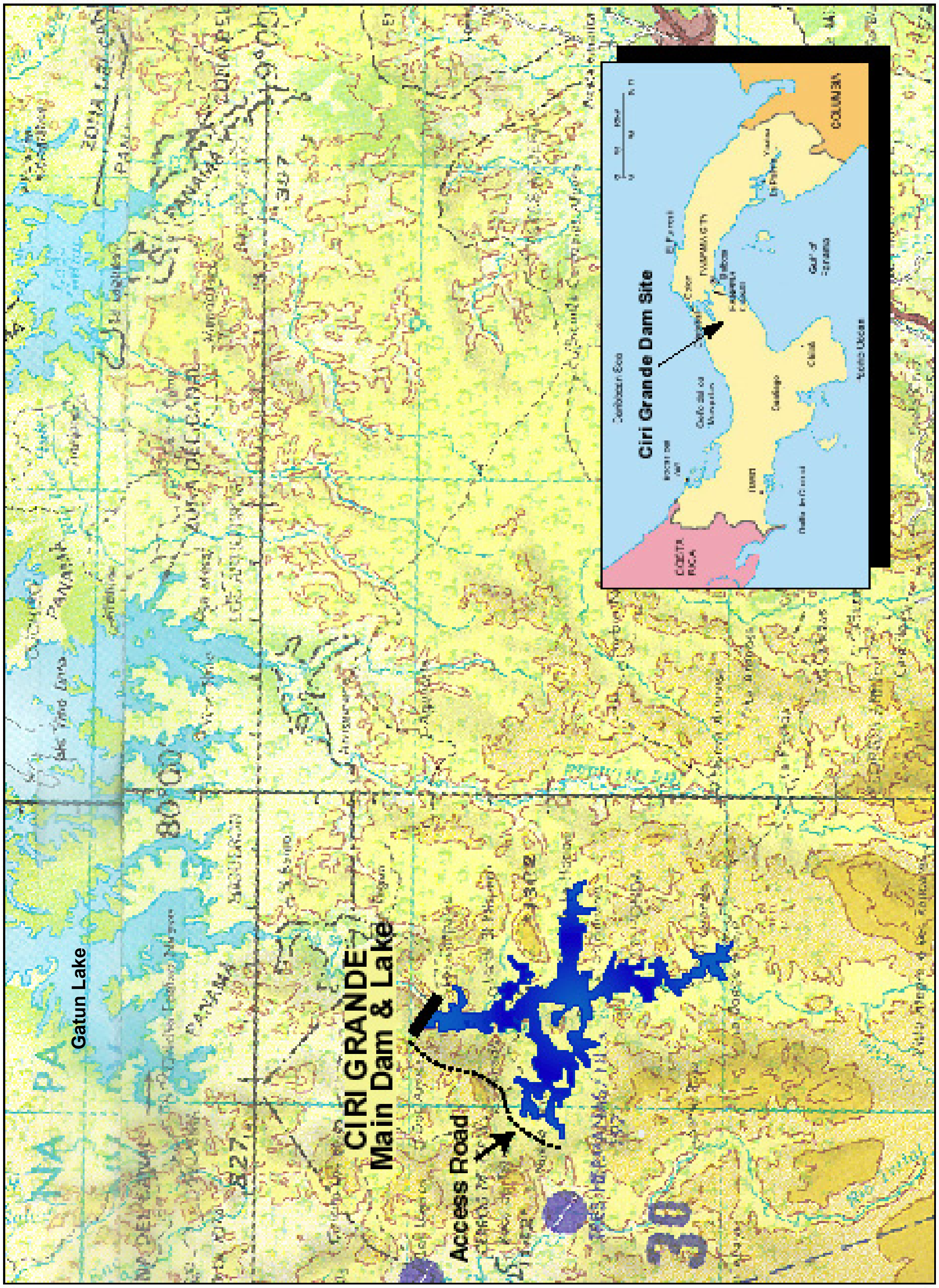
Table 20 – 16 Pertinent Data for Operating Option 1

GENERAL	
Dam site, above Gatun Lake	3.5 km
Drainage area above dam site	186 km^2
Average annual flow at dam site	9.3 CMS
LAKE	
Elevation of normal operating lake level	140 m MSL
Elevation of maximum flood storage lake level	144 m MSL
Elevation of minimum operating lake level	120 m MSL
Useable Storage between Max and Min levels	360 MCM
Area at normal operating lake level	2,610 ha
Area at maximum flood storage lake level	2,920 ha
Area at minimum operating lake level	1,100 ha
Top clearing elevation	140 m MSL
Lower clearing elevation	120 m MSL
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	145 m
Fixed crest width	13 m
Height	55 m
Overall length of dam	161 m
Saddle dam (North)	
Type of saddle dam	Earth / rock fill embankment
Top elevation of saddle dam	145 m MSL
Fixed crest width	13 m
Overall length of saddle dam	350 m
Saddle dam (South)	
Type of saddle dam	Earth / rock fill embankment
Top elevation of saddle dam	145 m MSL
Fixed crest width	13 m
Overall length of saddle dam	322 m
SPILLWAY	
Type of Spillway	Uncontrolled ogee
Total length	48.7 m
Elevation of spillway	140 m MSL
Maximum discharge	673 CMS

Table 20 - 17 Pertinent Data for Operating Option 1 (continued)

HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of each unit	2.2 MW
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	540 m
Tunnel diameter	6 m
Inlet invert	82 m MSL
Outlet invert	81 m MSL
MINIMUM FLOW CONDUIT	
Conduit diameter	460 mm
Conduit length	540 m
Inlet invert	80 m
Outlet invert	79 m
Conduit capacity	0.93 CMS

RIO CIRI GRANDE



Project Location Map

Plate 20 - 1   Project Location Map

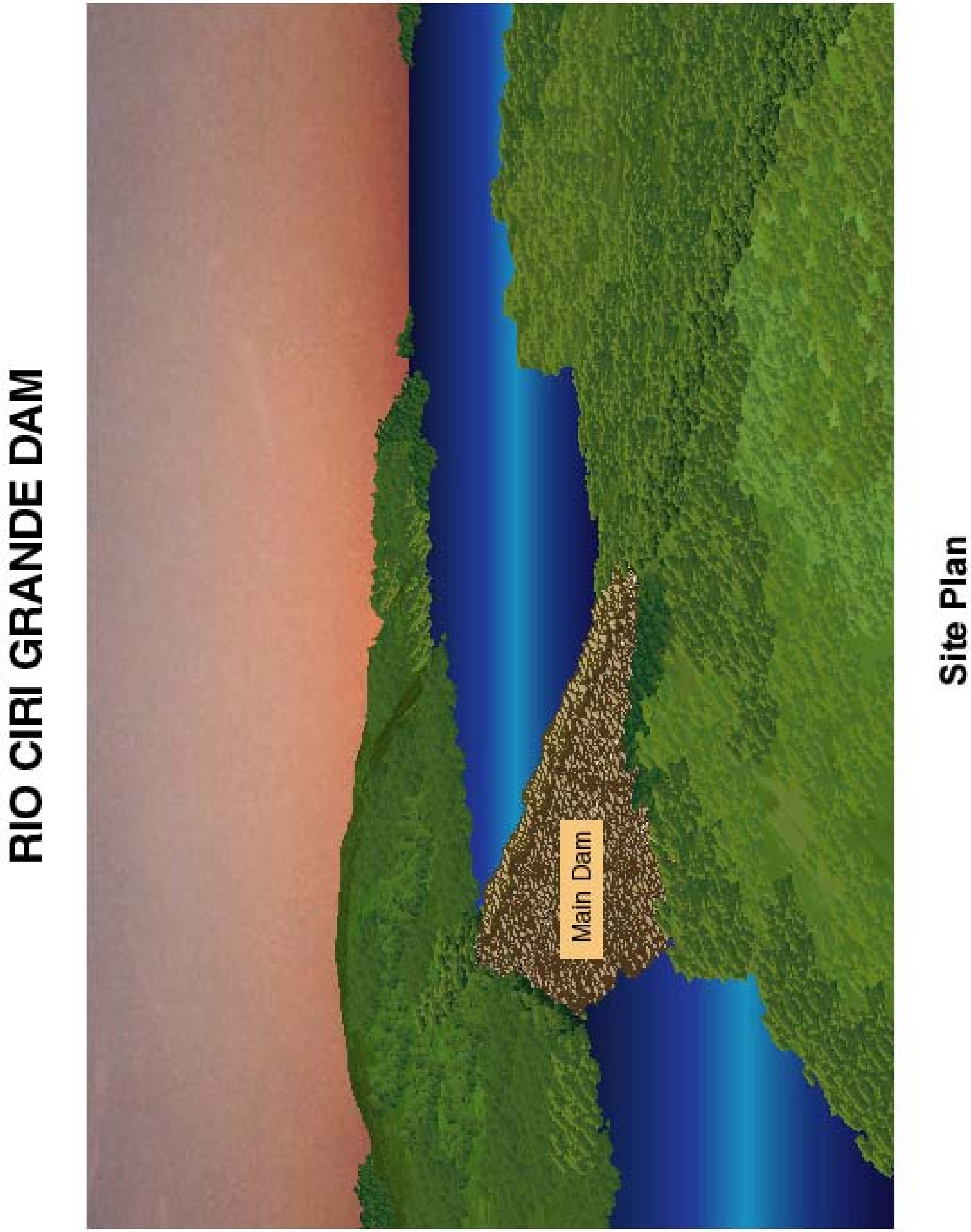


Plate 20 - 2   Site Plan

SECTION 21

Rio Caño Quebrado

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein considers a dam and lake on the Rio Caño Quebrado basin of the Panama Canal watershed within Gatun Lake. Water impounded in the Caño Quebrado Lake would add storage to the Panama Canal system of lakes. The water would be used as needed to support navigation.

The Rio Caño Quebrado watershed comprises a portion of the western side of the Panama Canal watershed. The proposed dam site would be located within Gatun Lake across the Rio Caño Quebrado arm near the city of La Laguna. The first section of the dam would extend from Punta Manguito on the west shore of the Rio Caño Quebrado arm of Gatun Lake in a northwest-southeast orientation to the eastern shore of the Rio Caño Quebrado arm. The second section would extend in an east-west orientation across the Rio Caño Quebrado eastern arm just north of the mouth of the Rio Paja. Plate 21 - 1 shows the location of the proposed Rio Caño Quebrado Dam project. The structures for the proposed Rio Caño Quebrado project would consist of two sections of rock fill dam and a gated spillway. This spillway would have 14 gate bays, each measuring 15.35 by 5.64 m.

The proposed Rio Caño Quebrado Dam project would contribute only slightly to the hydrologic reliability of the Panama Canal to serve its customers and would barely alter the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and the current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent (46.42 lockages) of the current level would be 98.8 percent. With construction of the proposed Rio Caño Quebrado project, the existing high hydrologic reliability could be continued as demand for lockages increases up to only 1.4 percent above current demand levels (0.54 lockages).

The proposed Rio Caño Quebrado project was weighed against the technical objectives stated in Section 4 of this report and found to be lacking in that the volume of water produced by this project would not be enough to significantly impact the reliability of the Panama Canal water supply (approximately 0.54 lockages per day).

The proposed Rio Caño Quebrado project would not provide additional water to the Panama Canal watershed for canal operations. Instead, it would only provide additional storage for existing flows. That additional storage allows demands on the system to increase only 1.014 percent (0.54 lockages) before the reliability of the system drops below current level of 99.60 percent. This would equate to approximately 0.54 lockages. The proposed project would not provide hydropower benefits. This alternative does not meet the first assessment criterion to provide at least one lockage per day. The plan for development of the Rio Caño Quebrado was not pursued further and was eliminated from the list of technically viable projects to be subjected to further scrutiny in this report. No formal cost, economic or environmental analyses were made for this alternative.

Site Selection

The proposed Rio Caño Quebrado dam site was recommended in previous reports and was chosen as a potential alternative for this study. The project definition and description were developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. The project area was also reviewed for other possible dam sites that might be more feasible.

The site chosen for the proposed Rio Caño Quebrado Dam would be approximately 22 km southeast of Gatun Locks and 14 km northwest of the Pedro Miguel Locks. The dam would be approximately 7 km southwest of Barro Colorado Island and 4 km northeast of the town of La Laguna. This site would accommodate construction of a dam with a maximum operating lake level at elevation 30.5 m MSL. Flood storage would be accommodated above the normal operating levels between elevations 30.5 and 24.8 m MSL.

Hydrologic Considerations

Three major rivers flow into Caño Quebrado Lake; Rio Caño Quebrado, Paja and Los Hules. All three rivers flow northward from the Continental Divide to Gatun Lake. The headwaters of the watershed begin at elevation 1,000 m MSL approximately 75 km inland and fall to 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Caño Quebrado watershed varies from 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side. The proposed Caño Quebrado Lake would receive runoff from approximately 310 km^2 of the existing Panama Canal watershed. Rainfall runoff would produce an average annual flow of 10.2 CMS at the proposed dam site.

The discharge at the Rio Caño Quebrado dam site was obtained by drainage area ratio to the established record for Gatun Lake. The Gatun Lake runoff was developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC)and the PCC in a separate study entitled HEC Models for Canal Expansion Study, dated 28 July 1998.

Since the Caño Quebrado Lake is located within Gatun Lake the monthly evaporation rates established for Gatun Lake were considered appropriate for the evaporation rates of Trinidad Lake.

Geologic Considerations

The main dam portion of the proposed Rio Caño Quebrado project is located in an area where volcanic rocks of the Tucue Formation are encountered at the surface. The rocks of the Tucue Formation consist of lava flows, breccias, tuffs and plugs, and are andesitic or basaltic in nature. These rocks probably show a wide variation in quality, from high quality of the extrusive lava flows, to possibly weathered and lesser quality volcanic tuffs. It is anticipated that most of the strata of the Tucue Formation would make satisfactory rock fill for a dam, but a significant amount may not be satisfactory for concrete aggregate. Volcanic rocks of the Tucue Formation may also contain constituents that are reactive with alkalies in cement. Neither weathered rock nor rock with reactive materials would be satisfactory for concrete aggregate. If this proposed project is carried forward, it is recommended that cores be drilled in the area of each abutment. This should be accomplished early during the planning studies to determine general depths of weathering and to determine the suitability of the rock for use as concrete aggregate.

The inter-basin transfer basin canal and spillway portions of the project are underlain by Oligocene aged sedimentary rocks of the Caimito Formation. Three recognized members of the Caimito Formation are the lower, middle and upper members. These rocks are mainly marine deposits but are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member is made up of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. It is not known which member of the Caimito Formation underlies the project area. It is considered that it will probably make an acceptable foundation for the canal and spillway. The Caimito Formation will be unacceptable for use as concrete aggregate and may be only marginally acceptable for use as fill in an earth and rock fill dam.

In the absence of detailed geologic mapping for the proposed Rio Caño Quebrado project, a degree of extrapolation was necessary. It was predicted that rock at the proposed construction locations outside the lake would be encountered at a shallow depth and would be of sufficient quality to serve as foundation for the appurtenant structures.

Lake Operation

Two operating options were considered in this study for periods when water would be stored in Caño Quebrado Lake and released to Gatun Lake for Panama Canal operations when needed. Operation of Option 1 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 30 m MSL down to the minimum operating lake level at elevation 24.8 m MSL. This would provide an additional useable storage of 104 MCM. For Operating Option 2 the water surface would fluctuate from the normal lake level of elevation 30 m MSL down to the minimum lake level at elevation 25.9 m MSL with 86 MCM of usable storage. The maximum flood lake level would be at elevation 30.5 m MSL. Flood storage would be accommodated between elevations 30.5 and 24.8 m MSL under Operating Option 1 by seasonally varying lake elevation of the Caño Quebrado Lake. Caño Quebrado Lake rule curve was designed to function similar to the rule curve of Madden Lake. Table 21 - 1 shows the lake levels for the two operating options.

Table 21 - 1 Lake Operating Options

Lake Level (m MSL)	Operating Option 1	Operating Option 2
Normal Operating Lake Level	30	30
Minimum Operating Lake Level	24.8	25.9
Maximum Flood Lake Level	30.5	30.5

Project Features

GENERAL

The structures for the proposed Rio Caño Quebrado project would consist of a rock fill dam in two distinct sections, and a gated spillway. The following paragraphs provide a description of the proposed structures and improvements for the Caño Quebrado Lake project. The major structural components indicated here are configured for Operating Option 1. In some instances, the proposed structures and improvements for Operating Option 1 and Operating Option 2 would be slightly different. Plate 21 - 2 depicts the location of the dam and the gated spillway.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the PCC that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The dam consist of two sections, the west and east embankments, with the top at elevation 31 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1004554 north and 632455 east. The right abutment would be 1004595 north and 632599 east coordinates. The embankments would be constructed by depositing cohesive materials along the alignment of the proposed dam until the stacked material reached its natural angle of repose and the consolidation, within the subgrade, had stabilized. The assumed side slopes would be 10 horizontal on 1 vertical within the submerged sections transitioning to 2 horizontal on 1 vertical in the portions traversing the existing islands. The subgrade is extremely soft and considerable displacement would be anticipated as evidenced by the original construction experience at Gatun Dam. The dam would be approximately 16 m high, and the overall length would be 404 m. The top of the dam would be 4.3 m above the maximum normal operating level in Gatun Lake. The total volume of fill material required to construct the embankments would be approximately 244,150 M^3 for the west embankment and 114,500 M^3 for the east embankment.

The crest width and side slopes are presented here for comparison purposes between projects. The actual crest width and side slopes would be determined during further study and would be contingent upon the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments. The embankment cross section for the dam would be similar to that shown for the Lower Trinidad Dam, Section 16 of this report.

SPILLWAY

Water would be released from the Caño Quebrado Lake to Gatun Lake through a gated spillway. This spillway would be constructed across a canal constructed through the low area between the Rio Caño Quebrado and Rio Trinidad arms of Gatun Lake some distance from the main dam. Each of the 14 spillway gates would have a nominal width of 15.35 m and would be 5.64 m high to provide 0.48 m freeboard above the maximum lake operating level. The gate bays would be separated / flanked by 3 m wide reinforced concrete piers (15 piers in all) which would provide support for the gates and access to the gate operating machinery. The overall length of the spillway, from out-to-out of the end piers would be 388 m. The spillway sills would be placed at the minimum lake operating level for Option 1, elevation 24.8 m MSL. The maximum discharge from the spillway would be 2,976 CMS at the maximum lake elevation during flood conditions of 30.5 m MSL.

A bridge would be provided across the tops of the spillway piers. This bridge should be at least substantial enough to allow small-motorized vehicles to traverse the spillway to service the gate operating machinery.

For this study, it was assumed that stoplogs for servicing the gates, guides, etc. would be placed from barges using floating cranes. It should be noted that, with the spillway sills at the prescribed levels, stoplogs would be required both upstream and downstream to allow work on the gate sills in the dry.

Alternatively, the spillway bridge and supporting structure could be designed to accommodate roadway traffic, including heavy cranes and construction vehicles. This would allow this roadway to be used during construction and for maintenance operations after construction was completed. This would be very costly, however, and was deemed not required for either the construction or the maintenance efforts.

The spillway would be situated 0.5 km south of Gigante on the west end of the lake away from the main dam. See Plate 21 - 1 for the proposed location of the spillway. Water would be released to Gatun Lake through Caño Gigante. This should allow the construction to be performed completely within a dry construction cut requiring a minimum of construction dewatering. Once the concrete structures are completed, the entrance and exit channels to the spillway could be opened.

IMPOUNDMENT

The lake formed by the proposed Rio Caño Quebrado Dam would have a normal operating lake level at elevation 30 m MSL. The surface area at the normal operating lake level would be approximately 2,490 ha. At the maximum flood lake level, elevation 30.5 m MSL, the surface area would be approximately 2,610 ha. With the minimum operating lake level at elevation 24.8 m MSL (Operating Option 1), the surface area would be approximately 1,460 ha. With the minimum operating lake level at elevation 25.9 m MSL (Operating Option 2), the surface area would be approximately 1,640 ha. It should be noted that the current operating levels of Gatun Lake vary up to elevation 26.5 m MSL; therefore area (approximately 1,750 ha) below the maximum Gatun Lake level are already subject to inundation.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas above the existing Gatun Lake that are required for construction of the dam (embankments and spillway), access roads, and disposal and staging areas. Clearing only would be required for the 740 ha in the Caño Quebrado Lake area between the maximum operating lake level of Gatun Lake and elevation 30 m MSL.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from the main population centers on the Atlantic and Pacific coasts, Colon and Panama City, respectively.

Access could best be gained from the Panama City area by way of existing roads as far as the village of Santa Clara, located to the south and east of the Rio Caño Quebrado dam site. From Santa Clara, a new roadway would be required to the dam construction site, a distance of approximately 8 km. Roadway access would also be required to the spillway site, which would be located some distance to the south and west, and across the existing lake from the dam site. Existing roadway access in this area is now available to the village of La Laguna. From a point just south of La Laguna, a new access road would be required around the south side of the existing lake to the spillway site. This route would require approximately 5 km of additional new roadway.

In addition to providing construction access, this new corridor into the remote areas surrounding Gatun Lake would be of benefit to those living in that region. It would provide ready access to the main centers of commerce in the southern part of the country, as well as access to the lake for recreation interests.

Sources of Construction Material

The materials used for the embankment construction could be obtained from upland sources, transported to the site and end-dumped along the proposed embankment alignment from the land contact. The material could also be obtained from dredged sources within Gatun Lake, deposited on the land for drainage, and then deposited along the proposed embankment alignment. It was assumed that rock fill required for armoring the slopes would be available within the immediate lake area.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would have to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Caño Quebrado Lake would be located within the former Panama Canal Zone and is presently managed and controlled by the PCC. It is assumed that the future management of the Panama Canal will retain the same authority and the acquisition of lands for the lake area would not be required. Construction of this proposed project would require acquisition of approximately 800 ha. Table 21 - 2 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 21 - 2 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

Relocations

The Caño Quebrado Lake would be located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Rio Caño Quebrado arm between the existing Gatun Lake level and elevation 30 m MSL would need to be relocated or modified. This region appears to have only a few settlements along the lakeshores and very limited access by land.

Hydrologic Reliability

In order to determine the effect of the proposed Caño Quebrado Lake on the hydrologic reliability of the Panama Canal, the lake was incorporated into the existing Panama Canal watershed model. The Caño Quebrado Lake was modeled to release flows into Gatun Lake and local inflows to Gatun Lake were reduced by the amount that the Caño Quebrado Lake would capture.

HEC-5 model simulations were conducted for both the existing Panama Canal system and the system operating with the proposed Caño Quebrado Lake providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record. Figure 21 - 3 presents the resulting hydrologic reliability for three configurations with demands increasing up to 180 percent of current demands. These configurations were:

- Existing system,
- Operating Option 1 (Caño Quebrado Lake fluctuating between the normal operating lake level at elevation 30 m MSL and the minimum operating lake level at elevation 24.5 m MSL), and
- Operating Option 2 (Caño Quebrado Lake fluctuating between the normal operating lake level at elevation 30 m MSL and the minimum operating lake level at elevation 25.9 m MSL).

The horizontal axis along the bottom of Figure 21 - 3 reflects demands as a ratio of the five-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 21 - 1, the existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent. The hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. With Caño Quebrado Lake included, hydrologic reliability with a demand ratio of 1.0 would be 99.65 percent for Operating Option 1, and the hydrologic reliability with a demand ratio of 1.8 would be 86.85 percent. With Operating Option 2, the hydrologic reliability with a demand ratio of 1.0 would be 99.63 percent, and the hydrologic reliability with a demand ratio of 1.8 would be 86.71 percent.

Without additional water supplies, the hydrologic reliability of the Panama Canal system would decrease. With the construction of the proposed Rio Caño Quebrado project, the existing high hydrologic reliability could be continued as demand for lockages increases up to only 1.014 percent (0.54 lockages) above current demand levels.

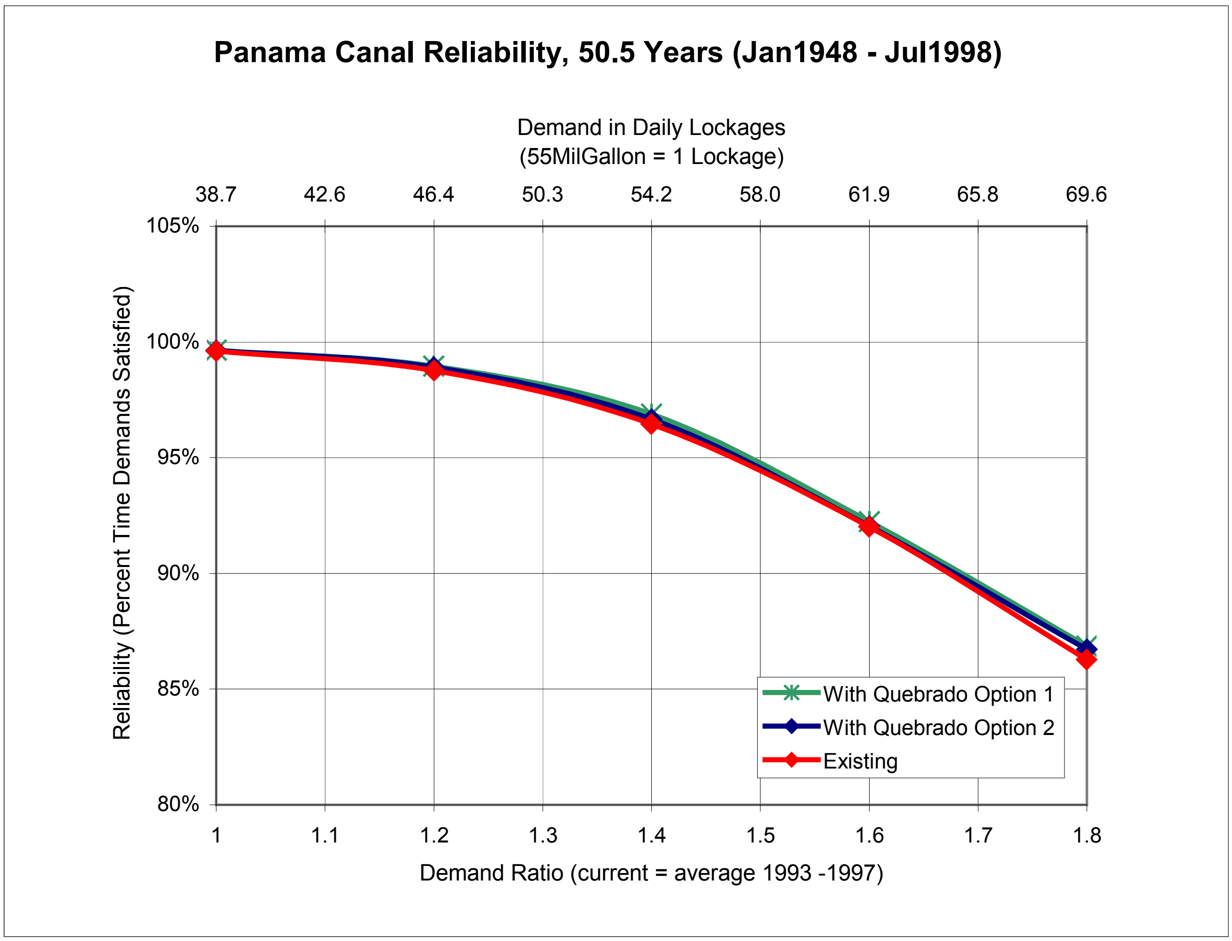


Figure 21 - 1 Panama Canal Hydrologic Reliability

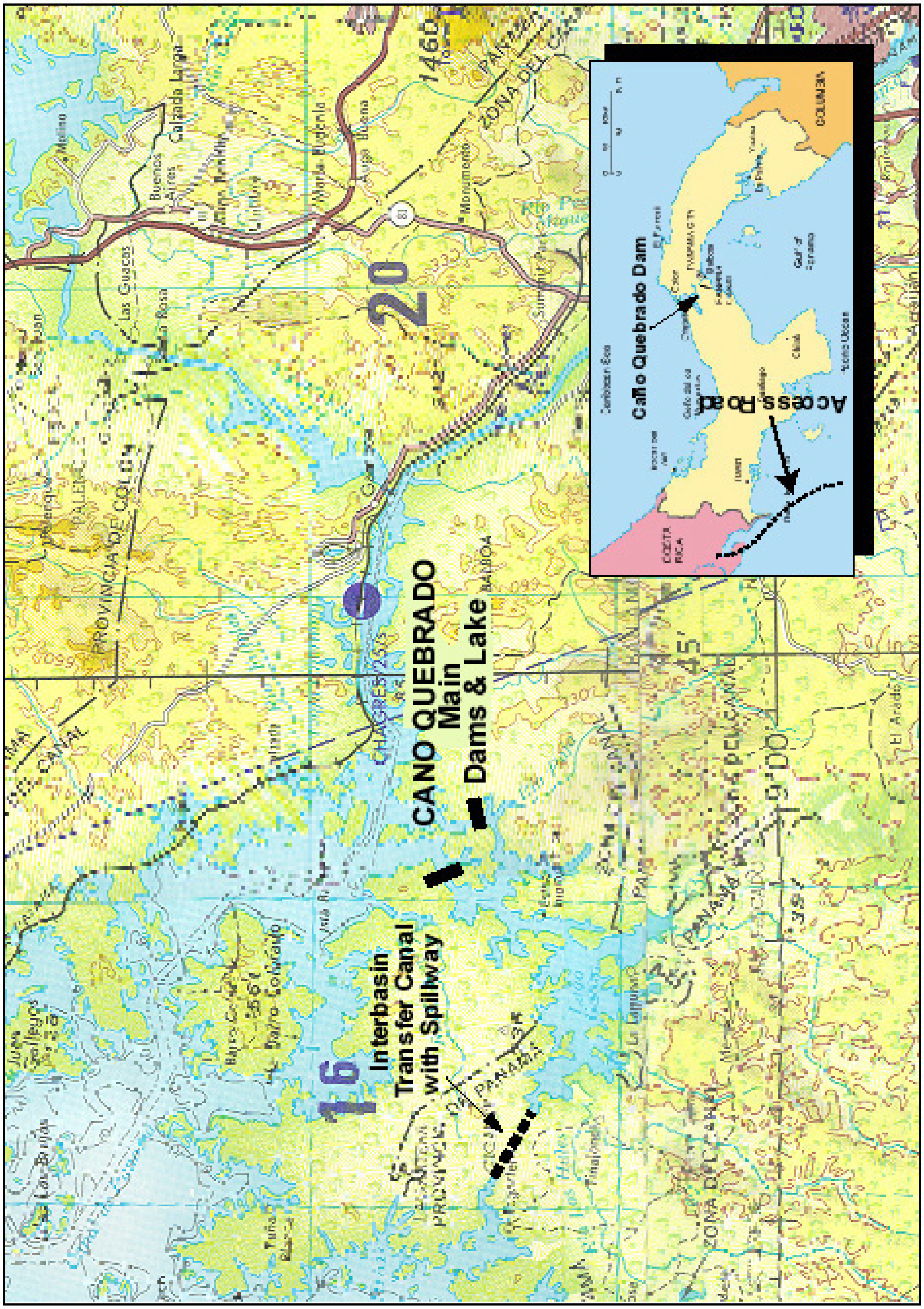
Pertinent Data

Table 21 - 4 presents pertinent data for Operating Option 1 and 2 of the proposed Rio Caño Quebrado project.

Table 21 - 3 Pertinent Data

GENERAL		
Dam site location, See Plate 21-1		
Drainage area above dam site	310 km^2	
Average annual flow at dam site	10 CMS	
LAKE	**Option 1**	**Option 2**
Elevation of normal operating lake level	30 m MSL	30 m MSL
Elevation of maximum flood lake level	30.5 m MSL	30.5 m MSL
Elevation of minimum operating lake level	24.8 m MSL	25.9 m MSL
Useable Storage between Max and Min levels	104 MCM	86 MCM
Area at normal operating lake level	2,490 ha	2,490 ha
Area at maximum flood lake level	2,620 ha	2,620 ha
Area at minimum operating lake level	1,460 ha	1,640 ha
Top clearing elevation	30 m MSL	30 m MSL
Lower clearing elevation	24.8 m MSL	25.9 m MSL
EMBANKMENTS		
Dam		
Type of dam	Rock fill embankment	
Top elevation of dam	31 m	
Fixed crest width	13 m	
Height	16 m	
Overall length of dam	404 m	
SPILLWAY		
Type of Spillway	Gated ogee with flip bucket	
No. / Type Spillway gates	14 / vertical operating Tainter	
Spillway gate dimensions	15.35 by 5.64 m	
Total length at flow surface	322 m	
Elevation of crest	24.8 m MSL	
Maximum discharge	2,977 CMS	
Width of piers	3 m	

CAÑO QUEBRADO DAM



Project Location Map

Plate 21 - 1   Project Location Map

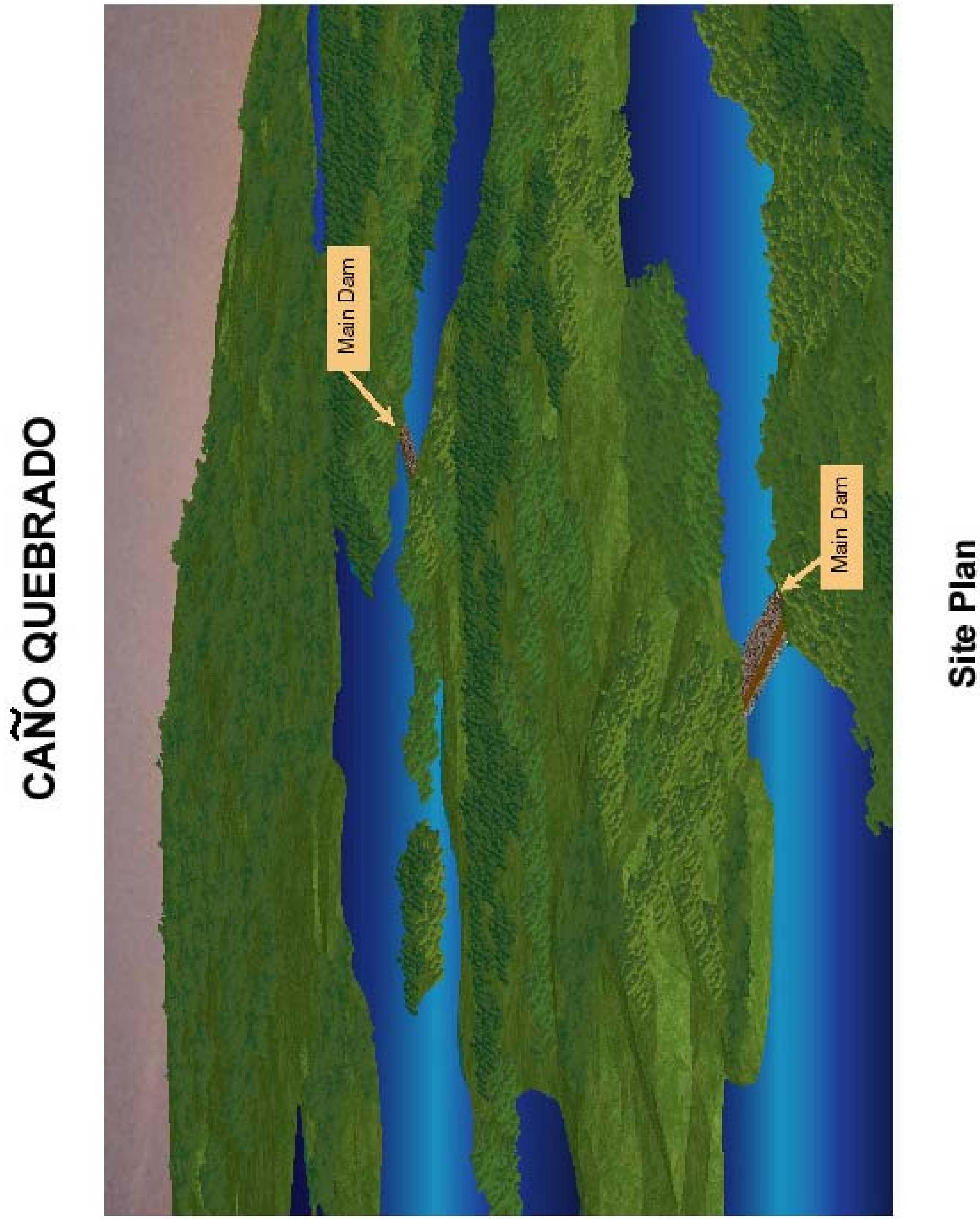


Plate 21 - 2 Site Plan

SECTION 22

Rio Caño Sucio

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented would include a dam and lake on the Rio Caño Sucio, connected by a tunnel to Indio Lake. Indio Lake would be connected to the Panama Canal watershed at Gatun Lake via a second tunnel (see Section 5 of this report for details of the Rio Indio development). Water impounded in these two lakes would be transferred to the Panama Canal watershed as needed to support navigation. Figure 22 - 1 presents a profile of the proposed system of lakes.

The Rio Caño Sucio is a southern tributary to the Rio Miguel de la Borda that is located approximately 50 km west of the Panama Canal. The Rio Caño Sucio flows into the Rio Miguel de la Borda approximately 20 km inland from the mouth of the Rio Miguel de la Borda. The development plan considers a normal operating pool at elevation 100 m MSL with operating withdrawal down to elevation 90 m MSL. The plan assumes that the Rio Indio project will be in existence at the time of this development. The estimated total first costs of the proposed Rio Caño Sucio project would be $40,227,000.

The current level of hydrologic reliability of the Panama Canal, based on the 50.5-year period of record from January 1949 through July 1998, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.2 (46.42 lockages) would be 98.8 percent. With construction of the proposed Rio Caño Sucio project in combination with the Rio Indio project, the current reliability could be continued as demand increases up to 35.75 percent (13.8 lockages) above current levels. The proposed Rio Caño Sucio project would, therefore, contribute somewhat to the reliability of the Panama Canal to serve its customers and would moderately reduce the need for imposing draft restrictions and the resulting light loading of vessels during traditional periods of low water availability in the short term. Nominal additional benefits would be realized in the form of increased hydropower production.

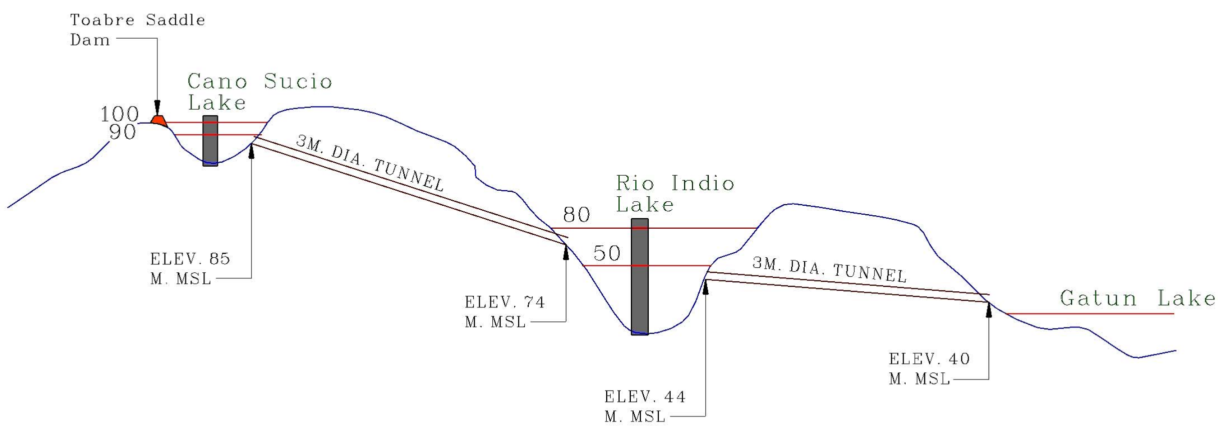


Figure 22 - 1 System Profile

Site Selection

The proposed Rio Caño Sucio dam site was chosen with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Caño Sucio watershed as possible while maintaining the reservoir high enough to allow for easy outflow to Indio Lake. In choosing a site for the dam, a location was sought where the surrounding hillsides would be relatively steep and high, and the valley was relatively narrow.

The proposed Rio Caño Sucio dam site would be approximately 25 km inland from the Atlantic Ocean. This site would accommodate construction of a dam with a maximum operating lake level at elevation 100 m MSL and a maximum flood storage lake level at elevation 104 m MSL.

Plate 22 - 1 shows the location of the proposed Rio Caño Sucio project.

Hydrologic Considerations

The Rio Caño Sucio flows from the north side of the Continental Divide into the Rio Miguel de la Borda, and then to the Atlantic Ocean.

The Rio Caño Sucio flows north northwestward from the north side of the Continental Divide into the Rio Miguel de la Borda, and then northeastward to the Atlantic Ocean. The headwaters of the Rio Caño Sucio watershed begin at approximate elevation 240 m MSL and fall to mean sea level at the mouth of the Rio Miguel de la Borda approximately 30 km downstream. Annual rainfall ranges from 3,000 mm along the coast to 2,000 mm in the higher ranges of the upper watershed. The proposed Caño Sucio Lake would receive runoff from approximately 111 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 7.4 CMS at the proposed Rio Caño Sucio dam site.

The Rio Caño Sucio is a stream without hydrological historical records. In order to establish the discharge at the dam site, it was assumed that this watershed would have the same yield per unit area as the neighboring basin of the Rio Indio measured at Boca de Uracillo.

Because of the proximity to Gatun Lake, and in the absence of additional information, the monthly evaporation rates recorded at Gatun Lake were used to establish the evaporation of Caño Sucio Lake.

It is recommended that a stream gage be installed in the vicinity of the dam site if this project is carried forward for additional studies.

Geologic Considerations

The location of the Rio Caño Sucio Dam is underlain by oligocene aged sedimentary rocks of the Caimito Formation. Three members of the Caimito Formation are recognized; the lower, middle and upper members. The deposits of each of these members are mainly marine, but are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member is made up of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone.

Moderately hard siltstone, fitting the description of strata of the principal member of the Caimito Formation, is well exposed in several waterfalls at the proposed Rio Caño Sucio Dam location. It is considered that this siltstone would make an acceptable foundation for an earth and rock fill dam, but would be unacceptable for use as concrete aggregate and only marginally acceptable for use as fill in an earth and rock fill dam.

In the absence of detailed geologic mapping for the proposed Rio Caño Sucio dam site, a degree of extrapolation was necessary. It was predicted that rock at the proposed dam site would be encountered at a shallow depth and would, as stated above, be of sufficient quality to serve as foundation for the rock fill dam and appurtenant structures.

Lake Operation

Two operating options were considered in this study for periods when water would be transferred from Caño Sucio Lake to the Panama Canal watershed for canal operations. For Operating Option 1, the water surface of the Caño Sucio Lake would fluctuate from the maximum operating lake level at elevation 100 m MSL down to the minimum lake operating level at elevation 90 m MSL, providing 72,500,000 M^3 of useable storage. Operating Option 2 would fluctuate from a maximum normal operating level of 100 to a minimum of 95 m MSL, providing 44,300,000 M^3 of useable storage.

For combination with the Caño Sucio Lake, the water surface of Indio Lake would fluctuate from elevation 80 m MSL down to elevation 50 m MSL.

Water would be transferred from Caño Sucio Lake (minimum operating lake level at elevation 90 m MSL) to Indio Lake (maximum operating lake level at elevation 80 m MSL) and then to the Panama Canal watershed for use in canal operations. A description of the project features for the proposed Rio Indio project is included in Section 5.

Project Features

GENERAL

The structures for the proposed Rio Caño Sucio project would consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, and outlet works. The following paragraphs provide a description of the proposed structures and improvements. Plate 22 - 2 depicts the site plan.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the PCC that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENT

The proposed Rio Caño Sucio Dam would be an embankment with the top at elevation 105 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 987292 north and 575960 east. The right abutment would be 987399 north and 576105 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam at its highest point would be approximately 20 m high, and the overall length would be 199 m. The total volume of fill required to complete the embankment is 109,200 M^3.

A small closure dam would be required at the western end of the Caño Sucio Lake to prevent water from flowing down the Rio Toabre arm of the Rio Cocle del Norte once the lake level approaches elevation 100 m MSL. This is particularly important since this low area is used for diversion of normal flows during construction.

The actual side slopes and crest width would be determined during further study and would be contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment.

SPILLWAY

At the proposed Rio Caño Sucio Dam, an uncontrolled ogee spillway with a length of 74 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 1,141 CMS at a maximum flood storage lake level at elevation 104 m MSL. The spillway design discharge was equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway would be located within the abutment adjacent to the left end of the dam and would consist of a mass concrete sill section embedded in the natural rock. A sloped and / or stepped, natural rock cut tailrace channel would return flow to the existing stream. The tailrace channel would extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. The spillway profile would be similar to that shown for the Rio Indio Dam, Section 5 of this report.

IMPOUNDMENT

The lake formed by the proposed Rio Caño Sucio Dam would have a maximum operating lake level at elevation 100 m MSL and would have a surface area of approximately 1,360 ha. At the minimum operating lake level at elevation 90 m MSL, the surface area would be 244 ha. At maximum flood storage lake level, elevation 104 m MSL, the surface area would be approximately 2,040 ha. At the top of dam, elevation 105 m MSL, the surface area would be approximately 2,230 ha.

CLEARING, GRUBBING AND RESERVOIR CLEARING

Clearing and grubbing would be required for all areas required for construction of the dam (embankments and spillways), inter-basin transfer facilities, other outlet works, hydropower plants, power line rights-of-way and switchyard sites, access roads, and disposal and staging areas. Clearing only would be required on the approximately 1,800 ha in the lake area between the maximum operating lake elevation at 104 m MSL and the minimum operating lake elevation at 90 m MSL.

INTER-BASIN TRANSFER FACILITIES

The finished tunnel connecting the easternmost end of Caño Sucio Lake to the westernmost leg of Indio Lake would be 3 m in diameter and approximately 2 km in length. This tunnel would have an inlet invert elevation of 85 m MSL and an outfall invert elevation of 74 m MSL. The maximum capacity of the tunnel would be approximately 43 CMS. The finished tunnel connecting Indio Lake and Gatun Lake and its appurtenant structures would be as described in Section 5 of this report.

The inter-basin transfer tunnel would be under pressure continually since flow through the tunnels would be controlled at the downstream end of each. This control would be in the form of a gate control structure and / or a hydropower plant. To allow for maintenance of the tunnel and to provide for rapid stoppage of flow through the tunnel, a gate / stoplog structure would be constructed at the upstream end of the tunnel. In the process of stopping flow through the tunnel, a water hammer effect could be generated. Therefore, sufficient surge protection shafts would be constructed. These shafts would require relatively minor surface structures to protect the openings and to provide for personnel safety.

It was assumed that the tunnel would be concrete lined and that rock bolting would be required over much of the length of the to stabilize the rock.

HYDROPOWER PLANTS

The flows, excess to the needs of the Panama Canal operation, at the proposed Rio Caño Sucio Dam were investigated for hydropower capability, as were the flows passed through the Caño Sucio Lake to Indio Lake transfers tunnel. It was concluded that the hydropower potential for both of these sites is so small that neither installation would be warranted. The 5 MW plant discussed in Section 5 of this report for installation at the downstream end of the Indio to Gatun transfer tunnel would not be altered by addition of the Caño Sucio Lake.

OUTLET WORKS

At the Rio Caño Sucio Dam, an outlet works system would be required only to provide minimum flows to the Rio Caño Sucio downstream of the dam. Diversion of the Rio Caño Sucio during construction could be provided by initially installing the Caño Sucio Lake to Indio Lake tunnel and by providing for flood releases through the divide between the Rio Caño Sucio and Rio Toabre basins to the west. The Caño Sucio Lake to Indio Lake tunnel would also allow for emergency drawdown of the lake after it is raised and placed in service.

These water handling facilities would consist of a 406 mm outlet pipe passing through the dam, an intake structure located in the lakeside face of the dam, and various gates and water conduits. Intake for minimum flow would be through individually gated water quality intake ports located at various levels in the intake structure. The elevations of these intakes would be established during environmental water quality investigations made during subsequent phases of study. The minimum flow outfall piping would be approximately 140 m in length. It would originate at the invert of the intake structure, elevation 85 m MSL, and would have an outlet invert elevation at 83 m MSL. The capacity of the minimum flow conduit would be 0.74 CMS.

ACCESS ROADS

Access to the lake site and the various construction sites must be provided from the main population centers on the Atlantic and Pacific coasts, Colon and Panama City respectively.

The route chosen for this study would originate at the Rio Indio dam site crossing the Rio Indio below the dam. It would then proceed westward and southward to the outlet end of the Caño Sucio Lake to Indio Lake inter-basin tunnel on the Rio Uracillo. From there it would extend westward to the inlet end of the tunnel, then westward to the Rio Caño Sucio dam site. The entire route would cover approximately 20 km through mountainous terrain and would require 7 stream crossings. This route and the features it would connect are shown on Plate 22 - 1.

DISPOSAL AREA

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

Sources of Construction Materials

Rock removed from the spillway site would be used as fill in the embankment portion of the dam. Cement would be available within the Republic of Panama. If possible, rock obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site. Materials suitable for use as random fill and the impervious core are assumed to be within the immediate pool area. If further investigations show that these materials are not readily available, then other materials such as roller compacted concrete may be considered for use in the embankment construction.

Real Estate Requirements

The proposed Rio Caño Sucio dam site is located in the Colon Province. This area is devoted primarily to subsistence farming, natural forest, and ranching. It does contain the village of Las Maravillas in the lake area. There are other dwellings and other structures scattered throughout the basin. Approximately 2,700 ha would be required for construction of this proposed project. The amount of land required for the various project features is shown in Table 22 - 1. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 22 - 1 Real Estate Requirements

Project Feature	Total Land Required (ha)
Lake	2,200
Dam site	100
Staging area	100
Housing and facilities	100
Disposal area	200
Total	2,700

Relocations

The lake would be located in a sparsely populated region with few roads and utilities. Relocations associated with the proposed construction could be substantial. Structures and individuals located below elevation 105 m MSL within the lake area would require relocation due to the normal lake inundation and the need to secure the lake perimeter for flood considerations. The village of Las Maravillas would be the most significant community requiring relocation efforts.

Development Sequence

For the economic evaluation of this project, it was assumed that the planning for the Rio Caño Sucio project would begin during the construction of the Rio Indio project and that construction would be started immediately following completion of the Rio Indio project.

Planning studies would be accomplished to evaluate alternative features of projects. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed for its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the alternative projects would be performed during the planning phase and the final design, advertising and award phase, and on through construction of the project. The final design, advertising, and award phase would be accomplished for the recommended project. Implementation of the project would begin with land acquisition and construction of the access roads. Access road would be constructed to the dam site and the inter-basin transfer tunnel entrance and exit sites. Once highway access to the sites has been established, a camp would be built to house workers during construction. Socio-economic programs would begin. Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the inter-basin transfer tunnel and tunnel intake and outlet structures, and construction of the spillway would follow with work being done simultaneously. To the extent practicable, materials removed from the nearest of these areas would be placed in the earth and rock fill portions of the dam that would comprise the construction cofferdams. Once the inter-basin intake and outlet structures and inter-basin transfer tunnel were completed, the dam construction site would be isolated by completion of the upstream and downstream cofferdams, which would eventually become part of the main dam, and the stream would be diverted through the Inter-basin transfer tunnel. The dam foundation would then be excavated and grouted, and the dam constructed. The minimum flow intake structure would be constructed, and the minimum flow conduit would be installed through the dam at this time. Upon completion of the dam and the inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped and reservoir filling would begin. Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work it is estimated that development of this project could be completed in approximately 8 years, from initial planning to lake filling. A development sequence of the various project features is presented in Figure 22 - 2.

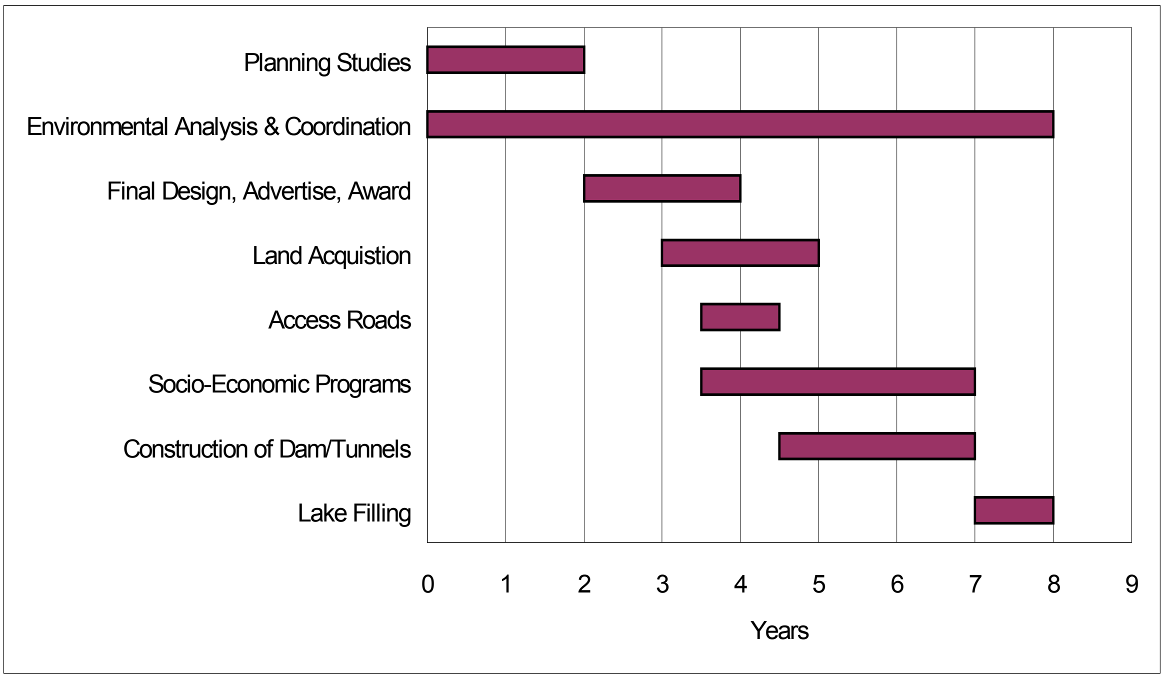


Figure 22 - 2 Development Sequence

Hydrologic Reliability

A HEC-5 model was constructed that linked the Caño Sucio Lake to the Indio Lake which was in turn linked to the Gatun Lake through the inter-basin transfer tunnels. Water stored in Caño Sucio Lake and Indio Lake was provided, as needed, to Gatun Lake when shortages were expected. Excess flows were still released down the Rio Indio, taking advantage of the hydropower generation when possible. Minimum flow requirements were deducted from the waters made available to the Panama Canal watershed and released down the Rio Indio and Rio Caño Sucio respectively.

HEC-5 model simulations were conducted for both current Panama Canal system and the system operating with Caño Sucio Lake providing water through Indio Lake to Gatun Lake. The simulations considered proportionally increasing demands beginning with current demand levels. The designated period considered the existing 50.5-year hydrologic period of record at Rio Caño Sucio. Figure 22 - 3 presents the resulting hydrologic reliability for three configurations with demands increasing up to 180 percent of current demands. These configuration are: (1) the existing system, and (2) Caño Sucio Lake operating with a conservation pool between elevations 100 to 90 m MSL, and (3) at Caño Sucio Lake operating between elevations 100 to 95 m MSL. The reliability of the two options is almost the same; therefore, the curves are very close. This appears to indicate that the Indio Lake is providing most of the support.

The horizontal axis along the bottom of Figure 22 - 3 reflects demands as a ratio of the last 5-year average and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

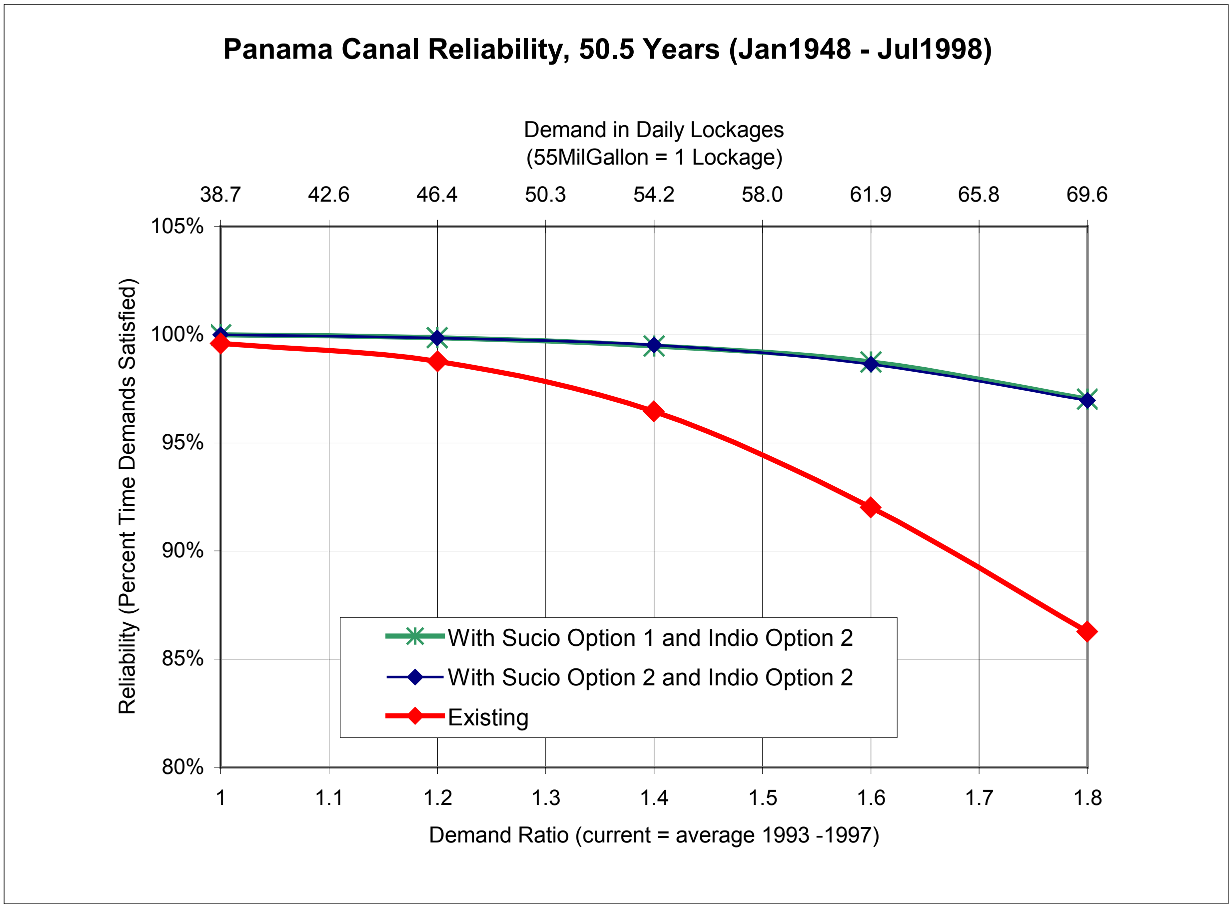


Figure 22 - 3 Panama Canal Hydrologic Reliability

As shown in Figure 22 - 3, the current level of hydrologic reliability of the Panama Canal based on the 50.5 year period of record is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This includes the first six months of the 1998 drought year. The current level of hydrologic reliability would be 100 percent with Caño Sucio Lake operating with a conservation lake between elevations 100 and 90 m MSL, and the hydrologic reliability with a demand ratio of 1.8 would be 97.0 percent. With the lake operating between 100 and 95 m MSL, the reliability at a demand ratio of 1.0 also would be 100 percent and at a demand ration of 1.8, it would be 96.96 percent. The number of lockages associated with various levels of reliability.

Without additional water supplies, the reliability of the Panama Canal system would decrease. With the construction of the Caño Sucio Lake in conjunction with Indio Lake, current high reliability could be continued as demand increases up to 35.78 percent (13.84 lockages) with Option 1 and 35.39 percent (13.69 lockages) with Option 2 above current levels.

Project Costs

GENERAL

The quantities estimated for the various items of work required in the construction of this proposed project have been derived from the site plan shown. The unit prices applied to these quantities were based on historical information from previous estimates prepared for similar construction by the PCC, estimates for similar construction in the Mobile District, U.S. Army Corps of Engineers information gathered from Mobile District Construction Division personnel in Panama.

Engineering and design is estimated to be 12 percent and supervision and administration is estimated to be 6 percent of the construction cost items. An allowance of 2 percent of the construction cost items was allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent was included for contingencies. The PCC provided the estimated cost of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $40,227,000. Table 22 - 2 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 22 - 2 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	6,750,000
Access Roads	6,860,000
Clearing and / or Grubbing	1,269,375
Inter-basin Transfer Tunnel	8,601,855
Intake for Inter-basin Transfer Tunnel	80,385
Cofferdam with construction diversion	137,145
Dam	818,685
Spillway	2,300,750
Subtotal	26,818,195
E&D, S&A, Field Overhead	5,363,639
Contingencies	8,045,459
Total Project First Costs	40,227,293 **approximately** 40,227,000

OPERATION AND MAINTENANCE

Staff
A staff would operate and maintain the proposed Rio Caño Sucio project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of five who would include a station manager, a leader (Electronics / Instrumentation, Electrical and Mechanical), two craftsmen, and one laborer. The annual costs of the staff are estimated to be $225,000.

Ordinary Maintenance
Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $50,000 per year for the main project facilities.

Major Replacements
The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 100 years. To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it was assumed that specific items would cost the same as at present. No allowance was made for salvageable fixed parts. Table 22 - 3 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements would be $35,000 and the average annual replacement costs would be $4,000.

Table 22 - 3 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	6,600,000	23,000
Bridges	50	1	3,600,000	12,000
Total			10,200,000	35,000
Average Annual Replacement Costs				4,000

Annual Costs

The project first costs for the proposed Rio Caño Sucio project are estimated to be $40,227,000. No additional costs are included to enlarge the inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed. The total project first costs also include the $245,868,000 costs for the Rio Indio project (see Section 5) and are estimated to be $286,095,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the total project first costs of $40,227,000 was computed from mid-year throughout the 8-year development period from initiation of Planning and Design until the lake was filled. Interest during construction for the Rio Indio project was computed from mid-year throughout its 15-year development period until lake filling was complete at the Rio Caño Sucio project. The interest during construction at 12 percent would be $20,395,000 for Rio Caño Sucio, and $418,289,000 for Rio Indio for a total interest during construction of $438,684,000. These costs were added to the total project first costs for total project investment costs of $724,779,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $87,275,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 22 - 4 contains a summary of the $88,590,000 total annual costs.

Table 22 - 4 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs – Rio Caño Sucio	40,227,000
Total Project First Costs – Rio Indio	245,868,000
Interest During Construction – Rio Caño Sucio	20,395,000
Interest During Construction – Rio Indio	418,289,000
Total Project Investment Costs	724,779,000
Annual Average Investment Costs	87,275,000
Operation and Maintenance Costs	
Staff Costs – Rio Caño Sucio	225,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Rio Caño Sucio	70,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Rio Caño Sucio	4,000
Major Replacement Costs – Rio Indio	196,000
Total Average Annual Costs	88,590,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Section 4. The following paragraphs present the results of the economic investigations for the proposed Rio Caño Sucio project. The 50-year planning period for this proposal is 2016 to 2065.

The proposed Rio Caño Sucio project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Figure 22 - 3 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages were obtained from the data used to develop Table 22 - 5. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 22 - 5 Panama Canal Hydrologic Reliability

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability		
			Existing System (%)	Operating Option 1 [1/] (%)	Operating Option 2 [2/] (%)
1	2000	38.68 [3/]	99.60	100.00	100.0
	2010	45.11	98.91	99.89	99.87
1.2		46.42	98.76	99.86	99.85
	2015	46.82	98.64	99.85	99.83
	2025	48.52	98.14	99.77	99.76
	2035	50.72	97.48	99.68	99.67
	2045	53.49	96.65	99.56	99.55
1.4		54.15	96.45	99.53	99.53
	2055	56.98	95.53	99.37	99.34
	2065	61.37	94.91	99.26	99.22
1.6		61.89	92.02	98.75	98.64
	2070	63.97	90.47	98.28	98.19
1.8		69.63	86.27	97.03	96.96

[1/] Operating Option 1 - Caño Sucio Lake fluctuating between the normal operating lake level at elevations 100 m MSL and the minimum operating lake level at elevation 90 m MSL and Rio Indio Operating Option 2 Lake fluctuates from the normal operating lake level at elevation 80 m MSL down to the minimum operating lake level at elevation 50 m MSL.

[2/] Operating Option 2 - Caño Sucio Lake fluctuating between the normal operating lake level at elevations 100 m MSL and the minimum operating lake level at elevation 95 m MSL and Rio Indio Operating Option 2 Lake fluctuates from the normal operating lake level at elevation 80 m MSL down to the minimum operating lake level at elevation 50 m MSL.

[3/] 2000 Daily Demand is Average of 1993-1997

Regardless of the operating option, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands grow, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Rio Caño Sucio project, these shortages would be less than they would be under the existing system. With a hydrologic reliability of 99.6 percent, Operating Option 1 would increase the amount of water supplied for navigation by approximately 13.84 equivalent lockages, and Operating Option 2 would increase that amount by 13.69 equivalent lockages. For Operating Option 1, the 99.6 percent hydrologic reliability would occur in the year 2041 with an equivalent daily average number of lockages set to 52.53. For Operating Option 2, the 99.6 percent hydrologic reliability level would also occur in the year 2041, but with an equivalent daily average number of lockages of 52.37. Benefits for these amounts of additional water would be attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages provided by each option. The average annual benefits for water supply would be $201,102,000 for

Operating Option 1 and $200,196,000 for Operating Option 2. Table 22 - 6 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Rio Caño Sucio project in operation, the annual benefits for meeting shortages and the average annual benefitsfor both options.

Table 22 - 6 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages With Operating Option 1	Remaining Daily Shortages With Operating Option 2	Annual Benefits for Operating Option 1 ($)	Annual Benefits For Operating Option 2 ($)
2016	8.14	0	0	171,094,000	171,094,000
2025	9.83	0	0	202,800,000	202,800,000
2035	12.04	0	0	248,211,000	248,211,000
2045	14.81	.96	1.12	285,514,000	282,261,000
2055	18.3	4.45	4.61	285,514,000	282,261,000
2065	22.69	8.84	9.00	285,514,000	282,261,000
Average Annual Benefits				201,102,000	200,196,000
With Option 1, the system will provide a total of 52.53 equivalent lockages at the 99.6 percent level of reliability or 13.84 more lockages than the existing system. With Option 2, the system will provide a total of 52.37 equivalent lockages at the 99.6 percent level of reliability or 13.69 more lockages than the existing system.					

With either operating option, the reliability of the system to provide all of the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Rio Caño Sucio project would be $13,682,000 for Operating Option 1 and $13,560,000 for Operating Option 2. Table 22 - 7 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits for each operating option.

Table 22 - 7 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Daily Lockage ($)	Annual Navigation Benefits For Operating Option 1 ($)	Annual Navigation Benefits For Operating Option 2 ($)
2016	40.0	2,260,000	10,239,000	10,104,000
2025	40.0	2,260,000	13,481,000	13,368,000
2035	40.0	2,260,000	18,123,000	18,043,000
2045	40.0	2,260,000	23,966,000	23,926,000
2055	40.0	2,260,000	37,382,000	37,173,000
2065	40.0	2,260,000	60,140,000	59,942,000
Average Annual Benefits			13,682,000	13,560,000

M&I WATER SUPPLY

The future demand for water supply for M&I purpose was based upon the growth in population. The PCC provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day. An equivalent lockage is 55 million gallons of water. One equivalent lockage was added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I. Using the increased hydrologic reliability of the system with the addition of the proposed Rio Caño Sucio project, the current costs to the PCC to process finished water at $0.69 per 1,000 gallons, the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability would be $2,122,000 for Operating Option 1 and $2,104,000 for Operating Option 2. Table 22 - 8 displays the population forecast, the resulting number of equivalent lockages demanded per day, the annual benefits for increased reliability, and the average annual benefits for M&I water supply.

Table 22 - 8 Average Annual Reliability Benefits For M&I Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits for Operating Option 1 ($)	Annual M&I Water Supply Benefits for Operating Option 2 ($)
2016	1,963,000	5.84	1,201,000	1,185,000
2025	2,396,000	8.52	1,927,000	1,911,000
2035	3,016,000	10.72	3,264,000	3,249,000
2045	3,796,000	13.49	5,429,000	5,420,000
2055	4,778,000	16.98	10,652,000	10,593,000
2065	6,013,000	21.37	21,581,000	20,434,000
Average Annual Benefits			2,122,000	2,104,000
The value of a daily lockage for M&I is $0.69 X 55,000 = $37,950				

SUMMARY OF ANNUAL BENEFITS

As shown in Table 22 - 9, total average annual benefits for Operating Option 1 and Operating Option 2 of the proposed Rio Caño Sucio project would be $216,906,000 and $215,860,000, respectively.

Table 22 - 9 Summary of Annual Benefits

Benefit Category	Average Annual Benefits	
	Operating Option 1 ($)	Operating Option 2 ($)
Navigation – Water Supply	201,102,000	200,196,000
Navigation – Reliability	13,682,000	13,560,000
M&I - Reliability	2,122,000	2,104,000
Hydropower	None	None
Total	216,906,000	215,860,000

To perform an analysis of benefits versus costs, a common point in time was selected. This common point was at the completion of the filling of the proposed Rio Caño Sucio project, the end of the year 2016. In these analyses, it was important to note that the average annual benefits or average annual costs were the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Rio Caño Sucio project would be to develop the Rio Indio project first (2001 – 2010) and then the Rio Caño Sucio project second (2007 – 2016).

The benefits attributable to the proposed Rio Indio project would begin to accrue in 2010 when that reservoir is filled. Thus, the Rio Indio project benefits for the period 2010 to 2016 were escalated by the project discount rate, 12 percent, in order to estimate their total present worth of $1,666,195,000 in the year 2016. The average annual benefits for the proposed Rio Indio project that accrue during the construction of the proposed Rio Caño Sucio project are estimated to be $200,638,000. The benefits for the proposed Rio Caño Sucio project are estimated with the assumption that the Rio Indio project would use its Operating Option 2. Although the discharge tunnel would be larger, the proposed Rio Indio project would be operated for the period 2010 through 2016 just as if the proposed Rio Caño Sucio project was not to be constructed.

To estimate the interest during construction, similar calculations were made for the costs of each proposed project. For the proposed Rio Indio project, interest during construction was taken from year 2001 to year 2016 and the interest during construction for the proposed Rio Caño Sucio project was taken from the year 2007 to the year 2016. Additionally, there would be added costs for the larger inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed that would only be required if the proposed Rio Caño Sucio project were to be constructed. Those amounts were subtracted from the cost estimate for the proposed Rio Caño Sucio project and added to the cost estimate for the proposed Rio Indio project. The revised estimated average annual costs for the Rio Indio portion of the overall project would be $80,991,000.

Total average annual benefits and average annual costs were then estimated, and the ratio of benefits to costs and the net benefits (net of costs) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. While there would be some differences in project features between Operating Option 1 and Operating Option 2 for the Rio Caño Sucio project, the differences would only have minimal impact on total project first costs at this level of investigation. Table 22 - 10 provides the benefit to cost ratio and the net benefits for the proposed project.

Table 22 - 10 Economic Evaluation

Item	Operating Option 1 ($)	Operating Option 2 ($)
Average Annual Benefits		
Rio Indio	200,638,000	200,638,000
Rio Caño Sucio	216,906,000	215,860,000
Sum	417,544,000	416,498,000
Average Annual Costs		
Rio Indio	80,991,000	80,991,000
Rio Caño Sucio	7,599,000	7,599,000
Sum	88,590,000	88,590,000
Benefit to Cost Ratio	4.7	4.7
Net Benefits	328,954,000	327,908,000

Internal Rate of Return

An internal rate of return analysis for each operating option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For Operating Option 1, the internal rate of return would be 31.7 percent, and for Operating Option 2, the internal rate of return would be 31.7 percent.

Socio-Economic Impacts

The socio-economic impacts of the project could be substantial. The relocation of the towns of El Caraño, Las Maravillas, Santa Maria (or Caño Sucio), and Riecito Abajo and their approximately 350 residents would be an important issue. The average monthly income of families in the project area is $100 per month. No indigenous groups of peoples are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to create the Rio Caño Sucio project. The relocation of agricultural and ranching activities would be a substantial issue, because approximately 70 percent of the impoundment area is used for farming and ranching. The surface area of the proposed lake would encompass 2,040 ha with another 400 ha for the dam and construction areas including permanent disposal areas.

The Rio Caño Sucio project would not produce hydropower; however, the project would be built only in conjunction with Rio Indio project or Rio Cocle del Norte project, both of which produce electricity. Therefore, post-construction revenues for the nation would be greater, because the project would create electric power generating potential. On a per hectare basis, the revenues from power generation would be greater than those produced by the current agricultural activity. It is estimated that after construction, 11 persons would be employed to operate and maintain the new facilities. During construction, the housing values in the areas adjacent to the channel would increase, because there could be a higher demand by workers for livable homes. However, after project completion, as the workers leave the area and housing demands decline, the housing values could drop to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and more public and community services may be offered to the local communities; however, after construction these services may be decreased or may not be provided.

To construct the project, roads would be built into the area. However, the dirt trails occurring within the impoundment would be significantly reduced, which would change the communication patterns and could cause some communities to lose cohesion and commerce with other communities. During construction, noise levels would increase and could negatively impact noise-sensitive receptors; however, after construction, noise levels should return to pre-construction levels.

The communities that receive the displaced people could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the project would permanently displace people and disrupt community cohesion, through the division of communities, separation of families, and loss of livelihood. Following completion of the channel, tourism trade in the affected region, including fishing and ecotourism could increase.

Environmental Setting

The project would include a dam and lake on the Rio Caño Sucio connected by tunnel to Indio Lake. Indio Lake would be connected to the Panama Canal watershed at Gatun Lake via a second tunnel. Water impounded in these two lakes would be transferred to the Panama Canal watershed as needed to support navigation. The project consists of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, and outlet works. The project area encompasses the area to be flooded as well as the area downstream from the dam site. This area is sparsely populated. It is characterized by rolling hills, low coastal regions, and water falls that attract visitors. The Rio Caño Sucio is located west of the Panama Canal and flows northward from the Continental Divide into the Atlantic Ocean. The Rio Caño Sucio watershed above the dam is approximately 111 km^2. The impoundment area covers approximately 2,040 ha and consists of approximately 5 percent of forested land, 35 percent of pasture land (used by ranchers), 35 percent of cropland, and 25 percent of newly slashed and burned land. The lake water elevation would fluctuate from elevation 90 to 104 m MSL. The tunnel portals and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The Rio Caño Sucio project area is defined as the areas to be flooded. It is inhabited by about 350 people, dispersed throughout the area with concentrations in the towns of El Caraño (population - 100), Las Maravillas (population - 70), Santa Maria (or Caño Sucio) (population - 60), and Riecito Abajo (population - 50), and approximately five smaller settlements.

Approximately 70 percent of the land in the project area is occupied by farms and ranches of various sizes. The land is hilly with steep contours throughout the project area. The dam site would be near or at existing waterfalls. Farm crops include mandioc, maize, rice, beans, sugarcane, and coffee. Ranches raise cows, horses, chickens, and hogs. Some of the farmers and ranchers run small commercial enterprises, and there is also cash crop and subsistence farming.

INFRASTRUCTURE

The towns obtain water from Rio Caño Sucio and its tributaries or groundwater wells. Some have electricity (from small generators) and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it might eventually reach the Rio Caño Sucio and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners: each home has an outdoor latrine (a deep hole in the ground). There are some known health problems such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses associated with the present waste disposal methods. No major industries or poultry or beef processing plants are located in the project area. The project area is traversed by dirt horseback riding trails that link the various communities.

TERRESTRIAL HABITAT

Forests along the river that could support a diverse wildlife population cover about 70 percent of the area immediately adjacent to the Rio Caño Sucio and its tributaries. As a result of slash and burn activities there are no large contiguous tracts of forests at lower elevations in the Rio Caño Sucio impoundment area.

ANIMALS ON ENDANGERED LIST

ANAM by its Resolution 002-80 on June 7, 1995, declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although it has not been determined, some or all of the listed animals and other species of concern might be found in the project area.

AQUATIC HABITAT

The Rio Caño Sucio in the project area displays traits characteristic of streams in mountainous regions. Its water is clear and cool, and the river bed ranges from sand to boulders, with numerous riffles, runs, and pools. The Rio Caño Sucio has three major tributaries: Rio El Cedro, Rio Escobal, and Rio Limon, and approximately 4 smaller creeks also flow into the Rio Caño Sucio. The river is approximately 9 km long; its width ranges from less than 1 m (in the dry season) to 20 m, and its depth ranges from less than 1 m to 5 m. The Rio Caño Sucio and its tributaries support some fish and benthic communities; however, information about these communities that occur within the project area is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. The wetlands consist of forested riparian habitat and are limited to the immediate vicinity of the stream banks. The width of the riparian habitat within the impoundment area varies from approximately 5 to 15 m. Approximately 70 percent of the streams above and below the channel along the Rio Caño Sucio are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season in March and earlier April, areas of established forests and secondary growth are cleared and burned to prepare the land for agricultural use. Based on observations in the Rio Caño Sucio project area, the amount of land burned varies annually.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

No parks are known to be located in the Rio Caño Sucio impoundment area. There is a potential for pre-Columbian archaeological remains, as the area was inhabited before the Spanish arrival. It should be noted that most of the Atlantic region of Panama within the interests and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in the impoundment area would be minor, since there are only 102 ha or 5 percent forest cover in the impoundment area. With the creation of the channel, migratory routes of some species could be adversely affected.

ANIMALS ON ENDANGERED LIST

The extent of potential effects cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. The significance of the forested riparian corridor along the area streams may increase if animals on the endangered list are found in the region. The Mesoamerican Biological Corridor is also promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity should be positive, because construction of the channel should result in an increase in the volume of stored fresh water in surrounding areas during the dry season. The impacts downstream from the channel should be minor, even though water should be released at lower rates, and seasonal extremes should be significantly reduced. Further, measures should be taken to release water at appropriate periods and amounts to avoid problems with water quality and temperature downstream. The cumulative impacts of the diversions over time should also be minor.

WATER QUALITY

The impacts downstream from the channel should be positive, because the water would not contain as much silt and would provide people downstream higher quality water. The proposed channel should also provide high quality water for people living along the impoundment.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts on downstream aquatic faunal communities should be minimal, because the dam would be designed to allow multi-level releases of water to avoid problems with water quality and temperature downstream. The Rio Caño Sucio channel should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation should not be a problem. The impacts of the interference with the migration of natural stream fishes are unknown. Streambed degradation below the channel should be minimal.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed channel would depend on water level fluctuations, which are anticipated to range from 80 to 100 m over a 3-month period. Since the water levels would fluctuate widely, much of the shore would be covered with mud, where neither aquatic nor terrestrial plant communities could thrive. Rooted aquatic plants tend to grow as deep as light penetration allows.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Caño Sucio and its upstream tributaries could be important. If aquatic fauna are able to thrive in the new reservoir they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. The new reservoir could provide some opportunities for recreational and subsistence fishing if it is responsibly managed and stocked with game fish by the Aquaculture Department. An increase in fish population could cause an increase in piscivorous predators, such as crocodiles, herons, etc. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well, but several riverine native species that formerly occupied the impoundments have disappeared.

WETLANDS

The impacts to wetlands could be significant, even though the wetlands are limited to forested riparian areas. Owing to the topography of the project area, relatively few wetlands would be impacted by the project. Due to minimum normal flow, the cumulative effects downstream of the dam site are expected to be minor.

AIR QUALITY

During construction of the dam, dust and emissions from equipment could impact the air quality in the project area. After construction, the air quality could improve because the Panamanian government currently discourages slash and burn activities.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The impacts on cultural resources and historic properties should be minor. The project area is relatively small and the presence of cultural resources might be limited. Prior to construction, surveys to locate cultural resources and historic properties would be conducted, and the important sites would be preserved or salvaged as appropriate.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Rio Caño Sucio alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an SIA. The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities.
  - Employment.
  - Land Use.
  - Property Values.
  - Public and Community Facilities and Services (including utilities and schools).
  - Community and Regional Growth.
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population.
  - Community Cohesion.
  - Recreational Resources.
  - Mineral resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major terrestrial and aquatic habitat types are identified and quantified.
- Conduct field studies to locate special habitat features such as wetlands, roosting sites, reproductive sites, and the relative quality of forested areas.
- Determine the present quality and ecosystem value of existing habitats within the Rio Caño Sucio project area.
- Address cumulative effects caused by natural flow diversions.
- Investigate floodplain shrinkage due to impoundment.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered list.
- Conduct site surveys to determine the presence of selected species.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.

WATER QUALITY

- As there are no water quality data available for the Rio Caño Sucio area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Information regarding cultural resources and historic properties is incomplete. Additional evaluation studies need to be completed to identify cultural resources and historic properties.

Evaluation Matrices

In accordance with evaluation procedures described in Section 4, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Section 35. Tables 22 - 11 through 22 - 13 present the evaluation of the proposed Rio Caño Sucio project as related to developmental effects, environmental effects, and socio-economic effects.

Table 22 - 11 Developmental Effects

Evaluation Criteria	Function	Measure 1/	Importance 2/	Composite 3/
Water Contribution (Water Yield)	Meets M&I demands	10	10	100
	Supplements Existing System	4	10	40
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	7	6	42
	Feasibility of Concept	8	6	48
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	8	2	16
	Operational resources required	7	2	14
Economic feasibility	Net Benefits	10	9	90
	Total			398

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 22 - 12 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	4	8	32
Animals on Extinction List	4	10	40
Water Quantity Impacts – Lake	7	10	70
Water Quantity Impacts – Downstream	4	7	28
Water Quality	6	10	60
Downstream Aquatic Fauna Habitat	4	8	32
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	5	5	25
Potential for Fishing on Lake	6	6	36
Wetlands	6	4	24
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			460

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 22 - 13 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	4	7	28
Relocation of People	3	10	30
Relocation of Agricultural/Ranching Activities	3	6	18
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	6	4	24
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	6	8	48
Traffic Volumes over Existing Roadway System During Construction	4	5	20
Traffic Volumes over New Roadway System Post-Construction	6	5	30
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	3	8	24
Community Cohesion	4	8	32
Tourism	6	5	30
Total			409

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Pertinent data for the proposed Rio Caño Sucio Dam are presented in Table 22 - 14.

Table 22 - 14 Pertinent Data

GENERAL	
Dam site, above mouth of Rio Caño Sucio	25 km
Drainage area above dam site	111 km^2
Average annual flow at dam site	7.4 CMS
RESERVOIR	
Elevation of maximum operating lake level	100 m MSL
Elevation of maximum flood storage lake level	104 m MSL
Elevation of minimum operating lake level	90 m MSL
Area at maximum operating lake level	1,360 ha
Area at maximum flood storage lake level	2,040 ha
Area at minimum operating lake level	244 ha
Top clearing elevation	104 m MSL
Lower clearing elevation	80 m MSL
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	105.0 m
Fixed crest width	13 m
Height above lowest foundation	20.0 m
Overall length of dam	199 m
SPILLWAY	
Type of Spillway	Uncontrolled ogee
Total length	74 m
Elevation of spillway	100 m MSL
Maximum discharge	1,141 CMS
INTER-BASIN TRANSFER TUNNEL	
Rio Caño Sucio to Rio Indio:	
Tunnel diameter	3 m
Tunnel length	2.0 km
Inlet invert	85 m MSL
Outlet invert	80 m MSL
Tunnel capacity	43 CMS
Rio Indio to Gatun Lake:	
Tunnel length	5.5 km (+/-)
Tunnel diameter	3 m
Tunnel capacity at maximum head	42.5 CMS
Inlet invert	44 m MSL
Outlet invert	40 m MSL

Table 22 - 15 Pertinent Data (continued)

MINIMUM FLOW CONDUIT	
Conduit diameter	406 mm
Conduit length	140 m
Inlet invert	85 m
Outlet invert	83 m
Conduit capacity	0.74 CMS

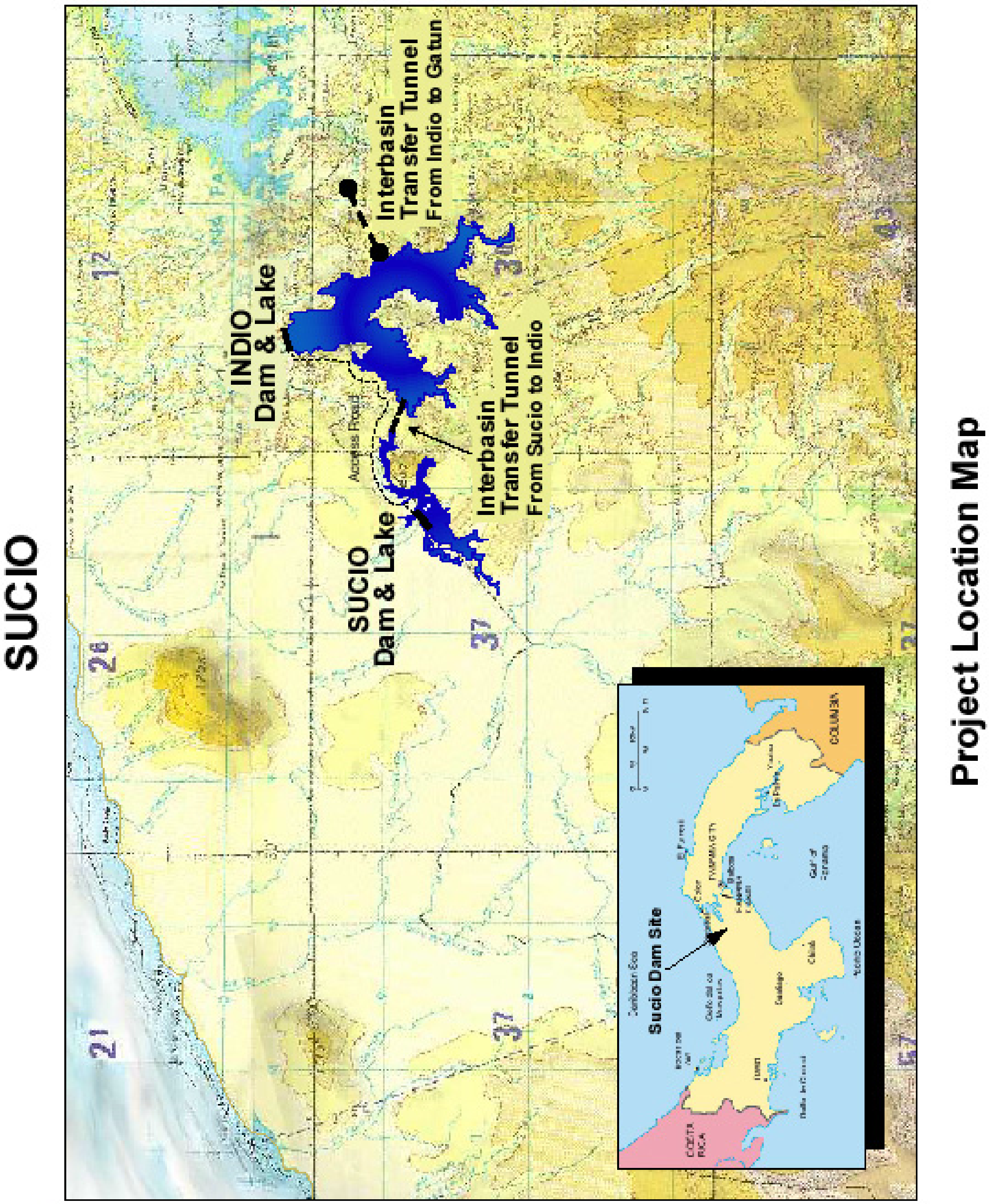


Plate 22 - 1 Project Location Map

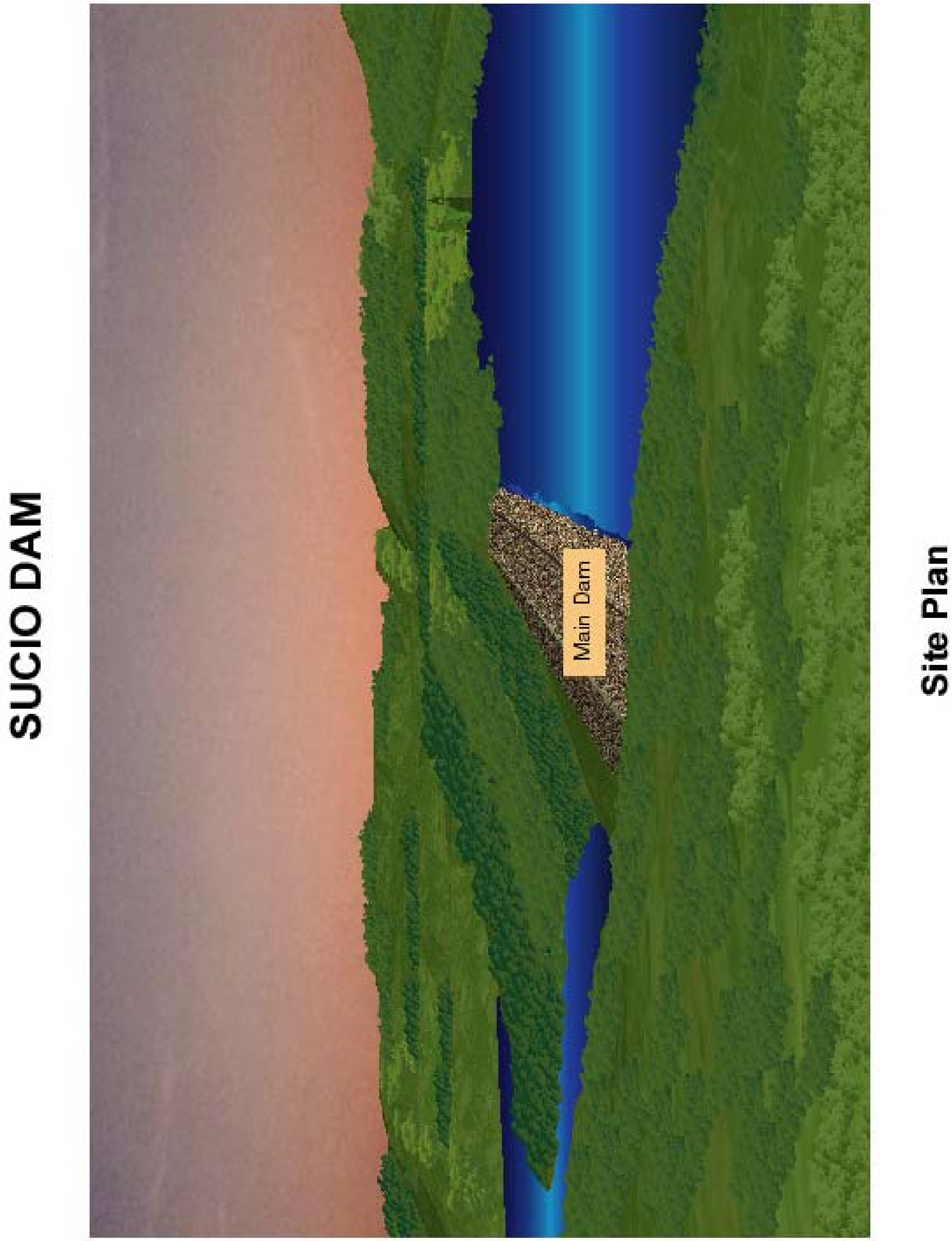


Plate 22 - 2   Site Plan

SECTION 23

Raise Gatun Lake Operating Levels

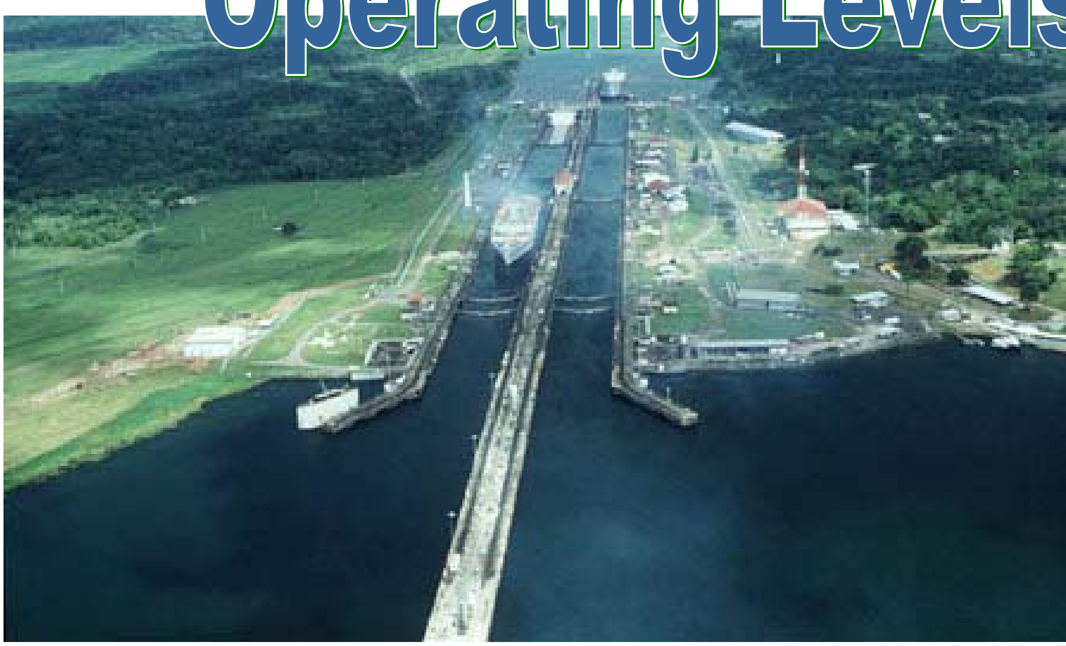


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The Raise Gatun Lake alternative would result in a revised maximum operating lake elevation of 89 ft (27.1 m) MSL. Currently, the maximum operating elevation for Gatun Lake is elevation 87.5 ft (26.67 m) MSL. The operating scheme proposed in this alternative would permit an increase of 1.5 ft (0.46 m) during the wet season and approximately 1 ft (0.30 m) during the dry season. The structures associated with the operation of the Panama Canal that would be impacted by this proposed project are Gatun Locks, Pedro Miguel Locks, and Gatun Spillway embankments and saddle dams. There would be some impact to other facilities along the perimeter of Gatun Lake. The increase in storage would intensify the existing Gatun Spillway deficiency problems.

The proposed Raise Gatun Lake alternative would contribute nominally to the hydrologic reliability of the Panama Canal to serve its customers and would slightly reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998, is approximately 99.6 percent. With implementation of the proposed Raise Gatun Lake project, the existing high hydrologic reliability could be continued as demand for lockages increases up to 4.3 percent (or 1.65 lockages) above current demand levels. The total project first costs of the proposed Raise Gatun Lake project are estimated to be $77,238,000.

Raising of Gatun Lake normal operating levels increases the average hydraulic head on the powerplant; however, increased reliability implies that more water will be used for navigation and less for power generation. The net result would be a small loss in hydropower production.

Project Features

GENERAL

The primary structures and facilities appurtenant to and potentially affected by any change in the operation of Gatun Lake can be grouped according to general types as follows: Locks, Spillways, Embankments, Railroads, Highways, Utilities and Miscellaneous Facilities. These features are addressed in the following paragraphs and the features requiring modification are detailed under Projects Impacts.

LOCKS

The upper chambers at Gatun and Pedro Miguel Locks were built on the standard Panama Canal footprint having nominal chamber dimensions of 1,000 by 110 ft (304.8 by 33.5 m). As noted in the paper by Hodges, 1915, the freeboard of the terminal locks of the summit level was assumed at 5 ft (1.52 m) above high water of Gatun Lake, placing the coping of upper Gatun and Pedro Miguel Locks at elevation 92 ft (28.04 m) MSL.. The sill of the opening through which the gate-operating strut protrudes is 3.54 ft (1.08 m) below the top of the lock wall.

SPILLWAYS

Existing Gatun Spillway

The existing spillway at Gatun Dam is the original structure installed with the construction of the Panama Canal and placed into service in 1914. It is a gated structure having a sill at elevation 68.89 ft (21.0 m) MSL. There are 14 gate bays, each 45 ft (13.7 m) wide, closed by vertical lift (Stoney) gates 19 ft (5.8 m) high, and separated by reinforced concrete piers, 10 piers 8.5 ft (2.6 m) wide and 3 piers, at the center of the spillway, 15 ft (4.6 m) wide. The stated top of gate elevation in the closed position is 87.89 ft (26.79 m) MSL. When fully raised the gates have a bottom elevation of 91.5 ft (27.89 m) MSL. A walkway bridge spans across the tops of the piers at elevation 115.5 ft (35.2 m) MSL imposing a top restraint on the height to which the gates can be raised. This height is further restricted by the gate operating mechanism, consisting of a lifting chain, pulley, and counterweight system with the chains attached to the tops of the gates.

During extreme flooding conditions when the lake elevation exceeds 91.5 ft (27.9 m) MSL, spillway releases will become orifice controlled and not free overflow of the spillway. Previous studies have not considered this impact on the spillway release capacity. Furthermore, hydraulic forces on the fully open gates could result in damage to the gates. This condition should be further studied and spillway ratings above 91.5 ft (27.9 m) better established even if this alternative is not selected for further consideration.

EMBANKMENTS

Gatun Dam

The dam as constructed has a top elevation of 115 ft (35.05 m) MSL, has side slopes varying from 7.67 horizontal on 1 vertical to 11.11 horizontal on 1 vertical in critical areas, is 1.5 mi (2.40 km) long, and is approximately 2,300 ft (701 m) wide at the widest point of its base.

The site on which Gatun Dam was constructed was underlain by soft materials to a depth of 200 to 260 ft (60.96 to 79.25 m). The overlying material is clayey marine deposits, soft and easily moved. Since it was impractical to extend the cutoff to the deep foundation rock, the dam was constructed using a combination of materials. Dry material, excavated from dams, was dumped along the upstream and downstream toe alignments. Hydraulically dredged materials from the channel was placed within the toe dikes and allowed to consolidate. Though there were many problems encountered during the construction of this dam, including slides and extreme settlement, tests made after completion of the embankment indicated that the material is uniform and densely compacted. The dam has served well for over 85 years.

Pedro Miguel Dam

The dam at Pedro Miguel Lock comprises the southern enclosure for the Gatun Lake. It was constructed from the earth and rock fill removed from the lock pit and extends northward from the upper west wingwall of the lock to a hill. It is practically an extension of the west wingwall of the lock. The top elevation of the dam is at elevation 105 ft (32.0 m) MSL and its total length is approximately 1,400 ft (427 m).

The barrier to the east of the lock is formed by a concrete core wall which connects the lock and the natural hillside.

Saddle Dams

The following Table 23 - 1 is a listing of the saddle dams around Gatun Lake derived from an inventory prepared by the PCC.

Table 23 - 1 Gatun Lake Saddle Dam Inventory

Saddle Dam Name	Type of Saddle Dam	Crest elevation (ft - m)	Top elevation of bedrock (ft - m)	Length of Saddle Dam (ft. – m.)
Arroyo No. 1	Natural	116.8 -35.6	89.9 - 27.4	351 - 106.98
Arroyo No. 2	Natural	113.0 - 34.44	74.2 - 22.62	968 - 295.05
Arroyo No. 3	Natural	116.8 - 35.6	86.0 - 26.21	673 - 205.13
Arroyo No. 4	Natural	114.8 - 34.99	80.1 - 24.4	312 - 95.1
Arroyo No. 5	Natural	108.0 - 32.92	65.0 - 19.81	Not mentioned
Arroyo No. 6	Natural	114.8 - 34.99	73.2 - 22.31	377 - 114.91
Barro No. 1	Natural	142.1 - 43.31	123.0 - 37.49	Not mentioned
Barro No. 2	Natural	104.0 -31.7	Unknown	Not mentioned
Barro No. 3[1/]	Natural	104.0 - 31.7	Not mentioned	Not mentioned
Canoa No. 1	Natural	119.1 - 36.3	114.8 - 34.99	968 - 295.05
Canoa No. 2	Natural	119.1 - 36.3	Unknown	Not mentioned
Canoa No. 3	Natural	119.1 - 36.3	Not mentioned	Not mentioned
Caño No. 1	Natural	114.8 - 34.99	81.0 - 24.69	328 - 99.97
Caño No.2	Man-made	114.8 - 34.99	76.8 - 23.41	328 - 99.97
Caño No. 3	Man-made	114.0 - 34.75	77.1 - 23.5	Not mentioned
Caño No. 4[2/]	Man-made	105.0 - 32.0	77.1 - 23.5	Not mentioned
Caño No. 5	Natural	93.2 - 28.4	74.8 - 22.8	Not mentioned
Caño No. 6	Natural	97.8 - 29.8	49.9 - 15.21	Not mentioned
Egronal	Natural	128.9 - 39.29	120.1 - 36.61	148 - 45.11
Escobal No. 1	Natural	114.8 - 34.99	89.9 - 27.4	230 - 70.1
Escobal No. 2[3/]	Natural	114.8 - 34.99	84.0 - 25.6	Not mentioned
Escobal No. 3	Natural	114..8 - 34.99	83.0 - 25.3	Not mentioned
Lagarto No. 1[4/]	Natural	105.0 - 32.0	89.9 - 27.4	Not mentioned
Lagarto No. 2[4/]	Natural	104.0 - 31.7	89.9 - 27.4	Not mentioned
Lagarto No. 3[5/]	Natural	114.0 - 34.75	85.0 - 25.91	49.2 - 15.0

[1/] People around this saddle have cut a trench over 15 ft (4.6 m) deep through the saddle for access to and from the lake.
[2/] This saddle dam has a filter on the downstream slope to protect it against piping. This filter was made in 1987. There are also three iron pipes for water level measurements in the downstream slope.
[3/] At the top of the saddle there are some homes.
[4/] Some houses have been built on this saddle dam and the main road from Escobal to Gatun crosses the saddle dam.
[5/] There is a house in this saddle dam.

GATUN LAKE HYDROPOWER INTAKE STRUCTURE

The Gatun Lake Hydroelectric plant lies between the lock and dam and consists of six (6) Francis type turbine units. The units vary in size and each are served by a 10 ft (3.05 m) diameter penstock with the top of the intake at elevation 73.5 ft (922.40 m) MSL. Intake and control for each penstock is located in a gate structure located immediately at the north end of the Gatun Spillway. Each penstock is gated at its inlet and has a draft vent pipe immediately inside the face of the concrete intake structure. The vent pipes are 3 ft (.914 m) in diameter and their inlets are centered at elevation 91.5 ft (27.89 m) MSL. The gate house which rests atop the intake structure has its floor at elevation 95 ft (28.96 m) MSL.

PANAMA CANAL RAILROAD

The Panama Canal Railroad runs approximately 47 mi (75.6 km) through the Panamanian Isthmus from Colon in the north to Panama City in the south. Its route closely follows the alignment of the Panama Canal. During the construction of the Panama Canal approximately 93,224,000 CY (71,277,460 M^3) of material were deposited into the railroad embankments. The railway runs through or immediately adjacent to Gatun Lake and Miraflores Lake for approximately half its length. The railway elevation at bridge crossings in Gatun Lake are 98 ft (29.87 m) MSL with a low steel elevation of 92 ft (28.04 m) MSL. Therefore, the railroad is approximately 4.5 ft (1.37 m) above the existing maximum operating lake level.

MISCELLANEOUS FACILITIES

There are other facilities surrounding Gatun Lake that might be adversely affected by any raising of the maximum pool levels. These features include both floating and fixed docks used by the Panama Canal Operations personnel and others, the Mount Hope potable water intake facilities, and the Panama Canal Dredging Division facilities at Gamboa.

Hydrologic and Hydraulic Considerations

REDUCTIONS IN FLOOD STORAGE

Gatun Lake was planned in the early 1900s to be filled during the rainy season to elevation 85 ft (25.91 m) MSL for normal operations, with storage above this level to be reserved for flood control operations. The designs of the lock walls and gates were based on the assumption that the lake level would seldom be permitted to rise higher than elevation 87 ft (26.52 m) MSL, 2 ft (0.61 m) above normal operating levels.

The 1991 Panama Canal Flood Control Plan increased the maximum normal operating level of Gatun Lake to 87.5 ft (26.67 m) MSL. Currently, Gatun Lake flood storage lies between the maximum normal operating level and 92.0 ft (28.04 m) MSL. This did not take into consideration that the bottom of the spillway gates in the fully raised position is 91.5 ft (27.89 m) MSL. Raising the maximum operating lake level from elevation 85 ft (25.91 m) to elevation 87.5 ft (26.67 m) reduced the available flood storage capacity by approximately one-third.

SURGE IN GAILLARD CUT

In 1977, the U.S. Army Corps of Engineers studied canal surge in Gaillard Cut. Normal lock operations at Pedro Miguel Locks can cause significant surging through the Gaillard Cut. By using a computer program developed by TVA, a surge of 1.4 ft (0.43 m) is estimated under normal lockage conditions, which closely fit the actually observed surge which ranges from 1 to 1.5 ft (0.46 m). This study revealed that the surge was not very sensitive to water elevation in the cut but the speed with which the gates opened or closed was very important.

PRESENT SPILLING PROCEDURES AND CAPABILITIES

For large flood flows into Gatun Lake, the present operating plan calls for opening of the 14 gates of the Gatun Spillway. If additional capacity is required, the Lock culverts are opened to pass flood flows. Opening of the lock culverts to pass flood flows would interrupt navigation traffic. Studies have indicated that flows up to approximately 260,000 CFS can be obtained through the spillway when the Gatun Lake level reaches 92 ft (28.04 m) MSL. Additional flows from 48,000 to near 54,000 can be achieved through the lock culverts.

Studies such as Brod W. Howard, 1941, The Panama Canal, The Third Locks Project, Part I, Flood Control; U.S. Army Corps of Engineers, 1979, Summary Report Inspection of the Panama Canal Flood Control Facilities; and others, have concluded that the original Gatun Spillway capacity is inadequate for current standards. In 1991, Vargas concluded that by taking into consideration that the maximum normal operating levels for Gatun Lake should not exceed 87.5 ft (26.67 m) MSL, the present spillway system at the Panama Canal is not adequate to safely handle a 100-year flood.

PROBABLE MAXIMUM FLOOD

The U.S. Army Corps of Engineers design standards indicate that the overall flood control system at Gatun Lake should pass the Probable Maximum Flood (PMF) Hydrograph. See Guidelines for Safety Inspection of Dams, U.S. Army Corps of Engineers, 1974.

Gatun Spillway was designed according to early 1900s standards using the limited hydrological information available. It was designed for a discharge capacity based on estimated maximum discharge of the 1906 flood, the maximum flood on record. The maximum spilling capacity was assumed to be 140,000 CFS (3,960 CMS).

In 1979 the U.S. Army Corps of Engineers computed the PMF for the basin and routed it through the system. The simulation package HEC-1 was used to compute the routed flows and lake elevations. It was found that the peak inflow to Gatun Lake was 847,000 CFS (24,000 CMS). The peak outflow from Gatun Lake was computed to be 329,000 CFS (9,320 CMS), if the existing spillway and the lock culverts at Gatun and Pedro Miguel Locks were utilized. The computed maximum lake elevation at Gatun Lake was 92.55 ft (28.21 m) MSL. It should be noted that these computations did not account for constriction of flow at Gatun Spillway caused by the low elevation of the bottom of the spillway gates.

SPILLWAY CAPACITY

Any further increase in the maximum operating lake level at Gatun Lake would drastically reduce the flood storage capacity of the reservoir. The above-sited studies, noting the insufficient flood capacity of the existing spillway, further support this conclusion. If this alternative is carried forward for further study, different spillway configurations should be considered to optimize the hydraulic and structural requirements.

It was assumed that sufficient spillway capacity would be installed to restrict the design flood water surface elevation to approximately 91.5 ft (27.89 m) MSL. In order to address the supplemental spillway needs, a simple two sub-basin HEC-1 model was developed and calibrated to reproduce the results presented in the COE Phase III and IV report dated Feb. 1979. A 24 hour PMF was used in the computations. Then additional spillway capacity was determined by increasing spillway capability in the model until the lake did not exceed elevation 91.5 ft (27.89 m) MSL with the 24 hour PMF. Flow through the lock culverts was not used in these computations. It was assumed that the supplemental spillway would be configured similar to the existing spillway. This effort revealed that a 60 percent increase in spillway capacity is needed to satisfy the criteria with the lake operating to the current normal maximum level of 87.5 ft (26.67 m) MSL. If the maximum operating lake level is increased to elevation 89.0 ft (27.13 m) MSL, the spillway capacity would need to be increased by 100 percent above current capacity.

Selection of Revised Pool Level

This study addresses raising the maximum operating lake elevation for Gatun Lake. The objective of this study is to increase the time during the driest years over which the full draft could be maintained through Gatun Lake and Gatun and Pedro Miguel Locks. This could be accomplished by reallocating water within the Panama Canal watershed so that more water would be available during the dry season for lockages. The most desirable revised pool level would provide these advantages while causing the least impact on existing facilities and require the least in added facilities.

The revised operating lake elevation chosen for this effort was 89 ft (27.13 m) MSL. It was determined that, with the operating lake at this level, the operational difficulties would be minimized. The new rule curve for Gatun was developed by specifying a maximum operating pool of 89 ft (27.13 m) MSL and proportionally increasing the storage from the previous values. This was done to insure that the new Gatun pool operation would continue to provide similar flood regulating ability. This resulted an increase of 0.86 ft (0.26 m) in the operating lake level during the dry season. The increased lake levels would provide approximately 90,000 AF (11.11 MCM) of additional storage during the dry season. Current and the proposed operating rule curves for Gatun lake are shown in Figure 23 - 1 below.

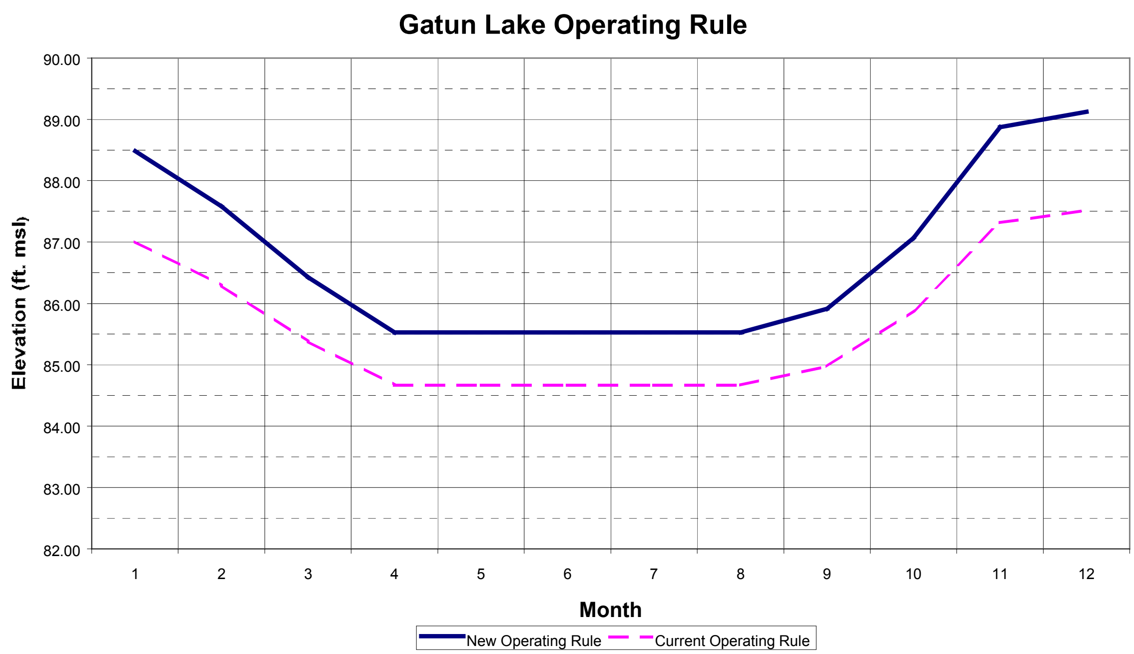


Figure 23 – 1 Gatun Lake Operating Rule Curves

This change to the operating scenario at Gatun Lake resulting in higher normal lake elevations would have detrimental effects on the appurtenant structures and facilities associated with, and surrounding the lake. The current operating scenario and the lake levels that would result under the Proposed Operating Option are outlined in Table 23 – 2. The revised maximum flood levels reflect a PMF on the system, with no relief from overtopping or from flows passing through the lock culverts. The various effects on structures and facilities are summarized below under Project Impacts.

Table 23 – 2 Lake Operating Options

Lake Level (m MSL)	Current Operating Levels		Proposed Operating Option	
	ft	m	ft	m
Maximum Operating Lake Level	87.5	26.67	89.00	27.13
Minimum Operating Lake Level	81.5	24.84	81.50	24.84
Maximum Flood Lake Level Without Added Spillway Capacity	93.4	28.47	94.45	28.79
Maximum Flood Lake Level With Added Spillway Capacity	91.5	27.89	91.50	27.89

Project Impacts

With the maximum operating lake at elevation 89.0 ft (27.13 m) MSL and potential flood level to elevation 91.5 ft (27.89 m) MSL, some features listed previously would suffer some adverse effects and would thus require modification in order to remain serviceable. These features are summarized below along with costs of remediation or modification.

LOCKS

The upper flight of locks at the Gatun site and the Pedro Miguel Locks would require some modification to accommodate the increase in water level indicated above. The current top of lock wall and lock gate elevation is 92 ft (28.04 m) MSL. Under normal operation with operating lake at elevation 89 ft (27.13 m), water would enter the gate operating machinery openings, with sill elevation 88.46 ft (26.96 m). These openings would require covering and sealing, with appropriate boots installed around the gate operator arms to seal out the water. This presupposes that the gate operating mechanisms have been retrofitted with hydraulic operator arms.

The reduced freeboard approximately 3 ft (.91 m) would require that larger vessels enter and exit the lock chambers at a much slower speed than is currently used, to minimize the water buildup in front of the vessels. This would result in a longer lockage time at both Pedro Miguel and Gatun Locks. During times of flooding this problem will be even more disruptive to navigation and will eventually require that measures be taken to prevent surge washover from flooding the lock operating gallery through openings in the top of the lock wall. This may require that lock operations be suspended for the duration of the extreme high water.

The alternative to this slower lockage speed would be to raise the top of the lock walls and gates. It was believed that this would be prohibitively expensive involving major modification to the lock gates and possibly requiring stabilizing and strengthening measures for the lock walls themselves. This would be very disruptive to lock traffic.

Studies conducted by the U.S. Army Corps of Engineers in 1979 found that wind generated waves can result in wave run-up impacts of as much as 4.0 ft (1.2 m) against the lock walls. With the lake level raised, the upper lock gates and lock walls could be overtopped by wind driven waves and surges from Gatun Lake. This would be an operational inconvenience. The problem can be partially mitigated by providing sealed hatch covers for all openings that must be flush with the top of the lock wall throughout the upper portion of the length of the upper chamber. The electrical feed rail would still be exposed and vulnerable to this wave action.

In times of extreme flooding protective measures would be required to prevent waves from overtopping the lake side lock gates and the upper lock chamber walls. These measures could be in form of sandbags or by more permanent construction.

A section of the center upper approach wall at Gatun locks has experienced approximately 5 ft (1.5 m) of settlement. The section now rests at approximate elevation 93.5 ft (28.5 m), 4.5 ft (1.37 m) above the proposed revised operating level. This should pose no difficulty to navigation or to the operation of the lock except during floods when the above restrictions would apply to the guide walls also.

SPILLWAYS

Existing Gatun Spillway

With the maximum normal operating lake level raised to elevation 89 ft (27.12 m) MSL, the total design static horizontal water load on the spillway gates (i.e. water to the top of the gates) would be increased. Assuming the gates are extended so that a freeboard of 1 ft (0.3 m) is provided, the new top of gate elevation would be 90 ft (27.4 m) MSL. The resulting total hydrostatic load on the gates would increase by a factor of 1.23 (23 percent increase over existing). This could require that the gates be strengthened and extended vertically.

Under current operation, with the gates in the fully raised position the bottom lip of the gates is at elevation 91.5 ft (27.89 m) MSL. With a fixed vertical extension on the spillway gates and the walkway bridge in its current position, the lower lip would be approximately at elevation 89.39 ft (27.24 m) MSL. To provide full gate clearance, the gate extensions would be of an operable type, and could be moved out of the way as the gates are raised. These would require an operating system for each gate extension (electrical, hydraulic, etc.) and a durable system of side and bottom seals to insure against leakage.

It was assumed that the spillway would be structurally adequate for the added service loads resulting from higher maximum operating water surface elevations. However, in the event that this alternative is carried forward for further study, a thorough investigation of the stability and integrity of the individual components of the concrete dam and spillway must be made. This would be necessary due to recent developments concerning the potential for seismic events in the various regions of the Republic of Panama. More precise methods of applying the forces associated with seismic events to structures have been recently developed. These studies will address internal stresses for all components including spillway gates and anchorages, concrete spillways, bridge piers, and non-overflow walls. The overall stability of each type of monolith must be checked to assure that the higher pool levels do not cause larger stresses at the foundation than allowed and to assure the stability of each monolith against overturning and sliding. These computations should also take into account the present condition of the structural components and the age of the materials.

New Spillway

The proposed additional spillway was configured for the Canoa Saddle dam site just east of Gatun Locks. The spillway at this location would require reconstruction of the bridge immediately downstream from the proposed new spillway and would have an outlet channel emptying into Las Minas Bay. Plate 23 – 1 shows the location of the spillway and outlet channel.

The new structure would be approximately 728 ft (222 m) out to out of the end piers. It would have 14 vertically rotating Tainter type gates, each 45 ft (13.72 m) wide by 19 ft (5.8 m) high and having a concrete ogee sill at elevation 69 ft (21.03 m) MSL. It would have a roadway bridge over the top of the gates to accommodate placement of the spillway stoplogs for maintenance of the gates and operating mechanisms. The outlet channel would be concrete lined and would taper from the width of the spillway to approximately 300 ft (91.44 m) within 500 ft (152.4 m) of the centerline of the spillway crest. The lined channel would extend to a point approximately 4,100 ft (1,250 m) downstream of the centerline of the spillway crest.

In conjunction with construction of the new Canoa Spillway a roadway bridge would be required over the outlet channel on Panama National Highway No. 3. This bridge would have six spans measuring 70 ft (21.336 m) in length for a total of 420 ft (128.02 m), and would be built to the lane width and clearance standards required by the Panama authority having jurisdiction.

EMBANKMENTS

No modifications would be required to the main dams at Gatun or Pedro Miguel.

Studies conducted by the U.S. Army Corps of Engineers in 1979 indicated that the wave runup on a sloped face could be as much as 5.9 ft (1.8 m) plus set-up of 0.1 ft (0.03 m). This indicates a freeboard requirement of 6 ft (1,83 m). A minimum acceptable Saddle Dam elevation can then be derived by applying this freeboard to the maximum lake elevation, 91.5 ft (27.89 m) MSL, yielding an elevation of 97.5 ft (29.72 m) MSL. The PCC inventory of saddle dams shown previously indicates that only one has top elevations below elevation 97.5 ft (29.72 m), the Caño No. 5 dam. Given this minimum saddle elevation, it follows that Caño No. 5 saddle should be raised 4.3 ft (1.31 m), from its actual elevation of 93.2 ft (28.41 m).

The notations accompanying the tabulation of saddle dams indicates that several of the dams have been modified and / or have had structures erected on them. This situation should be rectified, especially should this alternative be carried forward.

GATUN HYDROPOWER INTAKE STRUCTURE

The 6 draft vent intakes, one for each of the hydropower penstocks, would need to be reconfigured to clear the proposed maximum operating lake elevation. With the lake at elevation 87.5 ft (26,67 m) MSL the clearance to the invert of the pipe inlets is 2.5 ft (0.76 m). To re-establish this clearance for the higher lake elevation of 89.0 ft (27.13 m) MSL, the invert of the intakes would need to be raised to elevation 91.5 ft (27.89 m) MSL.

PANAMA CANAL RAILROAD

The existing railway embankments and finished rail elevations should be high enough to be clear of the water levels that could occur during a PMF flood event. The bridges now have approximately 4.5 ft (1.37 m) safety clearance between the low steel and the normal high operating lake elevation. The bridges at Gamboa and Monte Lirio would need to be raised 1.5 ft (0.46 m) to maintain the 4.5 ft (1.37 m) safety clearance. Ten to fifteen miles (16.09 to 24.14 km) of the railroad embankment would need rip-rap slope protection with 7 mi (11.27 km) of this requiring slope protection on both sides. Approximately 100 culverts through the embankment would need to be raised 1.5 ft (0.46 m).

MISCELLANEOUS FACILITIES

Dock Structures

Seventeen fixed docks and 7 floating docks were identified along the perimeter of Gatun Lake. Three feet of freeboard would provide sufficient clearance to avoid damage during annual flooding and concurrent wave action. Based on these criteria, 11 of the 17 fixed docks identified would require modification with the normal maximum lake level raised to elevation 89 ft (27.13 m). None of the seven floating landings would be affected. Table 23 – 3 lists the fixed docks and their current top elevations.

Table 23 – 3 Fixed Docks

Fixed docks	Top of dock elevation	
	(ft)	(m)
Paraiso tug landing	90.20	27.49
Gamboa tug landing	91.00	27.74
Gatun tug landing	89.50	27.28
Paraiso launch landing	90.50	27.58
Gamboa launch landing	89.00	27.13
Gatun launch landing	89.50	27.28
Gatun water bus landing	88.50	26.97
Gatun fuel barge landing	90.00	27.43
Paraiso tie up station	95.00	28.96
Dredging Division main dock	93.00	28.35
Atlas landing	93.00	28.35
Tender / tug landing	93.00	28.35
Siri landing, Gamboa	90.00	27.43
Reserve fleet area	92.00	28.04
Gatun salvage dock	92.00	28.04
Dock 45	89.40	27.25
Hydrographic boat dock	88.20	26.88

Mount Hope Intake

The Mount Hope potable water intake facilities would require some modification. The concrete gate control tower has a floor at elevation 91.7 ft (27.95 m) MSL and would not be affected. However, the intake tower has a top elevation of 90.5 ft (27.58 m) MSL and would require modification. The steel walk bridge leading to it would also require modification to maintain critical operational equipment access.

Utility Relocations

In addition to the above facilities modifications, other relocations would be the electrical transmission lines that parallel the railroad. These would need to be raised 1.5 ft (0.45 m) with the two railway bridges and adjacent track work.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed for its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would begin during the planning studies phase and would continue during the final design, advertising and award phase, and on through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin with land acquisition and construction of the access facilities. Land for project construction would be limited to that required for construction of the new Canoa Spillway outlet channel.

Socio-economic programs would begin concurrently with construction of the new spillway and continue throughout the construction phase.

Construction, in preparation for raising the lake, could be done at each individual site concurrently. The new spillway would be the most time consuming single effort. Spillway construction would begin with isolation of the site with a cofferdam. The excavation of the site would follow concluding with drilling and foundation grouting. The mass concrete spillway monoliths would then be put in place followed by the construction of the reinforced concrete pier sections. Once the concrete work is completed on a given spillway bay the installation of the spillway gates and control mechanisms would be done. As the spillway construction nears completion the spillway outlet channel would be excavated and the cofferdam downstream removed.

Concurrent with and in coordination with the spillway construction the roadway bridge crossing the spillway outlet channel would be replaced. The two railway bridges would be raised and the associated track and relocation work would be done. Modifications of the spillway gates at Gatun Spillway would be made, and the other miscellaneous smaller modifications and renovations completed.

Upon completion and certification of each component, the lake would be raised to its new operating level, elevation 89 ft (27.13 m) MSL.

Considering the climatic conditions and the obstacles posed by the congested area around the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 10 years, from initial planning to lake filling. Figure 23 – 2 depicts the development sequence of the various project features.

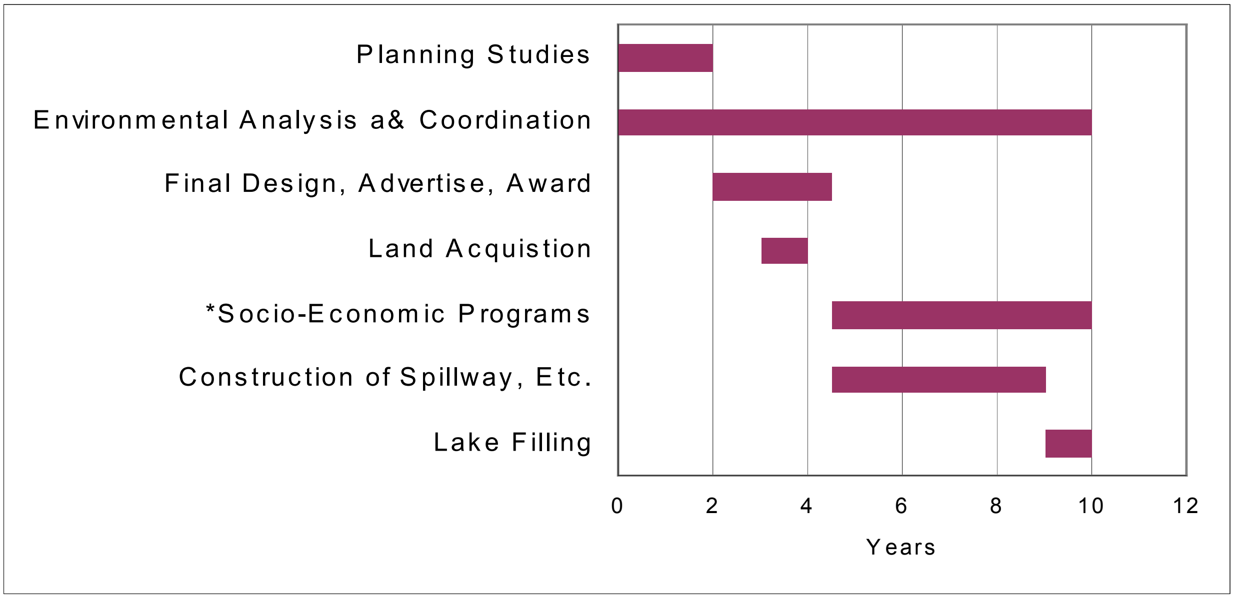


Figure 23 – 2 Development Sequence

*Socio-Economic Programs would be very limited for this project.

Hydrologic Reliability

In order to determine the effect of the proposed alternative to raise the normal operating lake levels of Gatun Lake on the hydrologic reliability of the Panama Canal, the lake was evaluated with the existing HEC-5 model of the Panama Canal, applying historic hydrology and imposing the alternative levels.

HEC-5 model simulations were conducted using the existing Panama Canal system model with the system operating along the existing rule curve and with the new rule curve. All points on the new rule curve were raised proportionally to the ratio of storage at elevation 87.5 and 89.0 ft (27.13 m) MSL. This resulted in an operating rule (rule curve) with a maximum change of 1.5 ft (0.46 m) during the maximum operating lake levels to only 0.86 ft (0.26 m) during the dry months when the pool is normally lowered. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. It was recognized that water required for lockages would increase with higher average lake levels. Therefore, lockage demands for the higher operating rule were increased by 1.5 percent based on the increased water needed to reach the higher lift of the lock. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record. Figure 23 – 3 presents the resulting hydrologic reliability for the existing rule curve and a rule curve raised 1.5 ft (0.46 m) with demands increasing up to 180 percent of current demands. These configurations were:

- Existing system. (Normal operating lake levels vary between elevation 87.5 and 84.6 ft (26.67 and 25.79 m) MSL), and
- Alternative. (Normal operating lake level varying between elevations 89.0 and 86.1 ft (27.13 and 26.24 m) MSL).

The horizontal axis along the bottom of Figure 23 – 3 reflects demands as a ratio of the five-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 23 – 3, the existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability with a demand ratio of 1.0 would be 99.75 percent if the maximum normal operating level is raised to elevation 89.0 ft (27.13 m) MSL, and the hydrologic reliability with a demand ratio of 1.8 would be 86.7 percent. Table 23 - 7 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the Panama Canal system would decrease. With the implementation of the proposed change in operation of Gatun Lake, the existing high hydrologic reliability could be continued as demand for lockages increases up to 4.3 percent (1.65 lockages) above current demand levels.

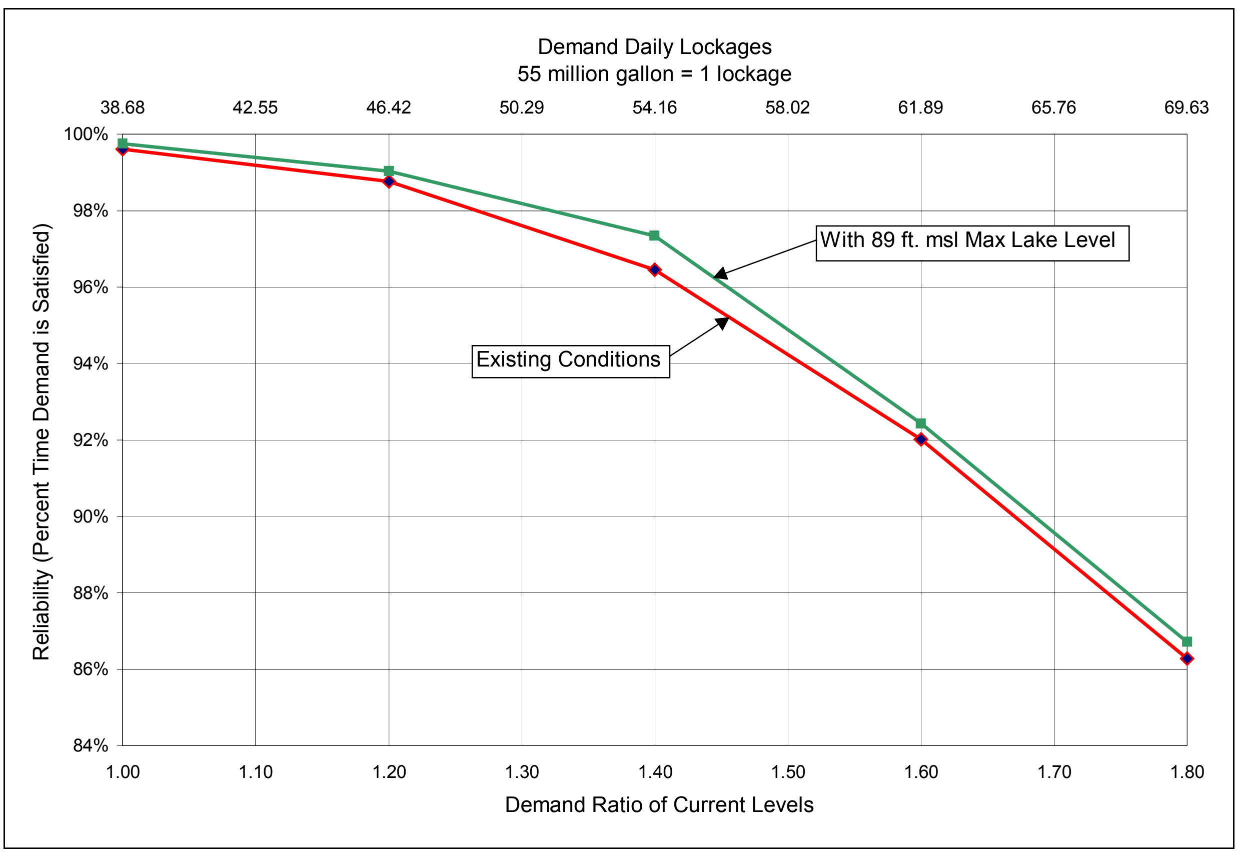


Figure 23 – 3 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts shown on Plates 23 – 1 through 23 – 2. The unit prices applied to these quantities were based on historical information from previous estimates prepared for similar construction in the Republic of Panama, previous estimates for similar construction in the Southeastern United States, information gathered from Mobile District Construction Division personnel in the Republic of Panama.

Engineering and design is estimated to be 12 percent and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent was included for contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $77,238,000. Table 23 – 4 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 23 – 4 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	15,000
Lock modifications	210,000
Spillway modifications	700,000
New Canoa Spillway	43,806,864
Raise Caño 5 Saddle Dam	100,500
Modify Gatun Hydropower Intake Vents	60,000
Panama Canal Railroad Modifications	4,763,010
Raise fixed dock structures	550,000
Mount Hope M & I Water Intake Mod	125,000
Electrical Transmission Line Relocation	99,000
National Highway Bridge	1,062,600
Subtotal	51,491,974
E&D, S&A, Field Overhead	10,298,395
Contingencies	15,447,592
Total Project First Costs	77,238,000

OPERATION AND MAINTENANCE

Staff
An adequate staff to operate the Gatun Lake and Locks project is already in place. It is assumed that this staff could absorb the additional duties of operating the new Canoa spillway with no additional cost. Thus, no staff costs are estimated for this proposed project.

Ordinary Maintenance
Ordinary maintenance and care would be required and would include minor repair materials, lubricants, and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $100,000 per year for the main project facilities.

Major Replacements
The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 100 years. To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it was assumed that specific items would cost the same as at present. No allowance was made for salvageable fixed parts. Table 23 – 5 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements would be $309,900 and the average annual replacement costs would be $37,000.

Table 23 – 5 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Gatun Lock Modification				
Seal Hatches	15	3	900,000	66,700
Extension Mechanical Operators	50	1	210,000	700
Electrical Controls	25	2	210,000	6,500
New Canoa Spillway				
Steel Bridge Girders	50	1	637,362	2,200
Tainter Gates	50	1	4,127,865	14,300
Tainter Gate Hoists	50	1	5,206,320	18,000
Tainter Gate Operating System	50	1	697,500	2,400
Stoplogs	50	1	577,500	2,000
Miscellaneous Mechanical Items	25	2	3,090,000	96,200
Electrical Controls	25	2	3,240,000	100,900
Total			18,896,547	309,900
Average Annual Replacement Costs				37,000

Annual Costs

The total project first costs are estimated to be $77,238,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the total project first costs was computed from mid-year throughout the 10-year period from initiation of planning and design until the lake was filled. The interest during construction at 12 percent would be $36,326,000 and it was added to the total project first costs for total project investment costs of $113,564,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $13,675,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 23 – 6 contains a summary of the annual costs.

Table 23 – 6 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	77,238,000
Interest During Construction	36,326,000
Total Project Investment Costs	113,564,000
Annual Average Investment Costs	13,675,000
Operation and Maintenance Costs	
Staff Costs	0
Ordinary Maintenance Costs	100,000
Major Replacement Costs	37,000
Total Average Annual Costs	13,812,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Section 4. The following paragraphs present the results of the economic investigations for the proposed Raise Gatun Lake project. The 50-year planning period for this proposal is 2010 to 2060.

The proposed Raise Gatun Lake project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. The project provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages were obtained from the data used to develop Figure 23 – 3. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 23 – 7 Panama Canal Hydrologic Reliability

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Raise Gatun [1/] (%)
1	2000	38.68 [2/]	99.60	99.75
	2010	45.11	98.91	99.15
1.2		46.42	98.76	99.03
	2020	47.61	98.41	98.77
	2030	49.55	97.83	98.35
	2040	52.02	97.09	97.81
1.4		54.15	96.45	97.34
	2050	55.13	95.89	96.72
	2060	59.05	93.65	94.23
1.6		61.89	92.02	92.42
	2070	63.97	90.47	90.89
1.8		69.63	86.27	86.71

[1/] Operating levels for Raise Gatun Lake fluctuates between the maximum operating lake level at elevations 27.13 m MSL and the minimum operating lake level at elevation 24.84 m MSL.

[2/] 2000 Daily Demand is Average of 1993-1997.

With the proposed Raise Gatun Lake project, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands grow, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Raise Gatun Lake project, these shortages would be less than they would be under the existing system. With a hydrologic reliability of 99.6 percent, the proposed project would increase the amount of water supplied for navigation by approximately 1.65 equivalent lockages. The 99.6 percent hydrologic reliability would occur in the year 2003 with an equivalent daily average number of lockages set to 40.33. Therefore, all shortages would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages provided by the alternative. The average annual benefits for water supply would be $33,472,000. Table 23 – 8 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Raise Gatun Lake project in operation, the annual benefits for meeting shortages, and the average annual benefits.

Table 23 – 8 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits ($)
2010	6.43	4.78	32,180,000
2020	8.93	7.28	33,975,000
2030	10.87	9.22	33,975,000
2040	13.34	11.69	33,975,000
2050	16.45	14.80	33,975,000
2060	20.36	18.72	33,975,000
Average Annual Benefits			33,472,000
With the Raise Gatun Lake alternative, the system will provide a total of 40.33 equivalent lockages at the 99.6 percent level of reliability or 1.65 more lockages than the existing system.			

With the proposed project, the reliability of the system to provide all of the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Raise Gatun Lake project would be $2,877,000. Table 23 – 9 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits for the new operating levels.

Table 23 – 9 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Daily Lockage ($)	Annual Navigation Benefits ($)
2010	39.0	2,086,000	1,874,000
2020	40.0	2,260,000	2,979,000
2030	40.0	2,260,000	4,267,000
2040	40.0	2,260,000	5,905,000
2050	40.0	2,260,000	6,817,000
2060	40.0	2,260,000	4,822,000
Average Annual Benefits			2,877,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was based upon the growth in population. The PCC provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day. An equivalent lockage is 55 million gallons of water. One equivalent lockage was added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I

purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Raise Gatun Lake project, the current costs to the PCC to process finished water of $0.69 per 1,000 gallons, the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability would be $394,000. Table 23 – 10 displays the population forecast, the resulting number of equivalent lockages demanded per day, the annual benefits for increased reliability, and the average annual benefits for M&I water supply.

Table 23 – 10 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2010	1,724,000	6.1	209,000
2020	2,141,000	7.6	381,000
2030	2,688,000	9.6	685,000
2040	3,384,000	12.0	1,191,000
2050	4,259,000	15.1	1,732,000
2060	5,360,000	19.0	1,543,000
Average Annual Benefits			394,000
The value of a daily lockage for M&I is $0.69 X 55,000 = $37,950			

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. Raising of Gatun Lake normal operating levels increases the average hydraulic head on the powerplant; however, increased reliability implies that more water will be used for navigation and less for power generation. With higher operational lake levels a small net loss in hydropower production would be realized with the inclusion of the proposed Raise Gatun Lake project. This loss of generation would increase over time. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, the proposed project would have negative benefits of $251,000. Table 23 – 11 provides the net lost megawatt hours of hydropower generation and the resulting negative annual and average annual benefits.

Table 23 – 11 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1/] (MWh)	Annual Hydropower Benefits ($)
2010	-2,186	-153,000
2020	-3,732	-261,000
2030	-5,746	-402,000
2040	-8,304	-581,000
2050	-10,704	-749,000
2060	-11,477	-803,000
Average Annual Benefits		-251,000

[1/] Net generation of Gatun, Madden, and Raising Gatun Lake hydropower plants less generation of Gatun and Madden hydropower plants.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 23 – 12, total average annual benefits for the proposed Raise Gatun Lake project would be $36,492,000.

Table 23 – 12 Summary of Annual Benefits

Benefit Category	Average Annual Benefits New Operating Levels ($)
Navigation – Water Supply	33,472,000
Navigation – Reliability	2,877,000
M&I - Reliability	394,000
Hydropower	-251,000
Total	36,492,000

Once average annual benefits and costs are estimated, the ratio of benefits to costs and the net benefits (net of costs) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. Table 23 – 13 provides the benefit to cost ratio and the net benefits for the proposed Raise Gatun Lake project.

Table 23 – 13 Economic Evaluation

Item	Value ($)
Average Annual Benefits	36,492,000
Average Annual Costs	13,812,000
Benefit to Cost Ratio	2.6
Net Benefits	22,680,000

Internal Rate of Return

An internal rate of return analysis for the new operation level was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For the proposed project, the internal rate of return would be 23.8 percent.

Socio-Economic Impacts

Due to the nature of this project, its socio-economic impacts could be minor. The raising of Gatun Lake could impact some local residents. The average monthly household income is between $200 and $300. No indigenous groups of people are known to reside in the affected region. Minor impacts on land use are anticipated. The towns are at some distance from Gatun Lake; therefore, the increase in noise levels would have no impact on these communities. Public and private docks could be effected.

Environmental Setting

The Raise Gatun Lake alternative would result in a revised maximum operating lake elevation of 89 ft (27.1 m) MSL. Currently the maximum operating elevation for Gatun Lake is 87.5 ft (26.67 m) MSL. The primary structures and facilities appurtenant to and potentially affected by any change in the operation of Gatun Lake can be grouped according to general types as follows: locks, spillways, embankments, railroads, highways, utilities and miscellaneous facilities. Private docks and marine facilities along current waters edge could be effected.

LAND USE

The Raise Gatun Lake project would increase the existing lake elevations during the wet season by 0.46 m and by 0.30 m during the dry season. The structures that would be impacted by the proposed project are Gatun Locks, Pedro Miguel Locks, and Gatun Spillway. Facilities along the perimeter of Gatun Lake would also be impacted. Some of the towns are drawing water from Gatun Lake for M&I and agricultural uses. The lake is also used for fishing, bathing, and transportation. Individual residences along the shores of Gatun Lake were constructed either of forest materials or concrete.

Some areas along the shores of Gatun Lake have been deforested. Approximately 65 percent of the lakeshore areas are forested, mostly with secondary growth. The remaining land is occupied by farms and ranches of various sizes, ranging from commercial cash crop enterprises to subsistence farming, and by activities associated with the operation and maintenance of the Panama Canal. Farm crops include maize, rice, beans, sugar, coffee, tobacco, and teak tree plantations. Ranchers raise cows, horses, chickens, and hogs.

Significant erosion caused by wave action induced by ships was observed along the shores of narrow passageways, peninsulas, and islands in Gatun Lake. The soils eroding into the lake should increase turbidity, reduce light penetration, and decrease channel depth as the deposited materials accumulate. There are no significant mineral resources or deposits along Gatun Lake.

INFRASTRUCTURE

Towns along Gatun Lake have cemeteries, churches, and medical centers. Potable water is obtained from Gatun Lake or from groundwater wells. Some homes have electricity and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it might reach Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners: some homes have septic tanks but most have an outdoor latrine (a hole in the ground). There are known health problems such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illness attributable to these waste disposal methods. The main industry in the project area is the shipping traffic on the Panama Canal. No major poultry or beef processing plants are located in the project area. The only roads in the project area are dirt roads, which are used for maintenance access by the PCC. These relatively isolated roads are valuable to the residents for transportation, community cohesion, commerce, and communication with neighboring communities and the PCC.

TERRESTRIAL HABITAT

The terrestrial habitat surrounding Gatun Lake consists of tropical forest ecosystems, with large areas of secondary growth forests and patches of primary forest. Approximately 65 percent of the Gatun Lake project area is forested. The lake contains islands inhabited by wildlife communities. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Barro Colorado Island, which was created through the formation of Gatun Lake, is used by scientists as a laboratory to study tropical ecosystems. Slash and burn activities has opened tracts of land for farming and cattle grazing; however, the majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding habitat. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities. This area may provide critical wildlife habitat to many native species.

ANIMALS ON ENDANGERED LIST

ANAM by its Resolution 002-80 on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although none have been identified to date, some or all of the listed animals and other species of concern may occur in the project area.

AQUATIC HABITAT

Gatun Lake is one of the largest man-made lakes in the world, with various water depths and a wide range of water quality, and contains many different types of aquatic habitat. Panama Canal construction inundated the forests, which are one such habitat. There are high traffic shipping lanes and various submerged topographical features. Water clarity ranges from high turbidity in the shipping lanes to clear in areas distant from the shipping lanes. Gatun Lake provides habitat for a variety of wildlife species, both resident and migratory, as well as for both native and introduced fish and other aquatic species.

WETLANDS

Areas which contain hydric soils and hydrophytic plant communities, and which are subject to hydrologic conditions are termed wetlands. Wetlands in the project area are shallow water habitat areas that experience frequent flooding. The shallow water areas along the shores of Gatun Lake receive sunlight to a depth of approximately 1 m, depending on water clarity. Sunlight stimulates the growth of plants in the form of submergent, emergent or floating mats of aquatic vegetation. These shallow areas are located away from the banks and into the deeper aquatic habitats. Wetlands occur in areas where topography is conducive to water pooling long enough to produce hydric soil conditions and allow plant communities to thrive. Wetlands in the project area are stressed by wave action from passing ships and runoff from slash and burn areas.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season in March or early April, areas covered with forest or secondary growth are burned and cleared to prepare the land for agricultural use. During this period the air is filled with smoke and ash, which may be transported by winds to Gatun Lake. Air quality monitoring has not been implemented within the project area. The natural environment could provide indicators that could be useful in evaluating air quality.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the National Academy of Sciences administered the biological reserve / laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946 the responsibility for its maintenance was assigned to the Smithsonian Institution. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in Gatun Lake would be minor. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by a mixture of species from the neighboring habitats but are unique, with high species diversity. Permanently raising Gatun Lake should have minimal impact on the wildlife habitat of the project area because water should not exceed previous high water levels.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered species cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Some endangered and / or threatened species may use Gatun Lake for some or all parts of their life cycle.

WATER QUANTITY

The impacts of the project on water quantity are expected to be minor. Species inhabiting at specific depths could be impacted when lake depth increases.

WATER QUALITY

Project impacts on water quality are unknown. Raising Gatun Lake should increase the amount of nutrients and debris in the lake. The rate at which nutrients and debris enter the lake will determine the severity of impact on water quality. Project implementation should cause an increase in turbidity and interfere with photosynthesis in the impacted areas. The increase in turbidity could deprive plants and other aquatic species from necessary sunlight. Aquatic plants and organisms serve to maintain water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat are expected to be moderate. Project implementation may impact the successful breeding and the nursery habitat of many juvenile aquatic species. Impacts to fish spawning areas may be detrimental when turbidity, nutrient content, and depth of the water suddenly increase. Plant populations may decrease as a result of increasing water depth, and a decrease in available sunlight, therefore, invertebrate populations may decline which could reduce the food supply for fish and other aquatic species. No information is available about currents in Gatun Lake; sediment and other debris from project implementation could spread wider than anticipated.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities depend on water quality and stable water levels. Plant species in Gatun Lake could be impacted by the increase in depth.

Aquatic plant communities could be impacted during project implementation; however, they should eventually re-establish themselves after conditions stabilize.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting Gatun Lake and the affected areas could be important. Aquatic faunas that currently thrive in Gatun Lake would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur, these impacts should be identified, and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. Gatun Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

WETLANDS

The impacts to wetlands could be significant. As present wetlands are inundated, they could become aquatic habitats. Project activities may lead to increased water depth, sedimentation and turbidity which could hamper the biological processes of the wetlands and decrease their productivity. Such impacts could be detrimental to the health of Gatun Lake. Fish and other aquatic species use shallow water as spawning areas as well as habitat for juvenile aquatic species. Juvenile aquatic species survive in shallow water wetlands until they are large enough to venture out into deeper water.

AIR QUALITY

During project implementation, emissions from construction equipment, along with local slash and burn activities, could cause temporary deterioration in air quality in the project area. Upon project completion, the air quality should return to its pre-project condition.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Habitat along the shores of Barro Colorado Island could be impacted as water levels rise and plant communities change. The potential impacts on cultural resources and historic properties can not be defined and mitigated. Prior to project implementation, surveys would be conducted to locate cultural resource and historic properties and the important sites would be preserved or salvaged as appropriate.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Raise Gatun Lake alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an SIA. The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities.
  - Employment.
  - Land Use.
  - Property Values.
  - Public and Community Facilities and Services (including utilities and schools).
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population.
  - Community Cohesion.
  - Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site specific habitat maps to ensure that all major terrestrial and aquatic habitat types are identified and quantified.
- Conduct field studies to locate rare and unique habitat features such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Collect samples from the bottom of Gatun Lake to determine whether there are pollutants that could be released during project implementation.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Provide species inventory lists for each site area identifying their status as native or exotic and whether they are threatened and or endangered species.
- Conduct additional research into water currents and estimated turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and / or threatened species list.
- Establish field methodology to assess wildlife habitat values
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts to determine the presence of these species

WATER QUALITY

- Since limited water quality data are available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Information regarding cultural resources is incomplete. Additional evaluation studies should be conducted to identify cultural resources and historic properties in the project area.

Evaluation Matrices

In accordance with evaluation procedures described in Section 4, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Section 35. Tables 23 – 14 through 23 – 16 present the evaluation of the proposed Raise Gatun Lake project as related to developmental effects, environmental effects, and socio-economic effects.

Table 23 – 14 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I demands	2	10	20
	Supplements Existing System	0	10	0
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	3	6	18
	Feasibility of Concept	3	6	18
Operational Issues	Compatibility	10	6	60
	Maintenance Requirements	6	2	12
	Operational resources required	8	2	16
Economic feasibility	Net Benefits	1	9	9
	Total			153

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 23 – 15 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	4	8	32
Animals on Extinction List	5	10	50
Water Quantity Impacts – Lake	10	10	100
Water Quantity Impacts – Downstream	5	7	35
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	5	8	40
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	5	5	25
Potential for Fishing on Lake	5	6	30
Wetlands	4	4	16
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			491

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 23 – 16 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	5	7	35
Relocation of People	5	10	50
Relocation of Agricultural/Ranching Activities	5	6	30
Post-Construction Business	5	5	25
Post-Construction on Existing Employment	5	5	25
Property Values During Construction	5	4	20
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	5	4	20
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	5	5	25
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	5	4	20
Communities Receiving Displaced People	5	8	40
Community Cohesion	5	8	40
Tourism	7	5	35
Total			455

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

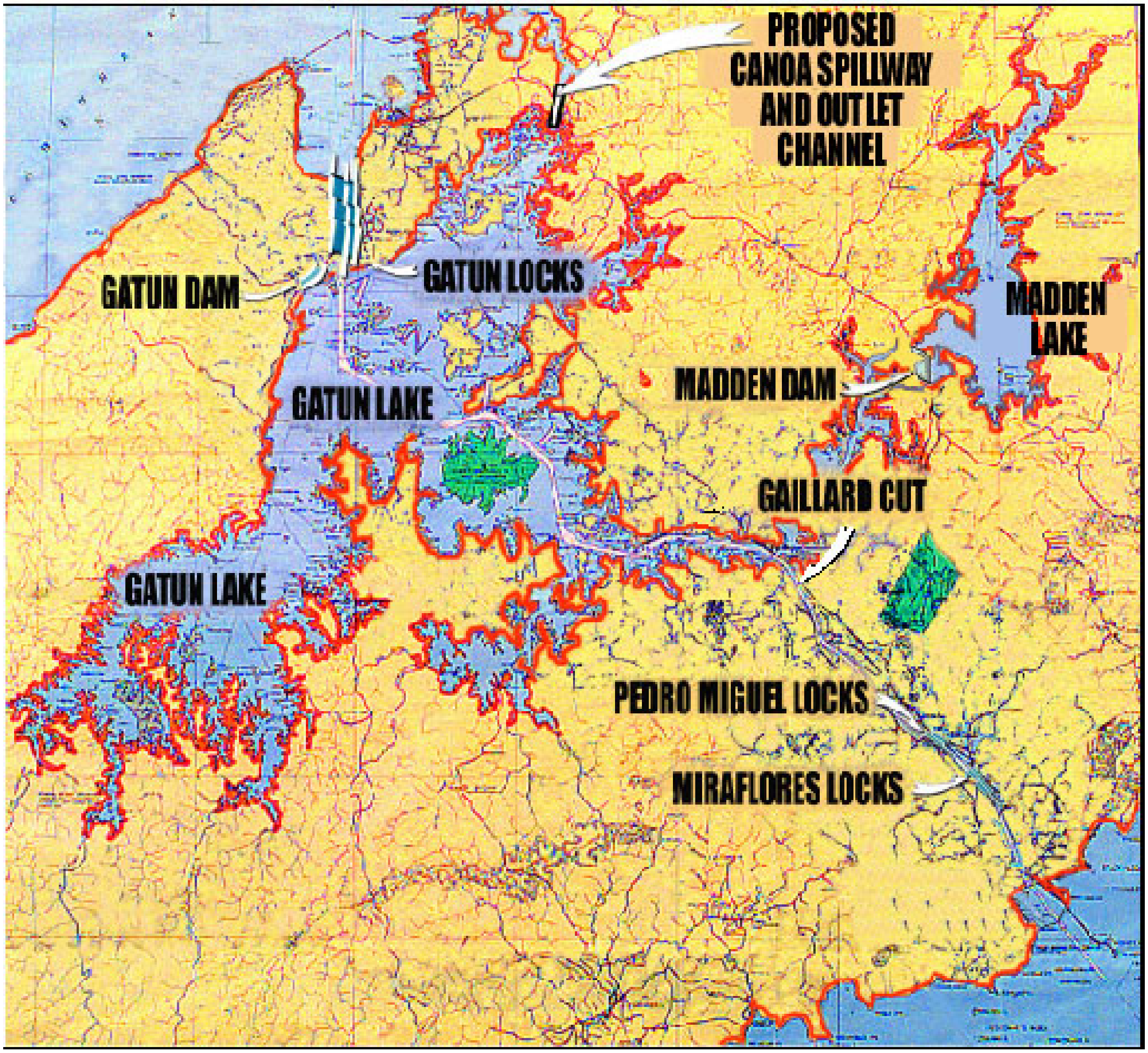
Pertinent Data

Table 23 - 18 presents pertinent data for the new operating levels in Gatun Lake.

Table 23 – 17 Pertinent Data for Raise Gatun Lake Alternative

LAKE	
Elevation of normal operating lake level	89 ft (27.13 m) MSL
Elevation of maximum flood storage lake level	91.5 ft (27.89 m) MSL
Elevation of minimum operating lake level	81.5 ft (24.84 m) MSL
Useable Storage between Max and Min levels	790,000 AF (975 MCM)
EMBANKMENTS	
Saddle dam (Caño No. 5)	
Type of saddle dam	Earth fill embankment
Top elevation of saddle dam (existing)	93.2 ft (28.41 m) MSL
Top elevation of saddle dam (revised)	97.5 ft (29.72 m) MSL
SPILLWAY	
Gatun Spillway	
Type of Spillway	Gated Ogee (Stoney Gates)
Total length spillway crest	630 ft (192 m)
Elevation of spillway crest	68.89 ft (21.0 m) MSL
Height of Gates (existing)	19.0 ft (5.79 m)
Height of Gates (revised)	21.0 ft (6.4 m)
Canoa Spillway	
Type of Spillway	Gated Ogee (Tainter Gates)
Total length spillway crest	630 ft (192 m)
Elevation of spillway crest	69 ft (21.0 m) MSL
Height of Gates (existing)	19.0 ft (5.79 m)
ROADWAY BRIDGE	
Panama Highway No.	3
Total Length of Bridge	420 ft (128.02 m)
Total Number of Spans	6
PANAMA CANAL RAILROAD	
Bridges to be modified	2
Culverts to be raised	100
Bank Protection – one side only	8 mi (12.9 km)
Bank Protection – two sides	7 mi (11.3 km)
Fixed Dock Relocations	
Number of docks	11
Height to be raised, maximum	3.8 ft (1.16 m)

RAISE GATUN LAKE



Project Location Map

Plate 23 - 1   Project Location Map

RAISE GATUN LAKE

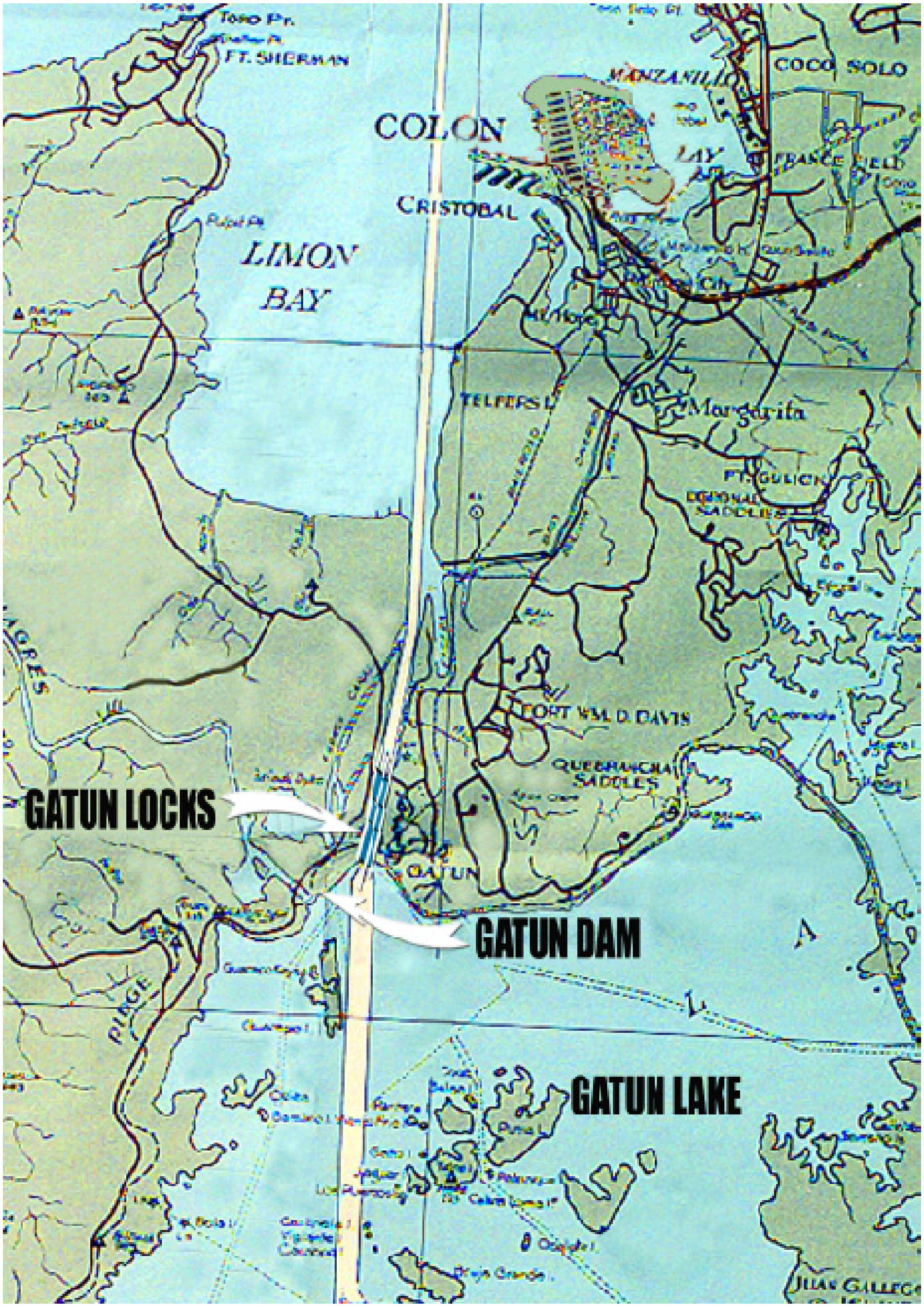


Plate 23 - 2 Existing Features Map

SECTION 24

Deepen Gatun Lake

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein would include deepening the existing channel depth 3 ft (0.91 m) from Gatun Locks through Gatun Lake and the Gaillard Cut to Pedro Miguel Locks.

The total project first cost of the proposed Deepen Gatun Lake project is estimated to be $200,661,000.

The proposed Deepen Gatun Lake project would contribute measurably to the hydrologic reliability of the Panama Canal to serve its customers. It would greatly reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. Construction of the proposed Lower Gatun Lake project would continue the existing high hydrologic reliability as demand for lockages increases up to 14.5 percent (5.62 lockages) above current demand levels.

Advantages and Difficulties

The development plan addressed herein would be the least disruptive to the existing lake system of any of the alternatives having to do with alteration of the existing channel and structures and would require no peripheral water supply reservoir construction. The deepening of the canal by 3 ft (0.91 m) through Gatun Lake and the Gaillard Cut to Pedro Miguel Locks would provide additional leeway in the operational range of water surface variation in Gatun Lake, the reservoir at the apex of the canal which supplies water for operation of the canal. This would allow for longer periods of operation without draft restrictions in extremely dry seasons.

Excavation of the deepened channel would require drilling and blasting to remove the rock to the revised channel template over much of the channel length. This would require that the shipping along the applicable portion of the channel be staged and managed while the drilling, blasting and rock material removal are being done. At least one continuous lane would be maintained open to shipping at all times with traffic suspended at the time of the blasting itself. This would result in productivity losses than would be the case were the work to be pursued without conflicts.

The removal of the excavated materials would be somewhat hampered also by the need to work around ongoing canal traffic. The barges hauling excavated materials to the disposal areas would have to time their passages to mesh with ship traffic to avoid delays and conflicts.

Hydrologic Considerations

The Panama Canal watershed has two distinct seasons, a dry season and a wet season. The dry season normally begins in mid December and lasts approximately 4 months. The remaining 8 months comprise the rainy season. Heaviest rains fall from the beginning of September to December. Average annual rainfall varies from 129.9 in (3,300 mm) along the Atlantic Coast to 63 in (1,600 mm) along the Pacific Coast. In the upper mountain ranges above the Madden Dam, average annual rainfall reaches almost 157.5 in (4,000 mm).

The Gatun and Madden Lakes provide storage for regulation and use of rainfall runoff during the dry seasons. They provide both navigation lockage water and raw water for M&I consumption. Gatun Lake also serves as the connector route for vessels transiting the Panama Canal. Therefore, during drought conditions, water is not only needed for water supply but also to insure sufficient navigation depth for ships. For this system, 85 years of hydrologic data and operational records are available.

Geologic Considerations

Two distinct geological zones underlie the proposed area for deepening the Panama Canal. These zones consist of the Gatun Lake area to the north, and the Central Divide area to the south.

The Gatun Lake zone includes the area between the Gatun Lake and Gamboa at the confluence of the canal with the Chagres River. The geologic bedrock underling this zone consists of the Oligocene aged Caimito, Bohio and Bas Obispo Formations, with minor occurrences of the Caraba and Gatuncillo Formations. The Caimito and Bohio Formations are sedimentary in origin and include rock types ranging from tuffaceous sandstones and siltstones to limestones and conglomerates. These sedimentary rocks are considered to be medium hard and excavateable with only limited use of explosives. The Bas Obispo Formation, however, is volcanic in origin and includes such rock types as agglomerate, tuff, basalt and andesite. These volcanic rocks are considered hard, generally requiring blasting for excavation.

The Central Divide zone is located between Gamboa and the Pedro Miguel Lock. The bedrock in this zone is divided into two sections by the Rio Limon fault, which is aligned north-south and is located approximately 2 km to the south of Gamboa. The geologic formations on the northwestern side of the fault are the same Oligocene formations found in the Gatun Lake zone, while southeast of the fault the formations are early Miocene. Five Miocene aged formations are represented in the Central Divide zone, as well as extrusive and intrusive (dikes and plugs) basalt. The represented formations include the Las Cascada Formation (agglomerate and tuff), the La Boca Formation (mudstone, siltstone, sandstone and tuff), the Culebra Formation (sandstone and siltstone), the Cucaracha Formation (clay shale or tuff), and the Pedro Miguel Formation (fine to coarse grained agglomerate). The clay shale of the Cucaracha Formation is soft to very soft, the sediments of the Las Cascada, La Boca and Culebra Formations are soft to medium hard, while the rocks of the Pedro Miguel Formation are generally medium hard to hard, and the basalts are generally very hard. The sediments of the Cucracha Formation have a well-known history of stability problems, whereas only small to moderate landslides have been noted in sediments of the Las Cascada, La Boca, and Culebra Formations. Moderate blasting is expected to be necessary for excavation of basalts and rock of the Pedro Miguel Formation, with little to no use of explosives necessary for excavation of the sediments of the other formations.

Lake Operation

Gatun Lake was planned in the early nineteen hundreds to be filled during the rainy season to elevation 85 ft (25.91 m) MSL for normal operations, with storage above this level to be reserved for flood control operations. The designs of the lock walls and gates were based on the assumption that the lake level would seldom be permitted to rise to more than elevation 87 ft (26.52 m) MSL, 2 ft (0.61 m) above normal operating levels.

The 1991 Panama Canal Flood Control Plan increased the maximum normal operating level of Gatun Lake to 87.5 ft (26.67 m) MSL. Currently, Gatun Lake flood storage lies between the maximum normal operating level and 92.0 ft (28.04 m) MSL. Raising the maximum operating lake level from elevation 85 ft (25.91 m) MSL to elevation 87.5 ft (26.67 m) MSL reduced the available flood storage capacity by approximately one-third.

The minimum lake elevation is dictated by allowable navigation draft for vessels passing through the canal. The current channel bottom is at elevation 37 ft (11.28 m) MSL yielding a 44.5 ft (13.56 m) channel depth with Gatun Lake at elevation 81.5 ft (25.91 m) MSL. This is the current lake level at which the canal authorities begin to impose draft restrictions on vessels traversing the canal. With Gatun Lake channel bottom lowered to elevation 34 ft (10.37 m) MSL, the currently provided full draft minimum channel depth of 44.5 ft (13.56 m) would be maintained with lake levels as low as elevation 78.5 ft (26.98 m) MSL. By lowering the channel bottom, the minimum operating pool levels for Gatun can be lowered an equivalent amount; thus, providing additional waters during dry periods without reducing the vessel draft requirements. An additional 362.9 MCM of storage provided by lowering the channel bottom from 37 to 34 ft (11.3 to 10.4m).

With Gatun Lake deepened according to the plan described above the lake operation scenario would not change except that the water surface could be allowed to fluctuate to lower levels than are now possible without affecting the draft and under keel clearance requirements of the vessels using the canal.

Project Features

GENERAL

No additional structures would be required for this proposed project. The existing structures have been reviewed for clearance restrictions. Details are presented in the following articles.

CHANNEL

The current overall channel width and minimum depth would be maintained in the deepened channel. It was assumed that this channel would be excavated to a template having a bottom width of 630 ft (192 m) in the straight reaches and 730 ft (223 m) in curves reaches. Side slopes of 1 horizontal on 3 vertical in rock and 1 horizontal on 1 vertical in softer overburden materials are maintained

Underwater drilling and blasting is extensively required in the Gaillard Cut and to a lesser extent in the Gamboa Reach. The remaining reach to Gatun Locks is lower than the new channel depth but maintenance dredging will be required in the outer edges. The materials removed would be transported by bottom dump barges and deposited in existing disposal areas of the lake.

LOCKS

In conjunction with this alternative, the upper lock sills at Gatun and Pedro Miguel would be lowered by approximately 0.33 ft (0.10 m). This would provide the same depth over these sills as will exist at the lower sill at Pedro Miguel Locks with the Miraflores operating level raised 1 ft (0.30 m), as is the practice now when required to accommodate deeper draft vessels.

The upper gate miter sills at Pedro Miguel and Gatun Locks are at elevation 37.33 ft (11.38 m) MSL yielding a water depth over the sill of only 41.17 ft (12.55 m) with Gatun Lake at elevation 78.5 ft (26.98 m) MSL, the minimum operating channel depth noted above.
The lower sill at Pedro Miguel Locks is at elevation +13 ft (+3.96 m) MSL, yielding a water depth over the lower miter gate sill of only 40.5 ft (12.34 m) with Miraflores Lake at 53.5 ft (16.31 m) MSL. With the water level in Miraflores Lake allowed to rise to elevation 54.5 ft (16.61 m) MSL the depth over the lower sill would be only 41.5 ft (12.65 m).

This indicates that the minimum clearance under current operating procedures would be at the upper miter gate sill. Using the maximum allowable draft of 39.5 ft (12.04 m) the under keel clearance at that point would be 1.67 ft (0.51 m). Under current operating procedures, the minimum under keel clearance is at the lower end of Pedro Miguel Locks and equals 2 ft (0.61 m). Therefore, in order to bring the revised operating condition, with the channel deepened, into agreement with the currently used minimum clearance, the upper miter gate sills at Pedro Miguel and Gatun Locks would have to be lowered approximately 0.33 ft (0.10 m) with matching extensions to the bottom seals on the miter gates. This would require that the miter blocks be removed and lowered to accommodate the lower seal elevation. This, and the concrete removal to precise elevation would require that the lock chambers be dewatered for the time required to modify the sills and install the extensions to the gates.

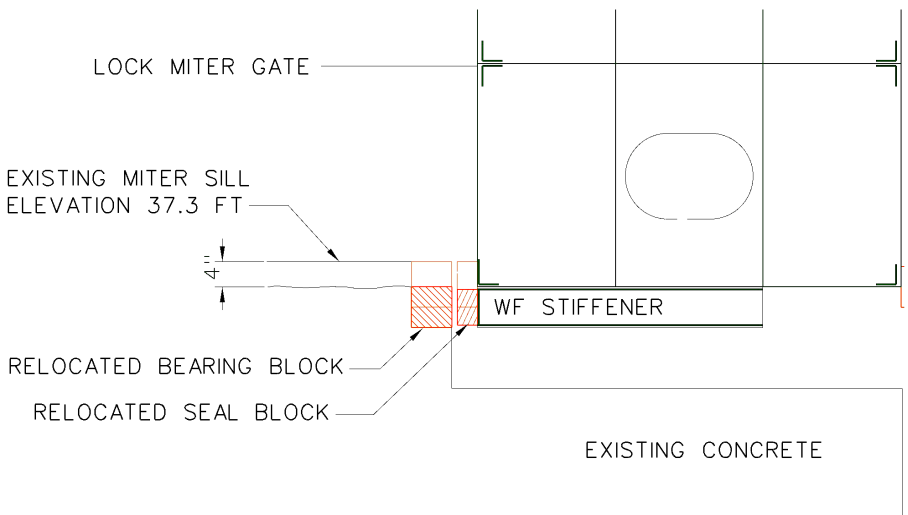


Figure 24 - 1 Typical Lock Gate Sill Lowering Detail

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed for its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising, and award phase. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Socio-economic programs would begin shortly before dredging began. Because this alternative involves only PCC property and facilities, the socio-economic efforts involved are assumed to be minor.

Construction would begin with the mechanical dredging of those portions of the channel requiring removal of softer overburden materials. At the same time the areas requiring drilling and blasting to remove rock materials already exposed in the existing channel bottom would be started. This work would be hampered by the requirement that navigation be delayed to the least extent possible. It was assumed that the channel would be required to be maintained fully open for approximately 12 hours per day with one lane open at all times, and that the drilling and blasting be timed to minimize interruption of traffic during construction hours.

Considering the climatic conditions, the type and scope of construction, and the necessity of keeping the canal open and fully functional the maximum time possible, it is estimated that development of this project could be completed in approximately 8.5 years, from initial planning to lake filling. The development sequence is shown in Figure 24 – 2.

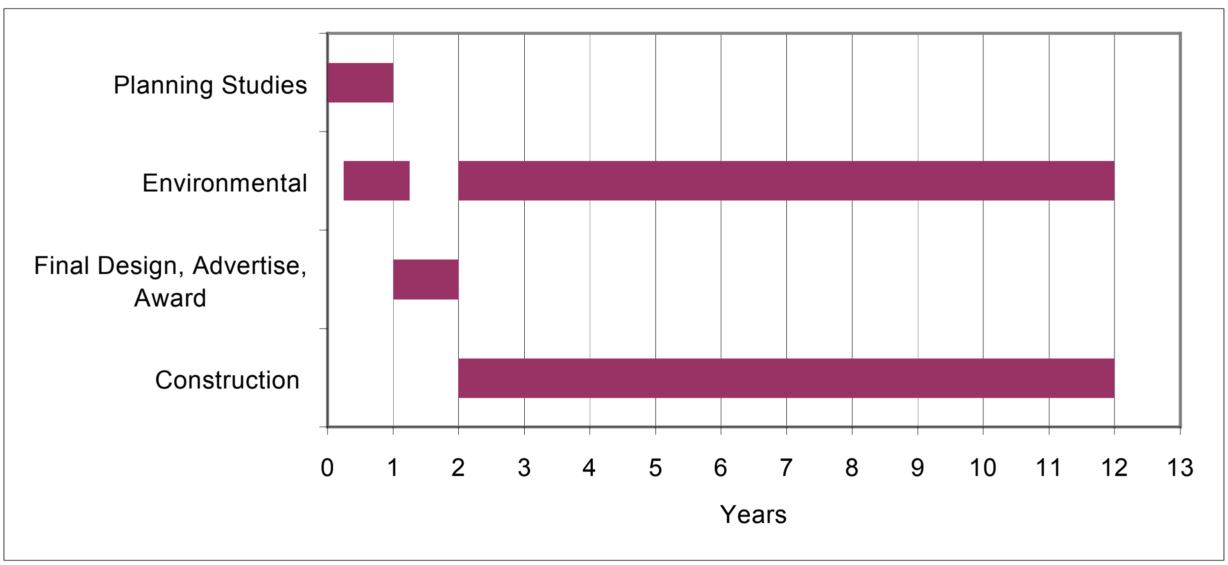


Figure 24 - 2   Development Sequence

Hydrologic Reliability

Deepening Gatun Lake by 3 ft would increase the operating range of the lake by allowing the minimum lake elevation to drop to 78.5 ft (23.93 m) MSL. In order to determine the effect of the proposed alternative on the hydrologic reliability of the Panama Canal, the lake was evaluated with the existing HEC-5 model of the Panama Canal, applying historic hydrology and imposing the alternative levels.

HEC-5 model simulations were conducted for the existing canal system and the system operating with the proposed new lake levels. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record. Figure 24 - 3 presents the resulting hydrologic reliability for the existing operating lake levels and the proposed new lake levels. Demands are increased up to 180 percent of current demands.

The horizontal axis along the bottom of Figure 24 - 3 reflects demands as a ratio of the five-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 24 - 3, the existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability with a demand ratio of 1.0 would be 99.95 percent for the Deepen Gatun alternative, and the hydrologic reliability with a demand ratio of 1.8 would be 89.51 percent. Table 24 - 3 displays the number of lockages associated with various levels of reliability.

With the construction of the proposed Deepen Gatun Lake project, the existing high hydrologic reliability could be continued as demand for lockages increases up to 14.5 percent above current demand levels. If one lockage is equal to 55 million gallons, this equates to 5.62 lockages.

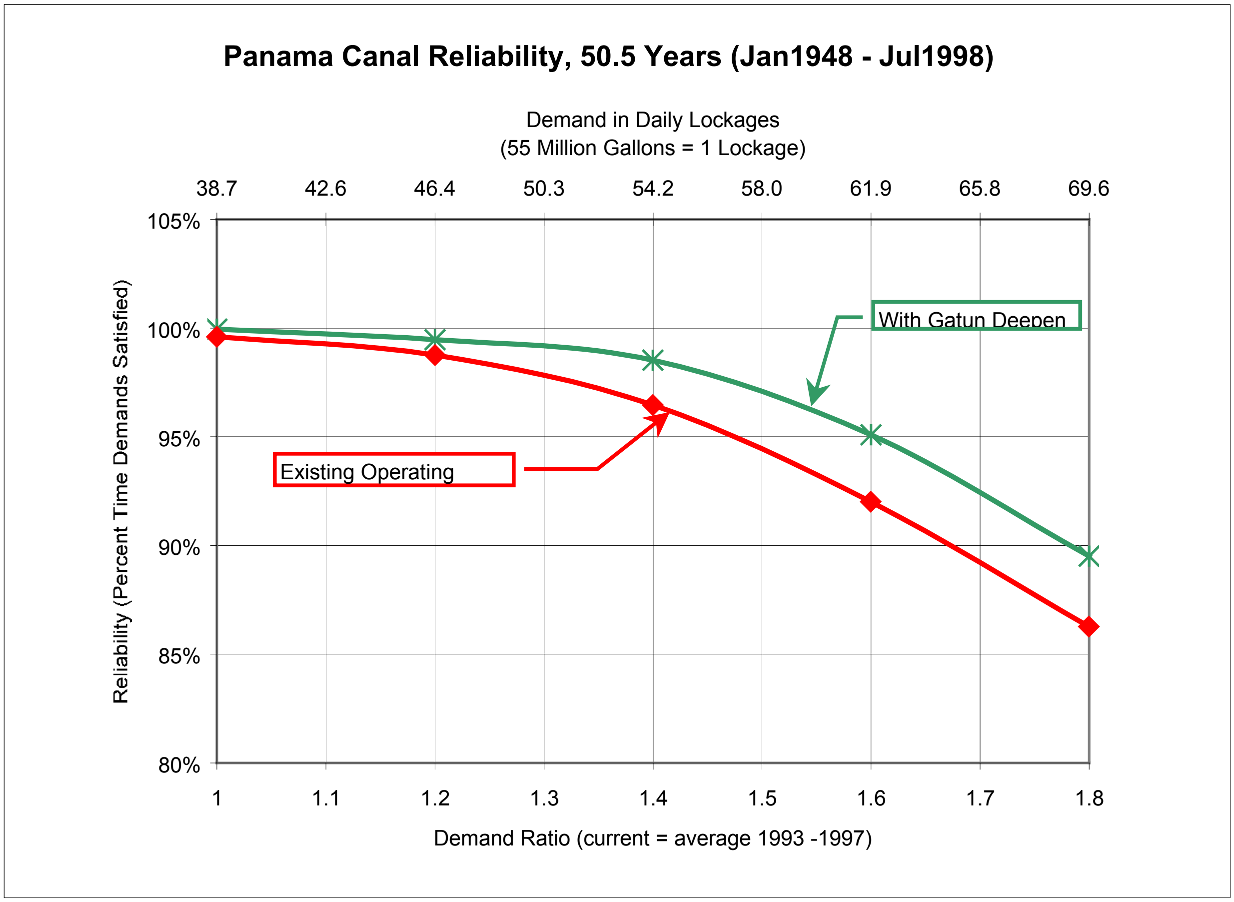


Figure 24 - 3   Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layout shown on Plate 24 - 1. The unit prices applied to these quantities were based on: historical information from previous estimates prepared for similar construction in the Republic of Panama, previous estimates for similar construction in the Southeastern United States, information gathered from U.S. Army Corps of Engineers, Mobile District, Construction Division personnel in the Republic of Panama, and the publication, Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, prepared by the U.S. Army Corps of Engineers, Hydrologic Engineering Center, 1979.

Engineering and design is estimated to be 12 percent and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). An allowance of 15 percent was included for contingencies. A 15 percent contingency was applied in this case since current unit costs and very good quantity estimates were available from the in-progress channel widening. It was assumed that a 25 percent contingency would be too conservative and would penalize this alternative in relationship to all other alternatives. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $200,661,000. Table 24 - 1 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 24 - 1 Summary of Project First Costs

Principal Feature	Costs ($)
Deepen Gatun Lake Channel	144,194,757
Lower Upper Lock Sills	238,900
Remove and Replace Concrete Floor	972,690
Subtotal	145,406,347
E&D, S&A, Field Overhead	29,081,269
Contingencies	26,173,142
Total Project First Costs	200,660,759 **approximately** 200,661,000

OPERATION AND MAINTENANCE

It is possible that the current operation and maintenance costs of the Gatun Lake channel and the Gaillard Cut channel would increase with the proposed deepening. Since these costs would be minimal at the most, they were not estimated.

Annual Costs

The total project first costs are estimated to be $200,661,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the total project first costs was computed from mid-year throughout the 8.5-year period from initiation of the Planning Studies until the channels are deepened. The interest during construction at 12 percent would be $105,105,000 and it was added to the total project first costs for total project investment costs of $305,766,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $36,819,000. Table 24 - 2 contains a summary of the annual costs.

Table 24 - 2 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	200,661,000
Interest During Construction	105,105,000
Total Project Investment Costs	305,766,000
Annual Average Investment Costs	36,819,000
Operation and Maintenance Costs	
Staff Costs	Not estimated
Ordinary Maintenance Costs	Not estimated
Major Replacement Costs	Not estimated
Total Average Annual Costs	36,819,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Section 4. The following paragraphs present the results of the economic investigations for the proposed Deepen Gatun Lake project. The 50-year planning period for this proposal is 2010 to 2060.

The proposed Deepen Gatun Lake project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 24 - 3 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages were obtained from the data used to develop Figure 24 - 3.

Table 24 - 3 Panama Canal Hydrologic Reliability

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Gatun Lake Deepened [1/] (%)
1	2000	38.68 [2/]	99.60	99.95
	2009	44.30	98.99	99.60
	2010	45.11	98.91	99.55
	2012	46.40	98.80	99.50
1.2		46.42	98.76	99.47
	2020	47.61	98.41	99.32
	2030	49.55	97.83	99.08
	2040	52.02	97.09	98.78
1.4		54.15	96.45	98.52
	2050	55.13	95.89	98.08
	2060	59.05	93.65	96.35
	2063	60.44	92.85	95.73
1.6		61.89	92.02	95.09
	2070	63.97	90.47	93.59
1.8		69.63	86.27	89.51

[1/] Gatun Lake channel bottom lowered to elevation 34 ft (10.37 m) MSL

[2/] 2000 Daily Demand is Average of 1993-1997

With the Gatun Lake channel and the Gaillard Cut lowered, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands increase, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Deepen Gatun Lake project, these shortages would be less than they would be under the existing system. With a hydrologic reliability of 99.6 percent, the proposed project would increase the amount of water supplied for navigation by approximately 5.62 equivalent lockages. The 99.6 percent hydrologic reliability would occur in the year 2009 with an equivalent daily average number of lockages set to 44.30. Benefits for this amount of additional water would be attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages provided by each option. The average annual benefits for water supply would be $114,168,000. Table 24 - 4 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Gatun Lake project in operation, the annual benefits for meeting shortages and the average annual benefits for both options.

Table 24 - 4 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits ($)
2010	6.43	0.81	109,760,000
2020	8.93	3.31	115,882,000
2030	10.87	5.25	115,882,000
2040	13.34	7.72	115,882,000
2050	16.45	10.83	115,882,000
2060	20.36	14.75	115,882,000
Average Annual Benefits			114,168,000
With the Deepen Gatun Lake alternative, the system will provide a total of 44.30 equivalent lockages at the 99.6 percent level of reliability or 5.62 more lockages than the existing system.			

With either operating option, the reliability of the system to provide all of the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Deepen Gatun Lake project would be $7,269,000. Table 24 - 5 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits for each operating option.

Table 24 - 5 Average Annual Reliability Benefits for Navigation

Year	Daily Average Number of Lockages	Value Per Daily Lockage ($)	Annual Navigation Benefits ($)
2010	38.98	2,086,300	4,900,000
2020	40.0	2,260,000	7,532,000
2030	40.0	2,260,000	10,344,000
2040	40.0	2,260,000	13,918,000
2050	40.0	2,260,000	18,059,000
2060	40.0	2,260,000	22,293,000
Average Annual Benefits			7,269,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was based upon the growth in population. The PCC provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day. An equivalent lockage is 55 millions gallons of water. One equivalent lockage was added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Deepen Gatun Lake project, the current costs to the PCC to process finished water of

$0.69 per 1,000 gallons, the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability would be $988,000. Table 24 – 6 displays the population forecast, the resulting number of equivalent lockages demanded per day, the annual benefits for increased reliability, and the average annual benefits for M&I water supply.

Table 24 – 6 Average Annual Reliability Benefits for M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2010	1,724,000	6.13	457,000
2020	2,141,000	7.6	963,000
2030	2,688,000	9.6	1,661,000
2040	3,384,000	12.0	2,808,000
2050	4,259,000	15.1	4,587,000
2060	5,360,000	19.0	7,132,000
Average Annual Benefits			988,000
The value of a daily lockage for M&I is $0.69 X 55,000 = $37,950			

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Deepen Gatun Lake project, the system would loose net additional megawatt hours of hydropower. The loss can be attributed to using more water for navigation with some loss of head differential. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, the negative benefits would be $606,000. Table 24 - 7 provides the net lost megawatt hours of hydropower generation and the resulting negative annual and negative average annual benefits.

Table 24 - 7 Average Annual Benefits for Hydropower Generation

Year	Net Lost Generation [1/] (MWh)	Annual Hydropower Benefits ($)
2010	(7,124)	(499,000)
2020	(8,824)	(618,000)
2030	(10,472)	(733,000)
2040	(12,565)	(880,000)
2050	(15,572)	(1,090,000)
2060	(20,376)	(1,426,000)
Average Annual Benefits		(606,000)
[1/] Net generation of Gatun, and Madden hydropower plants with Gatun Lake deepened versus generation of Gatun and Madden hydropower plants.		

SUMMARY OF ANNUAL BENEFITS

As shown in Table 24 - 8, total average annual benefits for the proposed Deepen Gatun Lake project would be $121,819,000.

Table 24 - 8 Summary of Annual Benefits

Benefit Category	Average Annual Benefits
Navigation – Water Supply	114,168,000
Navigation – Reliability	7,269,000
M&I - Reliability	988,000
Hydropower	(606,000)
Total	121,819,000

Once average annual benefits and costs are estimated, the ratio of benefits to costs and the net benefits (net of costs) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. Table 24 - 9 provides the benefit to cost ratio for and the net benefits for the proposed Deepen Gatun Lake project.

Table 24 - 9 Economic Evaluation

Item	Value ($)
Average Annual Benefits	121,819,000
Average Annual Costs	36,819,000
Benefit to Cost Ratio	3.3
Net Benefits	85,000,000

Internal Rate of Return

An internal rate of return analysis for each operating option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. The internal rate of return would be 26.2 percent.

Socio-Economic Impacts

The socio-economic impacts of the project will be minimal due to the nature of this project. The deepening of the navigation channel should not impact local residents in the Gatun Lake region. The average monthly income is between $200 and $300. No indigenous groups of people are known to reside in the impact region. Land-use in this area should not be impacted by the project. Towns exist at some distance from Gatun Lake therefore, noise levels will not impact the community.

Environmental Setting

The Deepen Gatun Lake alternative will include deepening the existing channel depth by 3 ft (0.91 m) from Gatun Locks through Gatun Lake and the Gaillard Cut to Pedro Miguel Locks. Currently the maximum operating elevation for Gatun Lake is elevation 87.5 ft (26.67 m) MSL. Excavation of the deepened channel will require drilling and blasting to remove the rock to the revised channel template over much of the channel length. No additional structures will be required for this proposed project. The existing structures have been reviewed for clearance restrictions. Private docks and marine facilities along current waters edge could be impacted.

LAND USE

The Deepen Gatun Lake project will deepen the existing lake by about 3 ft (0.91 m) from Gatun Locks, through Gatun Lake and the Gaillard Cut, to Pedro Miguel Locks. Some of the towns are using water from Gatun Lake for M&I and agricultural uses. The lake is also used for fishing, bathing, and transportation. Individual residencies along the shores of Gatun Lake were constructed either of forest materials or concrete.

Some areas along the shores of Gatun Lake have been deforested. Approximately 65 percent of the lake shore areas are forested mostly with secondary growth. The remaining land is occupied by farms and ranches of various sizes ranging from commercial cash crop enterprises to subsistence farming and by activities associated with the operation and maintenance of the canal. Farm crops include maize, rice, beans, sugar, coffee, tobacco, and teak tree plantations. Ranchers raise cows, horses, chickens, and hogs.

Significant erosion caused by wave action induced by ships was observed along the shores of narrow passageways, peninsulas, and islands in Gatun Lake. The soils eroding into the lake will increase turbidity, reduce light penetration, and decrease channel depth as the deposited materials accumulate. There are no significant mineral resources or deposits along Gatun Lake.

INFRASTRUCTURE

Towns along Gatun Lake have cemeteries, churches, and medical centers. Potable water is obtained from Gatun Lake or from groundwater wells. Some homes have electricity and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it might reach Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners: each home has an outdoor latrine (a hole in the ground). There are some known health problems such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illness attributable to these waste disposal methods. The main industry in the project area is shipping traffic on the canal. No major poultry or beef processing plants are located in the project area. The only roads in the project area are dirt roads, which are used as maintenance access by the PCC. The roads are maintained well by the PCC.

TERRESTRIAL HABITAT

The terrestrial habitat surrounding Gatun Lake consists of tropical forest ecosystems with large areas of secondary growth forests and patches of primary forest. Approximately 65 percent of the Gatun Lake project area is forested. The lake contains islands inhabited by wildlife communities. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Barro Colorado Island, which was created through the formation of Gatun Lake, is used by scientists as a tropical laboratory to study tropical ecosystems. Slash and burn activities have opened tracts of land for farming and cattle grazing; however, the majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding habitat. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities. This area may provide critical wildlife habitat to many native species.

ANIMALS ON ENDANGERED LIST

ANAM by its Resolution 002-80 on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although none have been determined, some or all of the listed species may occur in the project area.

AQUATIC HABITAT

Gatun Lake is one of the largest man-made lakes in the world and contains many different types of aquatic habitat with various water depths and a wide range of water quality. Inundated forests created during construction of the canal are one such habitat. There are high traffic shipping lanes and various submerged topographical features. Water quality ranges from high turbidity in the shipping lanes to clear in areas distant from the shipping lanes. Gatun Lake provides habitat for a variety of wildlife species both resident and migratory, as well as for both native and introduced fish and other aquatic species.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. Wetlands in the Gatun Lake project area are shallow water habitat areas and areas that experience frequent flooding. Shallow water areas along the banks of Gatun Lake receive sunlight to approximately 3 ft in depth, depending on water clarity. Sunlight stimulates growth of plants in the form of submerged, emergent, or floating aquatic mats of vegetation, which extent out from the banks and into the deeper aquatic habitats. Wetlands occur in topographic areas where water pools long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the project area are stressed by wave action from passing ships and runoff from slash and burn areas.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season, in March or early April, tracts of forests or secondary growth are burned and cleared to prepare the land for agricultural use. During this period the air is filled with smoke and ash, which may be transported by wind to Gatun Lake. Air quality monitoring has not yet been implemented within the project area. The natural environment could provide indicators of air quality that could be useful in evaluating air quality.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research. It is one of the first biological reserves established in the Neotropics. From 1923 through 1940, the biological reserve / laboratory was administered by a scientific committee of the National Academy of Sciences. In 1940, an Act of the United States Congress renamed the facility the Panama Canal Zone Biological Area and in 1946 gave the responsibility for maintaining the facility to the Smithsonian Institution. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in the Gatun Lake project area will be minimal, since most of the project activity will be confined to the waters of Gatun Lake. Disposal methods and location of excavated materials will determine the potential impacts to terrestrial habitats. The forests around Gatun Lake should remain undisturbed; however, the amount of forested areas continues to be reduced by local slash and burn practices.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered species cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Furthermore, the significance of the natural environmental features in this area may increase if species on the endangered list are found in the region. Some endangered and / or threatened species may use Gatun Lake for some or all parts of their life cycle.

WATER QUANTITY

The impacts of the project on water quantity should be beneficial, because the deepening of Gatun Lake will increase the volume of stored freshwater, which should reduce the need for navigational restrictions in the canal during the dry season.

WATER QUALITY

The impacts of the project on water quality are unknown. Excavating materials from the bottom of Gatun Lake could release pollutants into the water, causing detrimental impacts on aquatic and other wildlife species. The implementation of the project will cause a temporary increase in turbidity and interfere with photosynthesis in the impacted areas. The increase in turbidity could deprive plants and other aquatic species from the necessary sunlight. These impacts should be temporary, and water quality is expected to return to its pre-project condition.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial in some areas of Gatun Lake. The blasting could cause the benthic organisms to be covered with rock and sediment. The excavated material will be placed in existing disposal areas within Gatun Lake. Project implementation may impact the successful breeding and the nursery habitat of many juvenile aquatic species. Fish spawning areas may be impacted when turbidity suddenly increases. Plant populations may decrease as a result of a decrease in available sunlight; therefore, invertebrate populations may decrease which will reduce the food supply for fish and other aquatic species. No information is available about currents in Gatun Lake; therefore, it is not possible that sediment and other debris resulting from project implementation could spread beyond anticipated boundaries.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities depend on water quality and stable water levels. Aquatic plant communities will be temporarily impacted during project implementation, however these communities should re-establish themselves when conditions return to their previous state. The present condition of the aquatic plant community in Gatun Lake is expected to return to its original condition after project implementation.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting Gatun Lake and the affected areas could be important. Some unavoidable, adverse environmental impacts could occur, these impacts should be identified, and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. Gatun Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

WETLANDS

The impacts to wetlands will be minimal, since the excavated material will be placed in existing disposal areas within Gatun Lake.

AIR QUALITY

During project implementation, emissions from equipment will impact air quality in the project area. After project implementation, the air quality should return to its former condition.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The deepening of the existing channel should not impact the aquatic life along the shores of Barro Colorado Island. The potential impacts on cultural resources and historic properties can not be defined and mitigated. Prior to project implementation, surveys to locate cultural resource and historic properties will be conducted and the important sites will be preserved or salvaged as appropriate.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Deepen Gatun Lake alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an SIA. The SIA will consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities.
  - Employment.
  - Land Use.
  - Property Values.
  - Public and Community Facilities and Services (including utilities and schools).
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population.
  - Community Cohesion.
  - Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major types of terrestrial and aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique habitat features, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migratory flyways.
- Determine the present quality and ecosystem value of existing habitats within the project area.
- Collect samples from the bottom of Gatun Lake to determine if there are pollutants that could be released during project implementation.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Provide species inventory lists for each site area identifying their status as native or exotic and whether they are threatened and or endangered species.
- Impacts to the shallow areas along Barro Colorado Island will require additional research into water currents and estimated turbidity levels.
- Address cumulative effects of maintaining the depth of Gatun Lake.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and / or threatened species list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts to identify endangered species habitat.

WATER QUALITY

- As there are no water quality data available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Information regarding cultural resources and historic properties is incomplete. Additional evaluation studies need to be completed to identify cultural resources and historic properties.

Evaluation Matrices

In accordance with evaluation procedures described in Section 4, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Section 35. Tables 24 - 10 through 24 - 12 present the evaluation of the proposed Deepen Gatun Lake project as related to developmental effects, environmental effects, and socio-economic effects.

Table 24 - 10 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I demands	7	10	70
	Supplements Existing System	0	10	0
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	7	6	42
	Feasibility of Concept	7	6	42
Operational Issues	Compatibility	9	6	54
	Maintenance Requirements	10	2	20
	Operational resources required	10	2	20
Economic feasibility	Net Benefits	2	9	18
	Total			266

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 24 - 11 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	5	8	40
Animals on Extinction List	5	10	50
Water Quantity Impacts – Lake	9	10	90
Water Quantity Impacts – Downstream	5	7	35
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	5	8	40
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	5	6	30
Wetlands	5	4	20
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			488

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 24 - 12 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	2	7	14
Relocation of People	2	10	20
Relocation of Agricultural/Ranching Activities	2	6	12
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	4	5	20
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	4	5	20
Traffic Volumes over New Roadway System Post-Construction	7	5	35
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	4	8	32
Community Cohesion	2	8	16
Tourism	6	5	30
Total			367

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

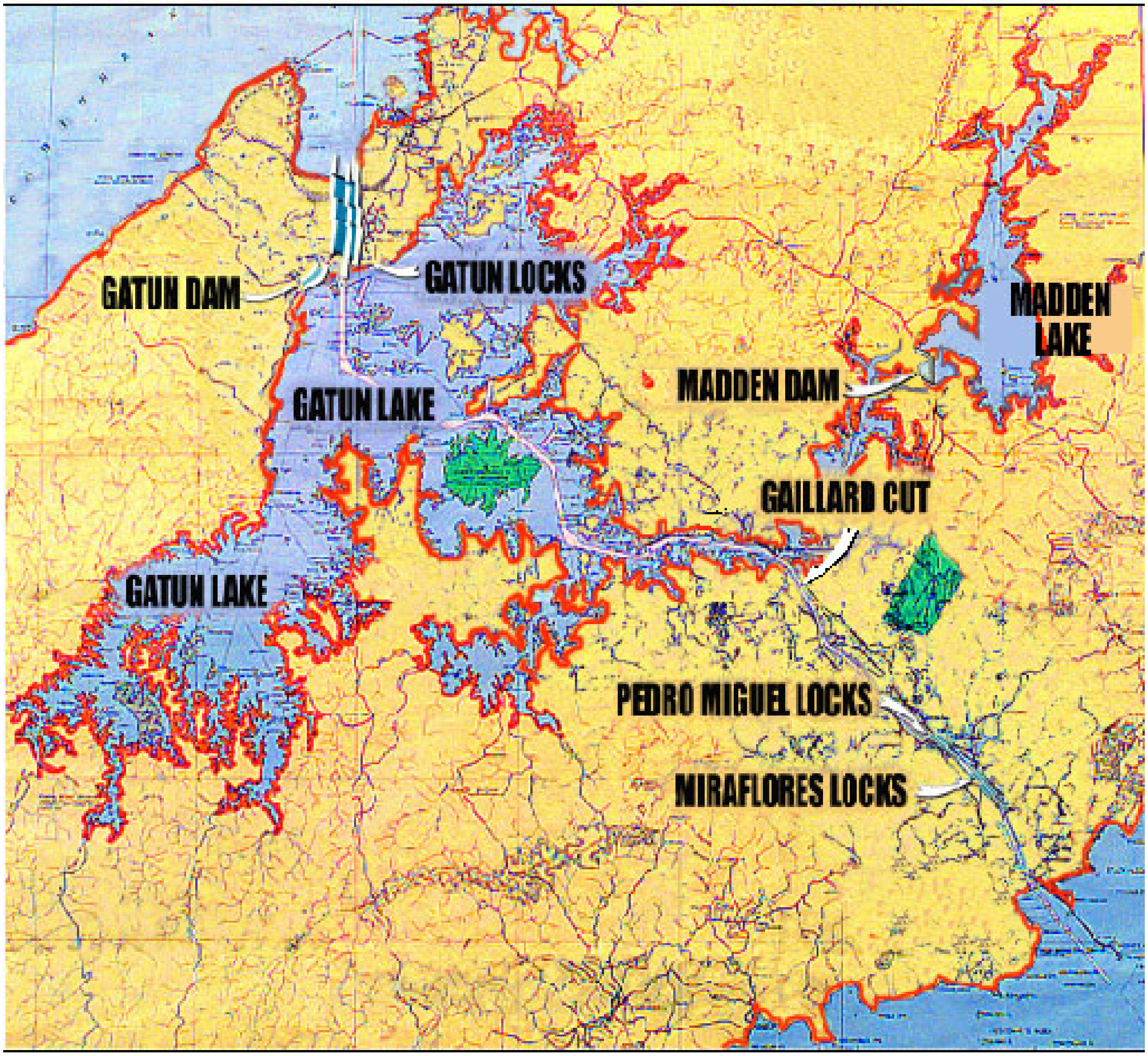
Pertinent Data

Table 24 - 13 presents pertinent data for both operating options of the proposed Deepen Gatun Lake project.

Table 24 - 13 Pertinent Data

GENERAL	
Drainage area above dam site	1,289.0 sq mi (3,338.5 km^2)
Average annual flow at dam site	882.87 CFS (25 CMS)
LAKE	
Elevation of normal operating lake level	87.5 ft (26.67 m) MSL
Elevation of maximum flood lake level	91.5 ft (27.89 m) MSL
Elevation of minimum operating lake level	78.5 ft (23.93 m) MSL
GATED SPILLWAY	
Total length	807.96 ft (246.27 m)
Net Length	630 ft (192.02 m)
Elevation of Crest	69 ft (21.03 m) MSL
Number of Gates	14
Overall length of dam	2,923.23 ft (891 m)
Type of Spillway	Gated
Maximum discharge	32,489.49 CFS (920 CMS)
GATUN LOCKS	
Nominal Size of Chambers	110 x 1,000 ft (33.53 x 304.8 m)
Upper Caisson Sill, Elevation	28.0 ft (8.53 m) MSL
Emergency Dam Sill Elevation	37.3 ft (11.37 m) MSL
Upper Guard Gate Sill Elevation	37.3 ft (11.37 m) MSL
Upper Chamber Intermediate Sill Elevation	15.0 ft (4.57 m) MSL
PEDRO MIGUEL LOCKS	
Nominal Size of Chambers	110 x 1,000 ft (33.53 x 304.8 m)
Upper Caisson Sill, Elevation	28.0 ft (8.53 m) MSL
Emergency Dam Sill Elevation	37.3 ft (11.37 m) MSL
Upper Guard Gate Sill Elevation	37.3 ft (11.37 m) MSL
Upper Chamber Intermediate Sill Elevation	15.0 ft (4.57 m) MSL

DEEPEN GATUN LAKE



Project Location Map

Plate 24 - 1   Project Location Map

SECTION 25

Raise Madden Lake

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

Madden Dam is located on the Rio Chagres approximately 800 m above the original site of the Village of Alhajuela. The dam is located approximately 19.3 km upstream from the Panama Canal and 40.2 km from Panama City. It consists of a concrete gravity dam including an overflow spillway section across the original river channel flanked by mass concrete non-overflow dam sections. These non-overflow sections extend to the canyon walls and the dam is continued north and south by earth and rock fill embankments with reinforced concrete cores or facings. The concrete gravity dam is 975 ft (297 m) long between the abutments and is 220 ft (67.1 m) at maximum height, with the foundation at elevation 49.2 ft (15 m) MSL. The dam and spillway contain four drum gates, each one 100 ft (30.5 m) long, 6 low-level sluiceways and 2 pipe outlets with needle valves.

Each drum gate is a steel structure, roughly triangular in cross-section. Each is anchored and hinged at its upstream corner to the concrete dam. The drum gates are raised and lowered using water pressure to control the water level of Madden Lake.

The present maximum operating lake elevation of Madden Lake is 252 ft (76.8 m) MSL. The two options considered for the Raise Madden Lake alternative would result in revised maximum operating lake elevations of 254 ft (77.4 m) MSL for Operating Option 1 and 256 ft (78.0 m) MSL for Operating Option 2. Both operating options would decrease the available flood storage in Madden Lake. The existing spillway capacity appears to be sufficient to pass the spillway design flow under Option 1 or Option 2. The Madden Lake drainage area is 396 mi^2 (1,026 km^2). The lake surface area is 12,400 acres (50.2 km^2) at elevation 252 ft (76.8 m) MSL. Available active storage of Madden Lake between elevations 190 and 252 ft (57.9 and 76.8 m) MSL is 529,000 AF (651 MCM). Storage below 190 ft (57.91 m) MSL is reserved for the Republic of Panama M&I use.

The proposed Raise Madden Lake alternatives, either Operating Option 1 or 2, would contribute to the hydrologic reliability of the Panama Canal to serve its customers and would reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.2 (46.42 lockages) would be 98.8 percent. By raising the maximum normal operating pool elevation of Madden Lake by 0.6 and 1.2 m for Options 1 and 2 respectively, the existing high hydrologic reliability could be continued as demand for lockages increases up to 2.5 percent (0.97 lockages) above current demand levels with Option 1, and up to 3.2 percent (1.24 lockages) above current demands with Option 2. The total project construction first costs of the proposed raising of Madden Lake are estimated to be $625,000 for Option 1 and $730,000 for Option 2, assuming no major structure modification or strengthening measures would be required.

The amount of hydropower that could be produced by the hydropower plants in the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water increase. By raising Madden Lake as indicated, some loss of power could be experienced because of operational changes taking advantage of the additional storage.

Certain investigations beyond the scope of this reconnaissance level study would be required before the options under consideration here could be implemented. It must be ascertained whether or not the existing gate anchorages, attachments, and structural components are capable of operating reliably and with a sufficient margin of safety with the operating water level raised, and if not, a means must be developed to strengthen these elements. A design must also be developed for physically increasing the height of the gates while not overstressing the existing gate members, and providing for smooth hydraulic flow over the top of each gate when it is in the closed position. The spillway and non-overflow dam must be investigated for structural stability and integrity considering the new maximum operating pool level(s). The cost of these additional investigations and design efforts should be on the order of approximately $100,000 provided that no rigorous seismic dynamic analysis is required. The total project first costs including these studies would be on the order of $625,000 for Option 1 and $730,000 for Option 2, provided that no other structural modifications result from the in-depth studies.

Since some advantage to navigation would accrue from the Raise Madden Lake alternative it is recommended that it be carried forward for engineering feasibility level study. It is further recommended that the feasibility study should include, but not be limited to, the additional investigations outlined in this report.

Current Conditions and Study Objective

The current normal operating scenario at Madden Lake allows the pool to fluctuate from a maximum normal pool elevation of 252 ft (76.81 m) MSL down to a low of 190 ft (57.91 m) MSL. High water levels above this maximum put the existing structures and embankments in jeopardy to increasing degrees as the water level rises in times of flooding. The original upper operating pool limit was set at elevation 240 ft (73.15 m) MSL during the rainy season, and was raised over the years to meet the higher demands for hydropower and lockage water to current maximum elevation of 252 ft (76.81 m) MSL. As a result, the amount of flood storage at Madden Lake has been reduced by 140,300 AF (173 MCM). The 1991 Panama Canal Flood Control Plan established a maximum permissible operating level for Madden Lake at 255 ft (77.72 m) MSL and states that this level should only be exceeded temporarily due to extreme floods. The forfeited flood storage at Madden Lake between elevations 252 ft (76.81m) MSL and 255 ft (77.72 m) MSL is 38,100 AF (47 MCM), leaving a net available flood storage above the current maximum operating pool level of approximately 102,200 AF (126 MCM). Increases of 2 or 4 ft (0.6 or 1.2 m) in the maximum normal operating level of Madden Lake would increase conservation storage by 25,100 and 51,100 AF (31 and 63 MCM) respectively, but further decreases flood storage by these same amounts.

The objective of this study is to develop a plan to increase the time during the driest years over which the full draft could be maintained through Gatun Lake and Gatun and Pedro Miguel Locks by reallocating storage in Madden Lake so more water would be available during the dry season for lockages. The most desirable revised pool level would provide these advantages while causing the least impact on existing facilities and require the least in added facilities. The existing operating facilities and the impacts expected on each and the new construction required by the higher pool levels are summarized below under Project Features.

Hydrologic Considerations

Madden Dam was planned in the 1930s to be filled to elevation 240 ft (73.15 m) MSL during the rainy season, with storage to be used for power generation and navigational water supply during the dry season. Available storage above elevation 240 ft (73.15 m) MSL would be used for flood control during the rainy season. With increases in both number and size of vessels using the Panama Canal, the need for greater navigational water supply became evident. In response to this need, Madden Lake was allowed to fill to higher levels. Extensions were added to the tops of the drum gates in the 1960s, raising the weir control from elevation 250 ft (76.20 m) MSL to elevation 252 ft (76.81 m) MSL. During the rainy season, the lake is allowed to fill to between elevations 250 and 256 ft (76.2 and 78.0 m) MSL with water flowing over the tops of the drum gates at levels above 252 ft (76.81 m) MSL. After the first of November each year, the lake is maintained between elevations 252 and 258 ft (76.81 and 78.64 m) MSL, except during periods of major flooding. When the floods come, the discharge from the spillway is limited to 50,000 CFS (1,416 CMS) until the lake level reaches elevation 260 ft (79.25 m) MSL. For elevations above 260 ft (79.25 m) MSL, emergency flood procedures are implemented allowing flows to exceed 50,000 CFS (1,416 CMS). After the first of December each year, the lake is permitted to fill to elevation 256 ft (78.03 m) MSL by allowing extended free flow over the tops of the fully raised drum gates.

Spillway Design Flow

The U.S. Army Corps of Engineers design standards indicate that the overall flood control system at Madden Lake should pass the Probable Maximum Flood (PMF) Hydrograph. See Guidelines for Safety Inspection of Dams, U.S. Army Corps of Engineers, 1974.

The PMF flood is estimated and routed through the Madden and Gatun watersheds by the U.S. Army Corps of Engineers in 1979. The simulation package HEC-1 was used to compute the routed flows and lake elevations. As the PMF is the ultimate hydrologic design criteria with no additional safety factor applicable, it is normally assumed that a previous storm has filled the lakes to full pool, i.e., storage for normal operations and normal flood control is filled, at the beginning of the PMF. Madden Lake was assumed to be at elevation 254 ft (77.42 m) MSL and held at that elevation until the spillway flow reached 150,000 CFS (4,248 CMS). As a result of this operating scenario, it was found that the peak inflow into Madden Lake was 451,100 CFS (12,771 CMS) and the peak outflow was 257,000 CFS (7,277 CMS). Using the operating procedures described above, the computed peak pool elevation at Madden Lake was 263 ft (80.16 m) MSL. The 1979 studies by the U.S. Army Corps of Engineers indicated the spillway has sufficient capacity to pass the PMF with the lake level starting at even higher levels. The HEC-1 model was also developed for this current study to evaluate the passing of the PMF with the higher operating pool levels. With Madden Lake starting at elevation 256 ft (78.03 m) MSL under Operating Option 1, and elevation 258 ft (78.64 m) MSL under Operating Option 2, the maximum water surface elevations predicted by the PMF routings are shown in Table 25 - 1. These computations included spilling through the existing Madden Spillway and the sluiceways and needle valves during the extreme flood (PMF) condition. The capacity of the existing spillway was found to be sufficient for all levels of inflow to Madden Lake investigated.

Lake Operation

Under the revised operating procedure, the maximum normal pool elevation would be raised to 254 ft (77.42 m) MSL for Option 1 and to 256 ft (78.03 m) MSL for Option 2. This change to the operating scenario at Madden Lake would result in higher frequency of high water events requiring operational response, and would have some degree of detrimental effects on the appurtenant structures and facilities associated with and surrounding the lake. The current operating scenario and the pool levels that would result under the proposed operating options are outlined in Table 25 - 1. The various potential effects on existing structures and facilities are summarized below under Project Features.

Table 25 - 1 Lake Operating Options

Lake Level	Operating Levels		
	Existing	**Operating Option 1**	**Operating Option 2**
Maximum Operating Lake Level	252 ft (76.81 m)	254 ft (77.42 m)	256 ft (78.03)
Minimum Operating Lake Level	190 ft (57.91 m)	190 ft (57.91 m)	190 ft (57.91 m)
Lake level at start of PMF Event	254 ft (77.42 m)	256 ft (78.03 m)	258 ft (78.64 m)
Maximum Flood Storage Lake Level	263 ft (80.16 m)	263.7 ft (80.38 m)	264.6 ft (80.65 m)

FREEBOARD

Many factors are involved in the determination of the minimum freeboard allowances. Parameters that should be considered include the duration of high water levels in the lake during the design flood, the effective wind fetch and lake depth available to support wave generation, the probability of high wind speed occurring from a critical direction, the potential wave runup on the dam based on roughness and slope, and the ability of the dam to resist erosion from overtopping waves.

WAVE RUNUP AND WIND SETUP

In 1977, the U.S. Army Corps of Engineers computed wave runup and wind setup for Madden Dam. These computations were made in accordance with U.S. Army Corps of Engineers Engineering Technical Letter (ETL) 1110-2-221 dated 29 November 1976. This criteria recommends the use of maximum wind velocity – duration data measured at the site. Accordingly, wind data published in the 1949 Isthmian Canal Studies and others were used in these estimates. Data taken at Madden Dam were used for that site. The ETL provides a procedure for estimating the maximum wave height, wave runup and wind set-up for a site based on critical wave velocity – duration developed from actual wind records, and the geometry of the lake and dam as measured by effective fetch, water depths, slope of dam and surface cover of dam. The results obtained are summarized in Table 25 - 2.

Table 25 - 2 Results of Wave Runup and Wind Setup Computations

Parameter	Madden Dam
Effective fetch	0.65 mi (1.05 km)
Wind velocity	28 MPH (45.1 kmph)
Wind duration	16 minutes
Wave length Ts	1.9 seconds
Significant wave height	1.01 ft (0.31 m)
Runup of the significant wave in a vertical smooth surface	-
Runup of the significant wave in a permeable rock surface, slope 1 vertical on 1.5 horizontal	1.9 ft (0.58 m) (slope 1 vertical on 1.75 horizontal)
Runup of the maximum wave in the spectrum	2.8 ft (0.85 m)
Wave setup	.01 ft (0.003 m)
Note that the significant wave height is the average height of the highest 1/3 waves in the spectrum.	

ELEVATION CHECK

With a maximum pool elevation during the PMF of 263 ft (80.16 m) MSL, inclusion of wave setup and runup yields a maximum water surface elevation of 265.8 ft (81.02 m) MSL in Madden Lake next to Madden Dam. The runup of the maximum wave is 2.8 ft (0.85 m). This would not result in overtopping of any existing structures.

Project Features

GENERAL

The primary structures and facilities appurtenant to, and potentially affected by any change in the operation of Madden Lake can be grouped according to general type as follows: Spillway, Concrete Non-overflow Dam, Embankments, Hydropower Plant, Highways, Utilities, and Miscellaneous Facilities. These features are addressed in the following paragraphs concluding an assessment of some potential structural problems that might result from raising Madden Lake.

SPILLWAY

The existing spillway crest at Madden Dam is 400 ft (121.9 m) in total length and has a crest elevation of 232 ft (70.71 m) MSL. The spillway is arranged in four sections that are separated by piers supporting concrete roadway bridge arches, thus providing for highway communication across the dam. Each section has a variable crest (or drum type) gate by which the level of the reservoir may be controlled for a height of up to 20 ft (6.1 m) above the crest of the spillway. This gate height includes an extension that adds 2 ft (0.61 m) to the vertical height of each drum gate. The extensions were added in the middle 1960s. Maximum discharge through Madden Spillway with the Madden Lake level at 263 ft (80.16 m) MSL is 262,000 CFS (7,419 CMS).

There are six 10 by 5.67 ft (3.05 by 1.73 m) gated rectangular sluiceways passing through the lower portion of the spillway. Flow through each sluiceway is regulated by two sluice gates of the sliding type which are arranged in tandem. The upstream gates, called emergency valves, are located 32.15 ft (9.8 m) from the upstream face of the dam, and are protected from debris by semi-circular trashracks. The others, called service valves are 8 ft (2.44 m) farther downstream. The sluice gates were designed to operate with a maximum head of 155.3 ft (47.34 m), which corresponds to a lake level of 250 ft (76.2 m). They are operated by a 2 ft (0.61 m) hydraulic hoist designed for a working pressure of 1000 PSI (704,000 kg/m^2).

Under present operating pool levels, sluice gates No. 1 through No. 4 can only be opened 70 percent to prevent cavitation. Sluice gates No. 5 and No. 6 can be fully opened.

CONCRETE NON-OVERFLOW DAM

The concrete non-overflow sections extend from either side of the spillway northward and southward to the canyon walls. These sections were constructed of mass concrete with a roadway across their top at elevation 270 ft (82.30 m) MSL, approximately 15 ft (4.58 m) above the current maximum operating lake level. The non-overflow sections immediately south of the spillway and upstream of the powerhouse contain two 8.5 ft (2.59 m) diameter outlet pipes. Flow through each of these pipes is controlled by a needle valve, which is located at the downstream end of the pipe inside the powerhouse structure.

The intakes and penstocks supplying water to the powerhouse are also contained within this area of the non-overflow dam. When the lake reaches elevation 80.47 m MSL, water would enter through a window opening above the powerhouse penstock trashracks and would likely damage mechanical operating equipment located there. This would cause flooding of the operating machinery area. If water levels are permanently raised higher than are currently used, this opening must be sealed to prevent damage to the machinery.

EMBANKMENTS

From the ends of the concrete non-overflow sections, continuous earth and rock fill embankments extend along the ridges to the north and south to complete the dam being interrupted at intervals by saddle dams as described below in Table 25 - 3. The embankment section extending to the south is of earth and rock fill with a heavy facing of rock fill placed on a 2.5 horizontal on 1 vertical downstream slope, and a reinforced concrete facing placed on a 1.75 horizontal on 1 vertical upstream slope.

Along the ridges forming the banks of the Madden Lake are a number of places where the ground elevations are lower than the currently predicted maximum water surface elevation of the reservoir, elevation 263 ft (80.16 m) MSL. There are thirteen low ridges, or saddles, around Madden Lake (see Table 25 - 3), which are bridged with earth and rock fill dams or saddle dams having top elevations of 269.7 ft (82.21 m) MSL.

The two major saddle dams are No. 5 and No. 8 that have upstream slope protection and concrete cores. Currently, the maximum permissible operational level at Madden Lake is 255 ft (77.72 m) MSL. If the lake elevation exceeds 260 ft (79.25 m) MSL (the elevation of the concrete core wall in saddle dam No. 5), after a period of time, seepage could occur through the relatively porous saddle dam fill. The saddle dams are well armored and filtered so that this seepage would not damage the dams. The duration of these events is not long and the problems imposed are not deemed significant.

The remainder are of lesser significance because of the relatively high natural ground elevation at each one. All saddle dams listed below in Table 25 – 3 have a crest width of 7.62 m, an upstream slope of 1 vertical on 4 horizontal, and a downstream slope of 2.5 horizontal on 1 vertical.

Table 25 - 3 Saddle Dam Data

Saddle Dam No.	Minimum Ground Elevation at Axis ft (m) MSL	Crest elevation ft (m) MSL	Top elevation of bedrock ft (m) MSL	Approximate length of saddle ft (m) MSL
5	220.0 (67.06)	273 (83.21)	188 (57.3)	425 (129.54)
6	250.0 (76.2)	273 (83.21)	240.2 (73.2)	340 (103.62)
7	250.2 (76.2)	273 (83.21)	243.0 (74.06)	320 (97.54)
8	180.0 (54.9)	273 (83.21)	170.0 (51.82)	400 (121.92)
9	254.9 (77.7)	273 (83.21)	233.0 (71.02)	180 (54.86)
10	259.3 (79.03)	273 (83.21)	243.1 (74.1)	150 (45.72)
11	253.0 (77.11)	273 (83.21)	258.0 (78.64)	280 (82.3)
12	254.9 (77.7)	273 (83.21)	235.0 (71.63)	790 (240.8)
13	259.0 (78.94)	273 (83.21)	240.2 (73.2)	190 (57.91)
14	254.9 (77.7)	273 (83.21)	243.0 (74.06)	165 (50.29)
15	259.0 (78.94)	273 (83.21)	233.0 (71.02)	230 (70.1)
16	259.0 (78.94)	273 (83.21)	249.0 (75.9)	200 (60.96)
17	270.0 (82.3)	273 (83.21)	Not stated	200 (60.96)

HYDROPOWER PLANT

The Madden Powerplant has 24 MW of installed capacity. It consists of three generators of 3 MW each, and three generators of 5 MW each. With the maximum operating lake level raised, additional energy could be generated because of the higher heads during the rainy season and longer duration of operating heads caused by the added storage in the lake. The average amount of additional energy generated is expected to be approximately 300 MWh under Operating Option 1 and 2,000 MWh under Operating Option 2. However, as demand for navigation water and M&I water increases, the required operational changes would result in a net decrease of hydropower production. Also, raising Madden Lake by 2 or 4 ft (0.61 or 1.22 m) could result in long-term deleterious effects on the existing hydropower turbines in the form of accelerated wear on the hydraulic turbines.

HIGHWAYS

The only highway in the area is Madden Road, which crosses the dam over its crest. This road is at elevation 269.9 ft (82.29 m) MSL. It would not be affected by raising Madden Lake to the extent currently under consideration.

UTILITIES AND MISCELLANEOUS FACILITIES

The Instituto de Acueductos y Alcantarillados Nacionales intake pumps are located inside Madden Lake at elevation 260 ft (79.25 m) MSL. This is the same elevation as the core walls of Saddle Dam No. 5. Since it has been shown that there exists enough spillway capacity to maintain the water level significantly below this elevation during all but the most extreme flood events, there should be no effect on the Instituto de Acueductos y Alcantarillados Nacionales intake structure by implementing either of the options under consideration.

STRUCTURAL PROBLEMS ASSOCIATED WITH RAISING MADDEN LAKE

In order to raise the operating level at Madden Lake, the current drum gate extensions would have to be altered or replaced. To increase the operating lake level the required gate extensions beyond the originally constructed gate, i.e. gate existing before the current 2 ft (0.61 m) vertical extension was added, would be as shown in Table 25 - 4.

Figure 25 – 1 and Table 25 – 4 indicate that with the 6 ft (1.83 m) gate extension, the extended arm will be very long as compared to the existing gate face measuring approximately 10.7 ft (3.26 m) along the extension of the gate face. This, and even the lesser extension, would require special detailing and possibly, modification to the concrete spillway crest and gate anchorages in order to be made functional. The gate module, the operating machinery, and the gate anchorages must be carefully checked to assure that the added quantity and distribution of weight with the extensions in place and the additional hydraulic loads would allow the gate to operate properly and to resist the additional forces.

Table 25 - 4 Gate Extensions

Extension Height ft (m)	Arc Length for Extension ft (m)
2.0 (0.61)	2.69 (0.82)
4.0 (1.22)	6.00 (1.83)
6.0 (1.83)	10.70 (3.26)

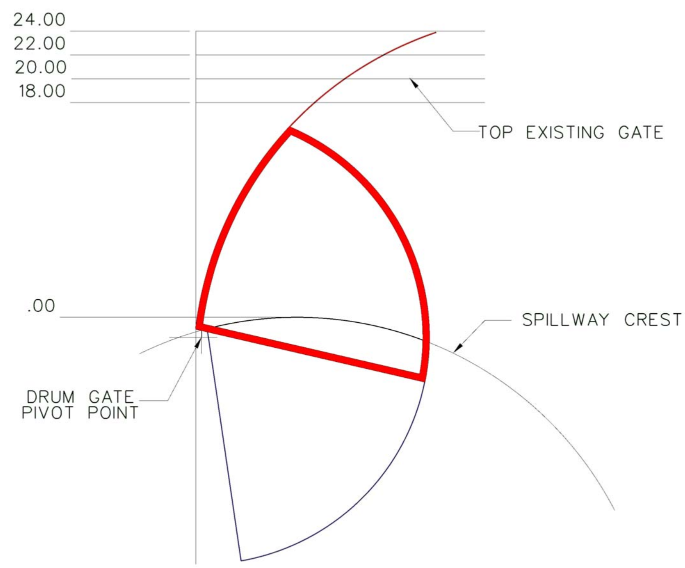


Figure 25 - 1 Gate Extension Schematic

The stability of the existing spillway monoliths was assessed by the U.S. Army Corps of Engineers in 1977, using operating pool levels and seismic criteria current at that time. These computations indicated that, for both the normal operating condition and the condition involving normal operating condition with seismic loading, the stability numbers were within the acceptable range for foundation bearing pressure and for overturning and sliding stability. It was assumed for this study that the results contained in that report would not change materially. Therefore, no provision is included in this study for strengthening or stabilizing existing structures.

In the event that either option contained in this alternative is carried forward for further study, a thorough investigation of the stability and integrity of the individual components of the concrete dam and spillway must be made. This must be done because of the increase in normal operating pool levels. Also, since the facilities were originally designed, more reliable data has been developed concerning the potential for seismic events in the various regions within the Republic of Panama. In estimating the cost of the seismic analysis, it was assumed that an equivalent static load analysis would suffice. In the event that a more rigorous analysis is dictated by the site geology and local seismic environment, the cost of this portion of the analysis would increase dramatically. These studies would address internal stresses for all components including spillway gates and anchorages, concrete spillway, bridge piers, and non-overflow walls. Also, the overall stability of each type of monolith must be checked to assure that the higher pool levels do not cause larger stresses at the foundation than the allowable and to assure the stability of each monolith against overturning and sliding. It is estimated that the cost of these studies would be on the order of approximately $100,000.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project option would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Environmental assessments of the proposed projects would begin during the planning studies phase and would continue during the final design, advertising and award phase and on through the construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

It should be noted that further study and design work done for this alternative must include a thorough analysis of the existing structures, using up-to-date criteria and modern analysis techniques to assure the stability and integrity of all the existing structures and their components under the increased constant loading conditions. These analyses would include appropriate flood conditions and seismic events as indicated in this study and in accordance with the requirements of the Panama Canal jurisdictional authority.

Socio-economic programs would begin upon firm establishment of the intended action. Socio-economic programs to assist those individuals potentially impacted by the raising of the Madden pool level would continue throughout the construction phase, but are expected to be minimal.

The following tentative summary of construction efforts required for implementation of the Raise Madden Lake alternative assumes that no structural strengthening or anchorage work would be required to accommodate the raised pool levels. In the event that future studies reveal that actions such as these are required, the scope of the renovation work would grow accordingly.

Construction would begin with the alterations to the existing spillway facilities including modification to, or replacement of, the existing spillway gate extensions, and modification to the existing gate operating equipment, gate anchorages, etc. Concurrent with the spillway gate modifications, any alterations required to the existing powerhouse facilities and equipment (needle valves, low level sluice gates, etc.) would be accomplished. The machinery room window immediately above the powerhouse penstock trashracks, noted previously, would be sealed during this time. Upon completion of these alterations, all facilities would undergo trial operations followed by commissioning for service. Once all new modifications to the existing facilities were accomplished, the water surface of the lake would be allowed to rise to the new operating level.

Considering the climatic conditions and the obstacles posed by the location of the construction site and the varied nature of the work, it is estimated that development of this project could be completed in approximately 3.25 years, from initial planning to lake filling. Figure 25 - 2 depicts the development sequence of the various project features.

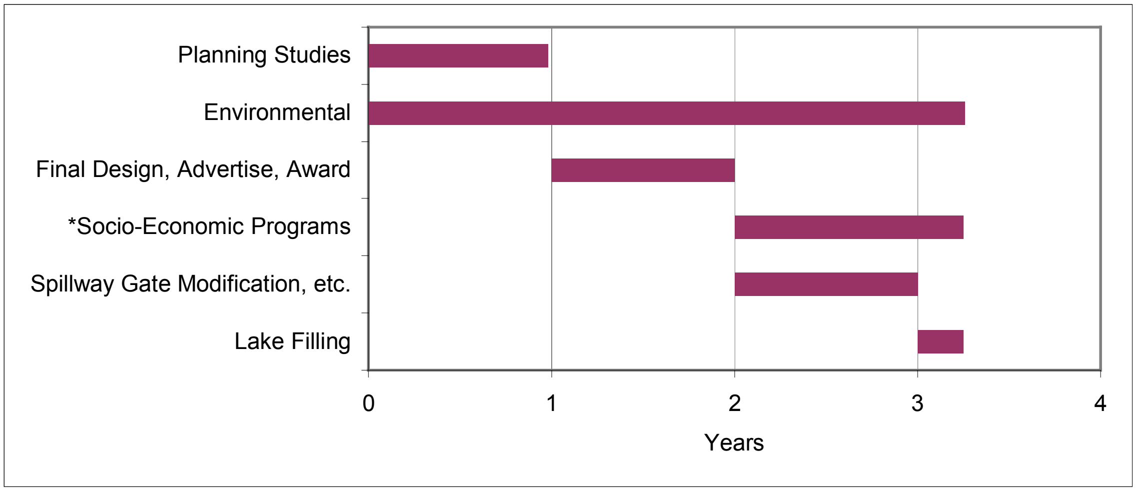


Figure **25 - 2 Development Sequence**

*Socio-Economic Programs would be very limited for this project.

Hydrologic Reliability

In order to determine the effect of the proposed alternative to raise the normal operating lake levels of Madden Lake on the hydrologic reliability of the Panama Canal, the lake was evaluated with the existing HEC-5 model of the Panama Canal, applying historic hydrology and imposing the alternative higher operating levels.

HEC-5 model simulations were conducted for both the existing canal system and the system operating with the proposed higher Gatun Lake level. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record.

The horizontal axis along the bottom of Figure 25 - 3 reflects demands as a ratio of the five-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 25 - 3, the existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability with a demand ratio of 1.0 would be 99.64 percent for Operating Option 1, and the hydrologic reliability with a demand ratio of 1.8 would be 86.46 percent. With Operating Option 2, the hydrologic reliability with a demand ratio of 1.0 would be 99.70 percent, and the hydrologic reliability with a demand ratio of 1.8 would be 86.63 percent. Table 25 - 8 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the Panama Canal system would decrease. With the construction of the proposed Raise Madden Lake project, the existing high hydrologic reliability could be continued as demand for lockages increases up to 2.5 percent (0.97 lockages) with Option 1 and 3.2 percent (1.24 lockages) with Option 2 above current demand levels.

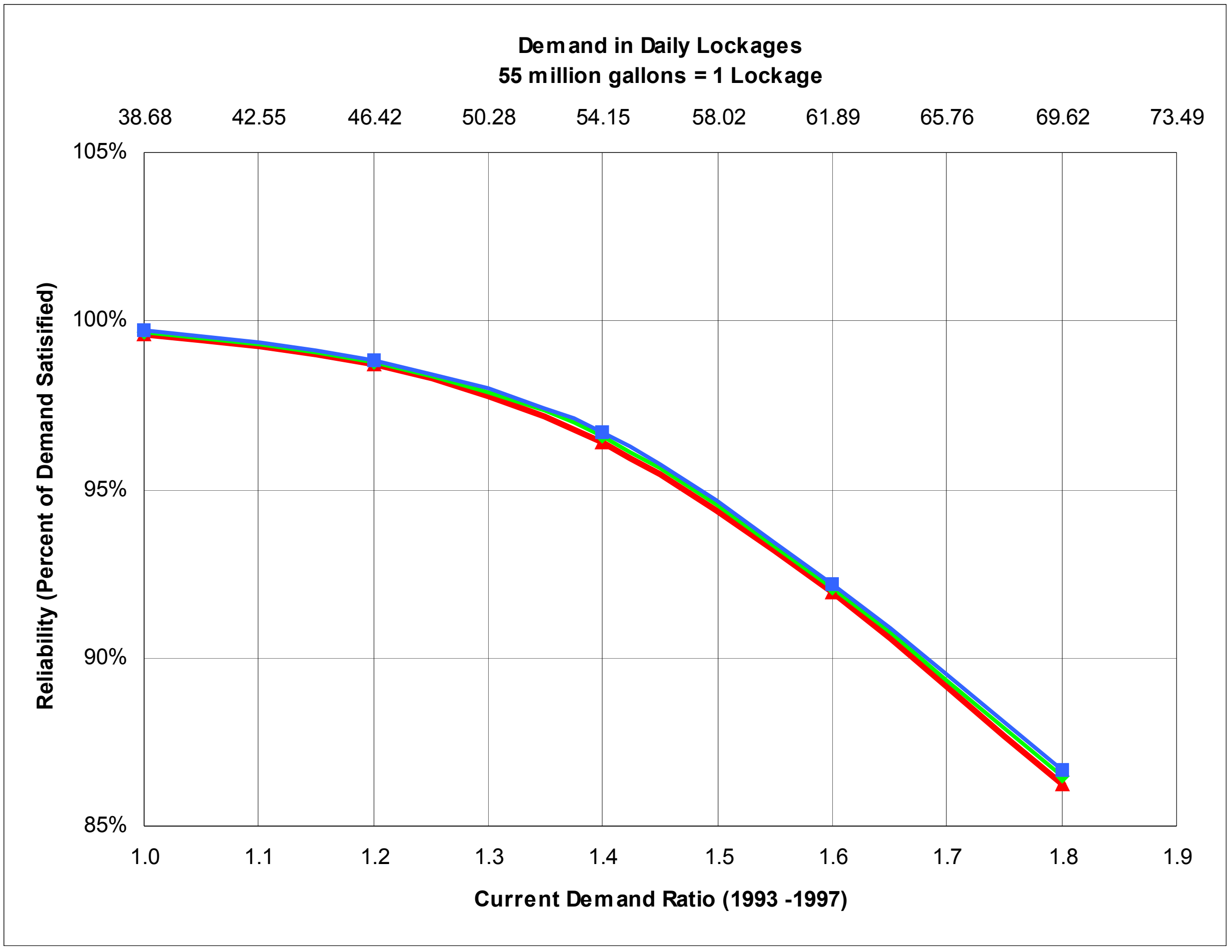


Figure 25 - 3   Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from preliminary engineering layouts. The unit prices applied to these quantities were based on historical information from previous estimates prepared for similar construction in the Republic of Panama, previous estimates for similar construction in the Southeastern United States, information gathered from U.S. Army Corps of Engineers, Mobile District Construction Division personnel in the Republic of Panama, and the publication, Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1979.

Engineering and design is estimated to be 12 percent and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.).

An allowance of 25 percent was included for contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $625,000 for Operating Option 1 and $730,000 for Operating Option 2. Table 25 - 5 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 25 - 5 Summary of Project First Costs

Principal Feature	Option 1 Costs ($)	Option 2 Costs ($)
Stability and Integrity Study	100,000	100,000
Extend Gates	295,426	366,420
Close Openings	20,000	20,000
Subtotal	415,426	486,420
E&D, S&A, Field Overhead	83,085	97,284
Contingencies	124,628	145,926
Total Project First Costs	623,139 approximately 625,000	729,630 approximately 730,000

OPERATION AND MAINTENANCE

Staff

An adequate staff to operate the Madden Lake project is already in place. It is assumed that this staff could absorb any additional duties of operating the modified project with no additional cost. Thus, no staff costs are estimated for this proposed project.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants, and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $10,000 per year for the modified main project facilities.

Major Replacements

The average service life of gates and other features would be less than the total useful life of the proposed project, which would be 100 years. To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it was assumed that specific items would cost the same as at present. No allowance was made for salvageable fixed parts. Table 25 - 6 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements would be $1,500 and $1,900 and the average annual replacement costs would be $180 and $230 for Operating Option 1 and Operating Option 2 respectively.

Table 25 - 6 Major Replacement Costs – Operating Option 1 and 2

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)		Present Worth of Replacement Costs ($)	
			Option 1	Option 2	Option 1	Option 2
Madden Dam Modifications						
Extend Gates	50	1	443,139	549,630	1,500	1,900
Total			443,139	549,630	1,500	1,900
Average Annual Replacement Costs					180	230

Annual Costs

The total project first costs are estimated to be $625,000 for Option 1 and $730,000 for Option 2. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the total project first costs was computed from mid-year throughout the 3.25-year period from initiation of Planning and Design until the lake was filled. The interest during construction at 12 percent would be $19,900 for Option 1 and $23,300 for Option 2. These costs were added to the total project first costs for total project investment costs of $643,000 for Option 1 and $752,900 for Option 2. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $77,400 for Option 1 and $90,700 for Option 2. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 25 - 7 contains a summary of the $88,000 and $101,000 average annual costs for both options.

Table 25 - 7 Summary of Annual Costs

Item	Option 1 Costs ($)	Option 2 Costs ($)
Total Project First Costs	623,100	729,600
Interest During Construction	19,900	23,300
Total Project Investment Costs	643,000	752,900
Annual Average Investment Costs	77,400	90,700
Operation and Maintenance Costs		
Staff Costs	0	0
Ordinary Maintenance Costs	10,000	10,000
Major Replacement Costs	180	230
Total Average Annual Costs	88,000	101,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Section 4. The following paragraphs present the results of the economic investigations for the proposed Raising Madden Lake project. The 50-year planning period for this proposal is 2004 to 2054.

The proposed Raising Madden Lake project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 25 - 8 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages were obtained from the data used to develop Figure 25 - 2. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 25 - 8 Panama Canal Hydrologic Reliability

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability		
			Existing System (%)	Operating Option 1[1/] (%)	Operating Option 2[2/] (%)
1	2000	38.68 [3/]	99.60	99.64	99.70
	2010	45.11	98.91	98.91	98.97
1.2		46.42	98.76	98.76	98.83
	2015	46.82	98.61	98.64	98.72
	2025	48.52	98.10	98.17	98.25
	2035	50.72	97.43	97.55	97.65
	2045	53.49	96.58	96.77	96.89
1.4		54.15	96.38	96.59	96.71
	2055	56.98	94.77	94.94	95.06
	2060	59.05	93.65	93.73	93.86
1.6		61.89	91.97	92.07	92.20
	2070	63.97	90.43	90.56	90.70
1.8		69.63	86.24	86.46	86.63

[1/] Operating Option 1 (Madden Lake raised to fluctuate between the normal operating lake level at elevations 254 ft (77.42 m) MSL and the minimum operating lake level at elevation 190 ft (57.91 m) MSL).

[2/] Operating Option 2 (Madden Lake raised to fluctuate between the normal operating lake level at elevations 256 ft (78.03 m) MSL and the minimum operating lake level at elevation 190 ft (57.91 m) MSL).

[3/] 2,000 Daily Demand is Average of 1993-1997.

Regardless of the operating option, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands increase, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Raising Madden Lake project, these shortages would be less than they would be under the existing system. With a hydrologic reliability of 99.6 percent, Operating Option 1 would increase the amount of water supplied for navigation by approximately 0.97 equivalent lockage, and Operating Option 2 would increase that amount by 1.24 equivalent lockages. For Operating Option 1, the 99.6 percent hydrologic reliability would occur in the middle of year 2002 with an equivalent daily average number of lockages set to 39.65. For Operating Option 2, the 99.6 percent hydrologic reliability level would occur in the end of year 2001 but with an equivalent daily average number of lockages of 39.92. Benefits for these amounts of additional water would be attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages provided by each option. The average annual benefits for water supply would be $18,832,000 for Operating Option 1 and $24,105,000 for Operating Option 2. Table 25 - 9 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Raise Madden Lake project in operation, the annual benefits for meeting shortages, and the average annual benefits for both options.

Table 25 - 9 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages With Operating Option 1	Remaining Daily Shortages With Operating Option 2	Annual Benefits for Operating Option 1 ($)	Annual Benefits For Operating Option 2 ($)
2004	2.45	1.48	1.21+	17,504,000	22,405,000
2005	3.06	3.10	1.82	17,728,000	22,692,000
2015	8.14	7.17	6.90	19,943,000	25,527,000
2025	9.83	8.87	8.60	19,943,000	25,527,000
2035	12.04	11.07	10.80	19,943,000	25,527,000
2045	14.81	13.84	13.57	19,943,000	25,527,000
2053	19.19	19.22	17.95	19,943,000	25,527,000
Average Annual Benefits				18,832,000	24,105,000
With Option 1, the system will provide a total of 39.65 equivalent lockages at the 99.6 percent level of reliability or 0.97 more lockages than the existing system. With Option 2, the system will provide a total of 39.92 equivalent lockages at the 99.6 percent level of reliability or 1.24 more lockages than the existing system.					

With either operating option, the reliability of the system to provide all of the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Raising Madden Lake project would be $298,000 for Operating Option 1 and $835,000 for Operating Option 2. Table 25 - 10 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits for each operating option.

Table 25 - 10 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Daily Lockage ($)	Annual Navigation Benefits For Operating Option 1 ($)	Annual Navigation Benefits For Operating Option 2 ($)
2004	36.61	1,815,300	200,000	619,000
2005	37.13	1,864,800	199,000	633,000
2015	40.00	2,260,000	255,000	845,000
2025	40.00	2,260,000	593,000	1,285,000
2035	40.00	2,260,000	1,032,000	1,857,000
2045	40.00	2,260,000	1,584,000	2,576,000
2053	40.00	2,260,000	1,473,000	2,517,000
Average Annual Benefits			298,000	835,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was based upon the growth in population. The PCC provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day. An equivalent lockage is 55 million gallons of water. One equivalent lockage was added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Raising Madden Lake project, the current costs to the PCC to process finished water of $0.69 per 1,000 gallons, the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability would be $39,000 for Operating Option 1 and $102,000 for Operating Option 2. Table 25 - 11 displays the population forecast, the resulting number of equivalent lockages demanded per day, the annual benefits for increased reliability, and the average annual benefits for M&I water supply.

Table 25 - 11 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits for Operating Option 1 ($)	Annual M&I Water Supply Benefits for Operating Option 2 ($)
2004	1,522,000	4.53	19,000	59,000
2005	1,552,000	4.62	19,000	59,000
2015	1,919,000	6.82	29,000	97,000
2025	2,396,000	8.52	85,000	184,000
2035	3,016,000	10.72	186,000	334,000
2045	3,796,000	13.49	359,000	584,000
2053	4,570,000	16.24	400,000	685,000
Average Annual Benefits			39,000	102,000
The value of a daily lockage for M&I is $0.69 X 55,000 = $37,950				

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Raise Madden Lake project, there would be some lost efficiency in the hydropower operation and the system could not produce as many megawatt hours of hydropower as it could without raising the dam. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, Operating Option 1 would have negative benefits of $222,000 and Operating Option 2 would have negative benefits of $141,000. Table 25 - 12 provides the net lost megawatt hours of hydropower generation and the resulting annual and average annual negative benefits for each option.

Table 25 - 12 Average Annual Benefits For Hydropower Generation

Year	Net Generation for Operating Option 1 [1/] (MWh)	Net Generation for Operating Option 2 [1/] (MWh)	Annual Hydropower Benefits for Operating Option 1 ($)	Annual Hydropower Benefits for Operating Option 2 ($)
2004	(1,097)	386	(77,000)	27,000
2005	(1,444)	(16)	(101,000)	(1,000)
2015	(4,134)	(3,182)	(289,000)	(223,000)
2025	(5,445)	(4,588)	(381,000)	(321,000)
2035	(7,149)	(6,415)	(500,000)	(449,000)
2045	(9,293)	(8,714)	(651,000)	(610,000)
2053	(11,870)	(11,480)	(789,000)	(759,000)
Average Annual Benefits			(222,000)	(141,000)
[1/] Net generation of Gatun, and Madden hydropower plants above generation of Gatun and Madden hydropower plants after Madden Dam is raised.				

SUMMARY OF ANNUAL BENEFITS

As shown in Table 25 - 13, total average annual benefits for Operating Option 1 and Operating Option 2 of the proposed Raising Madden Dam project would be $18,947,000 and $24,901,000, respectively.

Table 25 - 13 Summary of Annual Benefits

Benefit Category	Average Annual Benefits	
	Operating Option 1 ($)	Operating Option 2 ($)
Navigation – Water Supply	18,832,000	24,105,000
Navigation – Reliability	298,000	835,000
M&I - Reliability	39,000	102,000
Hydropower	(222,000)	(141,000)
Total	18,947,000	24,901,000

Once average annual benefits and costs are estimated, the ratio of benefits to costs and the net benefits (net of costs) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. While there would be small differences in some project features between Operating Option 1 and Operating Option 2, the differences would not have any impact on total project first costs at this level of investigation. The same facilities would be constructed for each operating option. Table 25 - 14 provides the benefit to cost ratios for Operating Option 1 and Operating Option 2 and the net benefits for both.

Table 25 - 14 Economic Evaluation

Item	Operating Option 1 ($)	Operating Option 2 ($)
Average Annual Benefits	18,947,000	24,901,000
Average Annual Costs	88,000	101,000
Benefit to Cost Ratio	215	283
Net Benefits	18,859,000	24,813,000

Internal Rate of Return

An internal rate of return analysis for each operating Option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For Operating Option 1, the internal rate of return would be 336.9 percent, and for Operating Option 2, the internal rate of return would be 352.4 percent.

Socio-economic Impacts

The socio-economic impacts of the project will be minor due to the nature of this project. There are no known towns or settlements within the project area; therefore, raising Madden Lake might not impact local residences. No indigenous groups of people are known to reside in the project area. The project should not impede transportation in the area. The incremental surface area will increase by a maximum of 51 km^2.

Environmental Setting

The Raise Madden Lake alternative will result in a revised maximum operating lake elevation of 256 ft (78.0 m) MSL. Currently the maximum operating elevation for Madden Lake is 252 ft (76.8 m) MSL. The raising of this elevation will be accompanied by adding extensions to the existing gates. The Madden Lake drainage area is 396 mi^2 (1,026 km^2). The existing impoundment area is in high terrain and has steep banks so surface area of lake will increase by a minimum of 12,600 acres (51 km^2). Madden Lake is a man-made lake located on the Chagres River, approximately 12 mi (19.3 km) upstream from the Panama Canal and contains aquatic habitats of various water depths and qualities. The primary structures and facilities appurtenant to and potentially affected by any change in the operation of Madden Lake can be grouped according to general types as follows: spillways, concrete dam, powerhouse, embankments, highways, utilities, and miscellaneous facilities. Private docks and marine facilities along the current water edge could be affected.

LAND USE

The Raise Madden Lake project consists of two Operating Options that will increase the existing lake elevations by 2 ft (0.6 m) for Option 1 and by 4 ft (1.2 m) for Option 2. The structures that will be impacted by the proposed project are Madden Spillway, Madden Powerplant, and the highway to the north of the dam. Field observations revealed that there are no towns along the perimeter of Madden Lake. There are no cleared areas for agriculture or grazing. The shores of Madden Lake are densely forested. There are no known significant mineral resources or deposits along Madden Lake. There are scattered, small local communities within the drainage basin.

INFRASTRUCTURE

Madden Lake is used as a supply of freshwater to municipalities and powerplants, and as a source of water for the Panama Canal. Roads leading to and from Madden Dam are paved and well maintained. The operation and maintenance of Madden Dam and its structures are the main industry in the project area.

TERRESTRIAL HABITAT

The terrestrial habitat surrounding Madden Lake consists of tropical forest ecosystems. The project area is densely forested. Forests are continuous, which suggests richness of habitat and species diversity. Terrestrial habitat is used by migratory and native wildlife species for resting, breeding, and feeding grounds. The densely forested shores of Madden Lake provide terrestrial species with unfragmented habitat vital for ecosystem health, well-balanced wildlife populations, and high species diversity. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities and may provide critical wildlife habitat to many native species.

ANIMALS ON ENDANGERED LIST

ANAM by its Resolution 002-80 on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although none have been identified to date, some or all of the listed species of concern may occur in the project area.

AQUATIC HABITAT

The lake is inhabited by diverse species of aquatic life, both resident and migratory, as well as both native and introduced fish and other aquatic species. Water levels vary between wet and dry seasons and with the demands from municipalities and the Panama Canal.

WETLANDS

Areas which contain hydric soils and hydrophytic plant communities, and which are subject to hydrologic conditions are termed wetlands. Wetlands in the Madden Lake project area consist of shallow water habitat and areas that experience frequent flooding. The shallow water areas along the shores of the lake receive sunlight to approximately 1 m in depth, depending on water clarity. Sunlight stimulates plant growth in the form of submergent, emergent, or floating mats of aquatic vegetation away from the banks, into the deeper aquatic habitats. Wetlands occur in topographic areas where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the project area are stressed by the fluctuating water levels between the wet and dry seasons.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities within the watershed. At the end of the dry season in March or early April, scattered areas of secondary growth are slashed and burned to prepare lands for agricultural use. The Panamanian government controls this activity within this area. During this period the air is filled with smoke and ash, which may be transported by winds to Madden Lake. Air quality monitoring has not been implemented within the project area. The natural environment could provide indicators that could be useful in evaluating air quality.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The Parque Nacional Chagres is within this watershed and is protected as a National Park. There are no historic properties within the project area. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in the Madden Lake project area will be substantial. The boundary between two types of habitats, in this case where a forest meets a lake, is called an ecotone. Ecotones are composed of a mixture of species from neighboring habitats but are unique areas with high species diversity. The shoreline of Madden Lake provides cover, feeding and resting grounds for many species. The raising of Madden Lake will inundate this habitat, with a direct impact on the species using this ecotone.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered species cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Some endangered and / or threatened species may use Madden Lake for some or all parts of their life cycle.

WATER QUANTITY

Species inhabiting specific depths will be impacted as lake depth increases and existing shoreline is inundated. The cumulative impacts downstream of the dam site over time should also be minor. The increased size of the impoundment may provide more storage to benefit downstream ecosystems during dry season.

WATER QUALITY

Impacts of the project on water quality have not been determined. Raising Madden Lake will increase nutrients and debris in the lake. The rate at which nutrients and debris enter the lake will determine the severity of the impact on water quality. Project implementation will cause an increase in turbidity and interfere with photosynthesis by depriving sunlight to plants and other aquatic species that help maintain water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. Project implementation should impact the breeding and nursery habitat of many aquatic species from the sudden increase in turbidity, nutrient content and water depth. Adverse impacts are anticipated for fish spawning areas due to altered conditions needed for successful hatching. Plant populations may decrease as a result of the increase in depth and decrease in available sunlight; consequently, invertebrate populations may decline, which will reduce the food supply for fish and other aquatic species.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts to future aquatic vegetation will depend on water quality and stability of water levels. Plant species will be impacted by the increase in depth. Plant communities will be impacted during project implementation; however, they are expected to re-establish themselves at slightly higher elevations when conditions stabilize.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting Madden Lake and the affected areas could be important. If aquatic faunas were able to thrive in the reservoir, they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur, these impacts should be identified, and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. Madden Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

WETLANDS

The impacts to wetlands could be significant. Wetlands will be inundated and become deeper aquatic habitats, thus permanently altering the established environment. Project activities may affect wetlands by increasing depth and adding, sedimentation and turbidity, which could affect biological processes and decrease species productivity, which will be detrimental to the health of Madden Lake. Fish and other aquatic species use shallow water areas as spawning areas as well as habitat for juvenile aquatic species. Juvenile aquatic species survive in shallow waters of the wetland areas until they are large enough to venture out into deeper water.

AIR QUALITY

During project construction, emissions from equipment will impact air quality in the project area. After project completion, the air quality should return to the pre-project condition.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties cannot be defined or mitigated. Prior to project implementation, surveys will be conducted to locate cultural resources and historic properties and important sites will be preserved or salvaged as appropriate.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Raise Madden Lake alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an SIA. The SIA will consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities.
  - Employment.

- Land Use.
- Property Values.
- Public and Community Facilities and Services (including utilities and schools).
- Transportation.
- Housing.
- Health (vector routes).
- Population.
- Community Cohesion.
- Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major types of terrestrial and aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique habitat features such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Madden Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Provide species inventory lists for each site area identifying their status as native or exotic and whether they are threatened and or endangered species.
- Address cumulative effects downstream on Rio Chagres.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for animals on the endangered and / or threatened species list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts to determine the presence of these species

WATER QUALITY

- As limited water quality data are available for Madden Lake, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Information regarding cultural resources and historic properties is incomplete. Additional evaluation studies are needed to identify cultural resources and historic properties.

Evaluation Matrices

In accordance with evaluation procedures described in Section 4, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Section 35. Tables 25 - 15 through 25 - 17 present the evaluation of the proposed Raise Madden Lake project as related to developmental effects, environmental effects, and socio-economic effects.

Table 25 - 15 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I demands	1	10	10
	Supplements Existing System	0	10	0
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	5	6	30
	Feasibility of Concept	6	6	36
Operational Issues	Compatibility	10	6	60
	Maintenance Requirements	10	2	20
	Operational resources required	10	2	20
Economic feasibility	Net Benefits	1	9	9
	Total			185

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 25 - 16 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	4	8	32
Animals on Extinction List	5	10	50
Water Quantity Impacts – Lake	10	10	100
Water Quantity Impacts – Downstream	5	7	35
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	5	8	40
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	5	5	25
Potential for Fishing on Lake	5	6	30
Wetlands	5	4	20
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			495

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 25 - 17 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	5	7	35
Relocation of People	5	10	50
Relocation of Agricultural/Ranching Activities	5	6	30
Post-Construction Business	5	5	25
Post-Construction on Existing Employment	5	5	25
Property Values During Construction	5	4	20
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	5	4	20
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	5	5	25
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	5	4	20
Communities Receiving Displaced People	5	8	40
Community Cohesion	5	8	40
Tourism	7	5	35
Total			455

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 25 - 18 presents pertinent data for the proposed project. Elevations are given in Precise Level Datum, MSL.

Table 25 - 18 Pertinent Data for Madden Dam and Lake

GENERAL		
Dam site above the Canal	12 mi (19.2 km)	
Drainage area above dam site	396 mi^2 (1,026 km^2)	
Average annual flow at dam site	2,580 CFS (73 CMS)	
LAKE	**Option 1**	**Option 2**
Elevation of Maximum Normal operating lake level	254 ft (77.42 m) MSL	256 ft (78.03 m) MSL
Elevation of maximum flood storage lake level	254 ft (77.42 m) MSL	256 ft (78.03 m) MSL
Elevation of minimum operating lake level	200 ft (60.96 m) MSL	200 ft (60.96 m) MSL
Area at normal operating lake level	19.8 mi^2 (51.26 km^2)	20.2 mi^2 (52.24 km^2)
Maximum Lake level during PMF	263.8 ft (80.4 m) MSL	264 8 ft (80.7 m) MSL
DAM		
Type of dam	Concrete Gravity	
Top elevation of dam	270 ft (82.3 m) MSL	
Height	220.1 ft (67.1 m)	
Overall length of dam	974.4 ft (297 m)	
SADDLE DAMS		
Number of saddle dams	6	
Type of saddle dams	Rock fill with concrete cutoff	
Top elevation of saddle dams	269.7 ft (82.21 m) MSL	
LOW LEVEL OUTLETS		
Number of Sluiceways	6	
Dimensions	10 by 5.67 ft (3.05 by 173 m)	
Number needle valve outlets	2	
Diameter	8.5 ft (2.59 m)	

SPILLWAY		
Type of Spillway	Gated	
Number of gates	4	
Type of gates	Drum	
Length of gates	30.5 m	
Top of gates in closed position	77.42 m MSL	78.03 m MSL
Elevation of access bridge over spillway	82.3 m MSL	
Total length (including piers)	140.2 m	
Elevation of spillway crest	70.71 m MSL	
Maximum discharge @ EL 80.77 m MSL	8,350 CMS	

Table 25 - 19 Pertinent Data for Madden Dam and Lake (continued)

HYDROPOWER PLANT	
Number of units	6
Capacity of each unit	
3 units at	3 MW
3 units at	5 MW

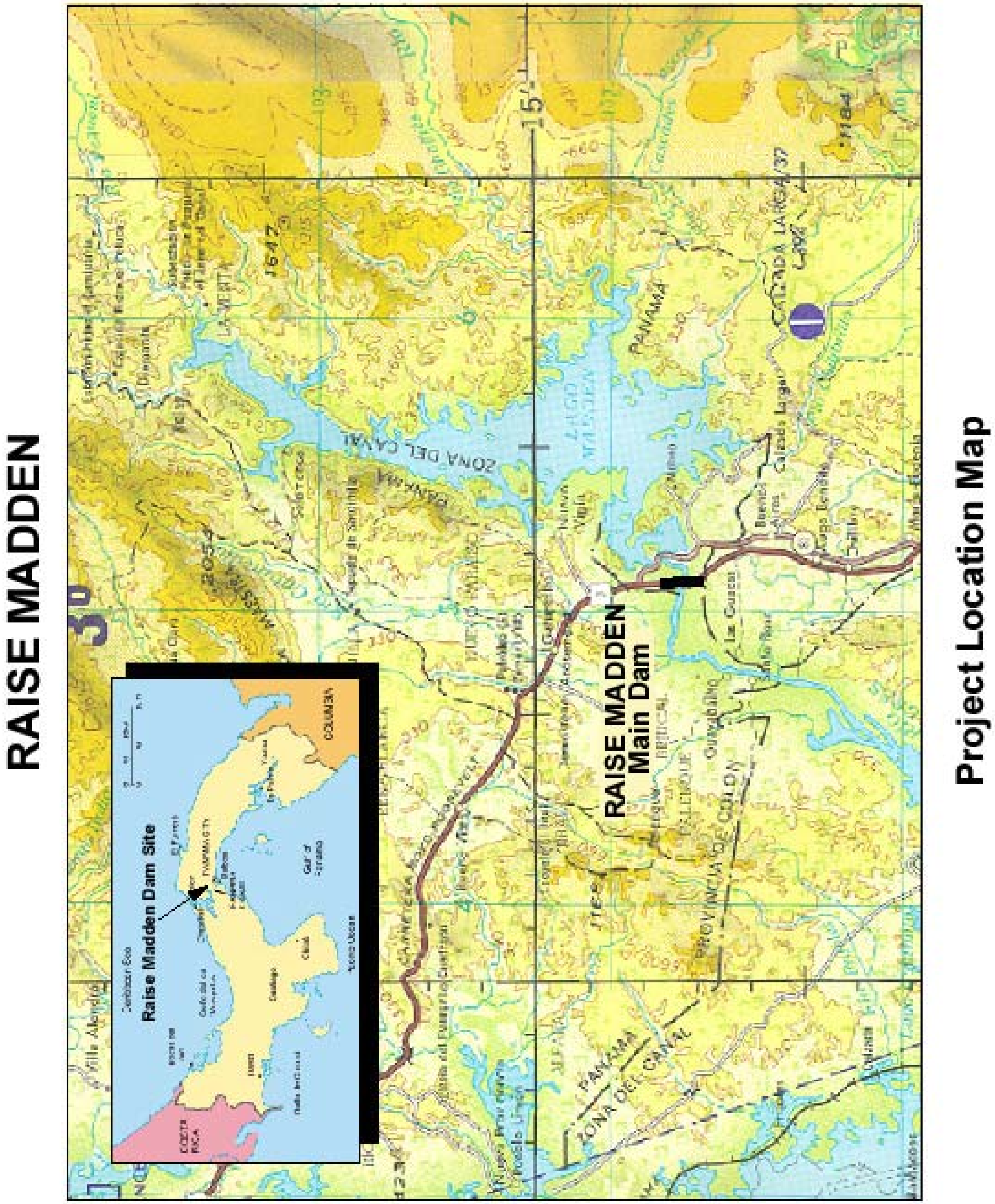


Plate 25 - 1 Project Location Map

RAISE MADDEN LAKE

Plate 25 - 2 Proposed Feature Map

SECTION 26

Raise Miraflores Lake

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

Synopsis

This proposed alternative considers raising the normal operating level of Miraflores Lake by 1 ft (0.3 m) allowing an increase of the maximum operating level from 54.5 ft (16.61 m) MSL to a maximum of 55.5 ft (16.92 m) MSL. The Miraflores Locks are the southern most locks (Plate 26 – 1) that connect the Panama Canal to the Pacific Ocean. The Miraflores spillway was completed in 1914 and consists of locks and earth and rock fill dam. The Miraflores Lake flooded the lower valleys of the Rio Grande, Rio Cocoli, Rio Caimitillo and the Rio Pedro Miguel.

The goal in raising Miraflores Lake by 1 ft was to decrease water usage at Pedro Miguel Lock and thus to reduce lockage withdrawals from Gatun Lake. The studies made in conjunction with this report addressed not only the water used at Pedro Miguel Lock, but also the total water used in the entire southern descent of the Panama Canal. These studies indicate that raising Miraflores Lake would be only nominally advantageous from a water use standpoint.

The proposed Raise Miraflores Lake alternative would contribute in a very minor way to the hydrologic reliability of the Panama Canal to serve its customers and would have practically no effect on the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.2 (46.42 lockages) would be 98.8 percent. By raising the Miraflores Lake maximum operating elevation by 1 ft (0.3 m), the existing high hydrologic reliability would be virtually unchanged.

The proposed Raise Miraflores Project was weighed against the technical objectives stated in Section 4 of this report and was found to be lacking in the following areas:

The volume of water produced by this project would not be enough to significantly impact the reliability of the Panama Canal water supply (approximately 0.7 lockages per day).

The plan for raising Miraflores Lake was not pursued further and was eliminated from the list of technically viable projects to be subjected to further scrutiny in this report. No formal cost, economic or environmental analyses were made of this alternative.

This alternative does not meet the first assessment criterion, which is to provide at least one lockage per day. Therefore, further consideration of this alternative is not recommended.

Selection of Revised Pool Level

Miraflores Lake level is a controlling factor to determine draft allowances for transiting ships. Present policy is to maintain Miraflores Lake level above 53.5 ft (16.31 m) MSL, keeping at least 2 ft (0.61 m) of water between the keel of any ship and the 13 ft (3.96 m) MSL level of the south sills at Pedro Miguel Locks.

According to the current operating procedures of the PCC, Miraflores Lake level can be raised to 54.5 ft (16.61 m) MSL when necessary for the transit of deep-draft ships. However, it should not be maintained above elevation 54 ft (16.46 m) MSL except to provide the 2 ft (0.61 m) clearance over sills.

The alternative presented here considers raising Miraflores Lake by 1 ft (0.3 m). The maximum allowable lake elevation would then become 55.5 ft (16.92 m) MSL.

The existing operating facilities and the impacts expected on each and the new construction required by the higher pool level are summarized below under Project Features.

Hydrologic Considerations

Miraflores Lake has enough spilling capacity to handle the possibility of an accident at Pedro Miguel Locks allowing free flow into the Miraflores Lake. Therefore, the Miraflores spillway has ample capacity and an increase in the spilling capacity of Miraflores Lake is not considered necessary for this alternative. More details are given below under Project Features.

Lake Operation

Under the revised operating procedure the maximum normal pool elevation would be raised to 55.5 ft (16.92 m) MSL, 1 ft (0.3 m) above that currently used. This change to the operating scenario at Miraflores Lake would have little impact on flood elevations, given the small increment and the generous spilling capacity of the Miraflores spillway. Raising the maximum normal operating pool elevation would have some impact on the appurtenant structures and facilities associated with and surrounding the lake. The current operating scenario and the pool levels that would result under the proposed operating option are outlined in Table 26 - 1. The various effects on structures and facilities are summarized below under Project Features.

Table 26 - 1 Lake Operating Options

Lake Level (m MSL)	Current Operating Levels		Alternative Operating Levels	
	(ft MSL)	(m MSL)	(ft MSL)	(m MSL)
Maximum Operating Lake Level	54.5	16.61	55.5	19.91
Minimum Operating Lake Level	53	16.15	53	16.15
Maximum Flood Storage Lake Level Without Added Spillway Capacity	56	17.07	56	17.07

Project Features

GENERAL

The primary structures and facilities appurtenant to, and potentially affected by, any change in the operation of Madden Lake can be grouped according to general type as follows: locks, spillways, embankments, highways, utilities, railroads and miscellaneous facilities. These features are addressed in the following articles.

MIRAFLORES LOCKS

Some modifications would be necessary at Miraflores Locks. Following are conceptual designs, conservative cost estimates, and time estimates necessary to realize the modifications:

1) The bullwheel fender is at elevation 55 ft (16.76 m) MSL. For this study, it was assumed that the bullwheel and operator arm mechanism would be replaced with a hydraulic ram type operator. Bulkheads, seals, and flexible operator arm boots would need to be installed so that the operator recesses would remain dry.

2) The miter gate top girder is at elevation 55.1 ft (16.79 m) MSL. An extension of the wall quoin and the mitering ends to elevation 55.5 ft (16.92 m) MSL would be necessary. Miscellaneous holes under the walkway would have to be sealed.

3) Chain fender, floatwell and other miscellaneous openings would have to be sealed.

SPILLWAYS

Existing spilling facilities

Miraflores Lake watershed inflows are usually small, even in the rainy season, and a smaller spillway would have been sufficient if no other condition had been considered. Mainly two situations require large spills through the Miraflores spillway:

1) An accident at Pedro Miguel Locks, allowing Gatun Lake water to flow without control through the locks into Miraflores Lake. While this is a remote contingency, considering all the protective devices that were built into the locks, it is not an impossibility.

2) Flood events requiring emergency spilling through the three Pedro Miguel Locks culverts, with a discharge of approximately 21,000 CFS (595 CMS). This inflow plus the estimated Miraflores watershed maximum inflow will total about 40,000 CFS (1,130 CMS) into Miraflores Lake.

The spillway design is of the same general type as the Gatun spillway, with the crest piers and the gates being exactly the same. The eight stony gates, 19 ft (5.79 m) high and 45 ft (13.72 m) wide at the Miraflores spillway, were designed to discharge about 100,000 CFS (2,830 CMS) with the lake level 18 ft (5.49 m) above the crest of the dam.

Present spilling procedures and capabilities

Normal spilling operations at the Miraflores spillway constitute spills up to 18,000 CFS (510 CMS). Emergency spilling at the Miraflores spillway becomes necessary when lake inflows exceed 18,000 CFS (510 CMS).

Discharge rate will vary with the number of gates and openings. Six gates open 1 ft (0.3 m), with Miraflores Lake level at 54 ft (16.46 m) MSL, discharges about 3,750 CFS (106.2 CMS). Six gates open 2.6 ft (0.79 m), and two gates open 5.2 ft (1.58 m), with lake level at 54.5 ft (16.61 m) MSL discharge approximately 18,000 CFS (510 CMS).

Miraflores Lake outflow is the sum of the Miraflores spillway and Miraflores Locks culverts discharges. Prolonged spills in excess of 40,000 CFS (1,130 CMS) with high tide, and 70,000 CFS (1,980 CMS) with low tide, could damage the spillway apron, damage the downstream bridge and flood the Miraflores Power Station. Portions of the Gaillard Highway may also flood.

Structural problems associated with raising Miraflores Lake

With the lake level raised to its revised maximum operating level, elevation 56 ft (17.06 m) MSL, the design freeboard of 4 ft (1.22 m) would be reduced to 3 ft (0.92 m).

In light of the original design documents and subsequent stability studies made for this structure, it was assumed that the spillway and its gates would be structurally adequate for the added service loads resulting from the higher maximum operating water surface elevation. In the event that this alternative is carried forward for feasibility assessment this assumption should be confirmed or corrected based on structure specific computations addressing both the structural stability and the integrity of the structures. These computations should also take into account the present condition of the structural components and the age of the materials.

Amount of water saved by raising Miraflores Lake

The amount of water saved by raising Miraflores Lake by 1 ft is directly related to the reduction in lift in Pedro Miguel Locks. Independent of the elevation of Gatun Lake, the outflow through Pedro Miguel Locks will be reduced by 1 ft (0.3 m). What happens downstream of Pedro Miguel Locks has no impact on the amount of water savings of this alternative. However, the lower ranges of Pacific tide levels will have the effect of depleting Miraflores Lake as successive lockages are passed through Miraflores Locks creating the need for water to be artificially supplied to Miraflores Lake at Pedro Miguel Locks.

According to Hodges, the area of the 1,000 ft (304.8 m) lock at Pedro Miguel is 134,000 ft^2 (12,448 M^2). The prism of lift for 1 ft (0.3 m) in Pedro Miguel Locks is therefore 134,000 ft^3 (12,448 M^3), or 1.002 million gallons (3,793 M^3). This amount is fixed for any elevation of Gatun Lake. This is a water savings of 1.82 percent of the consumption in an average lockage in the Panama Canal, if one lockage is assumed to be equivalent to 55 million gallons. This would provide a savings of 0.7 lockages per day. The value for one lockage (defined in Section 4) used in this analysis represents the average amount of water used to transit a vessel through the Panama Canal. This is approximately equal to two lock chambers of water plus waste and other losses during canal operation.

Ways to prevent a water shortage in Miraflores Lake

Potential ways to counter loss of water from Miraflores Lake and maintain a stable water level:

1) Reduce the amount of water spilled through the Miraflores spillway.
   a) Define better ship scheduling or operating policies in the locks around the lake in order to minimize spilling. There is little room for improvement in this area and this is not foreseen to be an effective solution.
   b) Increase the storage capacity of Miraflores Lake. The greater the storage capacity of Miraflores Lake, the greater its regulation potential. Unfortunately, Miraflores Lake is small. By raising the operating elevation of Miraflores Lake, there will be a reduction in flood storage, and consequently, an increase in the amount of water that must be spilled. The present navigable bottom of Miraflores Lake is 9 ft (2.74 m). Deepening or widening this channel will gain little.

2) Reduce the amount of water spilled through Miraflores Locks: This would imply water saving methods in Miraflores Locks, such as recycling ponds, ship lifts, cross filling, reductions in tidal gate (covered in Section 30), hydraulic assist, etc.

3) Add an additional source of water supply to Miraflores Lake.
   a) Reroute Rio Cardenas: An additional source of water supply to Miraflores Lake could be obtained by rerouting Rio Cardenas, which now flows into Miraflores Lake at a point just downstream of Miraflores Locks. This would entail nearly 2362 ft (720 m) of channel to divert water from Rio Guanabano (a tributary of Rio Cardenas) into Rio Dominical, providing an additional 2.12 mi^2 (5.5 Km^2) of drainage area. An additional development could provide 3.1 mi^2 (8 Km^2) more of drainage area, and would include a 1969 ft (600 m) channel from Rio Mocambo (another tributary of Rio Cardenas) to Rio Guanabano. It would also require a small dam, about 30.5 ft (10 m) high and 305 ft (100 m) wide at its crest. With this dam, a small lake with an area of about 0.19 mi^2 (0.5 $Km^{2)}$ would be created.
   b) Pump seawater into Miraflores Lake: This is a controversial alternative from an environmental point of view.

4) Increase the outflow from Pedro Miguel Locks: This would be effective, but at the cost of reducing the water savings gained by raising Miraflores Lake.

The optimal solution to the water shortage in Miraflores Lake could lie in a combination of the proposed solutions. The choice and development of this solution is beyond the scope of this study, with the small advantage in water savings estimated (less than 0.7 lockages per day).

MIRAFLORES DAM

The elevation of the right and left abutments of Miraflores Dam is 85.17 ft (25.96 m) MSL and the west side earth and rock fill dam extending approximately 2,700 ft (823 m) between the upper wing wall and the west abutment has a top elevation of 70 ft (21.34 m) MSL. This is considerably above the top elevation of the upper chamber wall of 58.67 ft (17.88 m) MSL. Therefore, no significant impact on Miraflores Dam is anticipated from raising Miraflores Lake to elevation 55.5 ft (16.92 m) MSL.

MIRAFLORES SADDLE DAMS

The only saddle dam in Miraflores Lake is the one that prevents water from flowing into the area that was excavated during the 1940 decade for a third set of locks. No significant impact is anticipated in this saddle dam by raising Miraflores Lake to elevation 55.5 ft (16.92 m) MSL.

FREEBOARD

During the construction of the Panama Canal, the coping of the Miraflores Locks upper chamber was placed at elevation 58.67 ft (17.88 m) MSL, considering a freeboard of 4 ft (1.22 m) over a maximum elevation of Miraflores Lake of 54.67 ft (16.66 m) MSL. By raising Miraflores Lake to a maximum operation of 55.5 ft (16.94 m) MSL, then only 3.2 ft (0.97 m) of freeboard are left in Miraflores Locks. The movement of certain large ships in the chamber will cause a standing wave with a height close to this freeboard.

This would affect a change in the speed at which larger vessels would be allowed to enter the upper lock chambers. The rise in water level in the chamber ahead of a large entering ship is proportional to the speed of the ship. This water level increase ahead of an exiting ship does not occur. The water build up ahead of the ship is caused by the insufficient space between the ship hull and the chamber surfaces, and the lock culverts to exhaust the displaced water fast enough. Recent tests in Miraflores Locks have indicated a maximum wave runup in these instances of 2.35 ft (0.72 m).

RAILROAD

The railroad causeway is above elevation 70.0 ft (21.34 m) MSL and would not be affected by the slight rise in Miraflores Lake under consideration here.

HIGHWAYS

Gaillard Highway is above elevation 65.0 ft (19.8 m) MSL and would not be affected by the slight rise in Miraflores Lake under consideration.

UTILITIES AND MISCELLANEOUS FACILITIES

The floor of the Pedro Miguel lakefront boat sheds is close to elevation 55.5 ft (16.92 m) MSL. Some modification of these facilities may be necessary if the lake operating level is permanently raised.

Real Estate Requirements

The Lake View Golf Course would lose approximately 10 percent of its area. All housing in the Pedro Miguel town site is above elevation 55.5 ft (16.92 m) MSL and would not be affected. Some swampy area on the west bank would be flooded at elevation 55.5 ft (16.92 m) MSL.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed for its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would begin during the planning studies phase and would continue during the final design, advertising and award phase. The final design would be accomplished for the recommended project. At completion of the final design, plans and specifications would be prepared for the advertising and award phase pursuant to any modification required by the lake level raising. The required modifications would be made and the operating scenario would be revised.

Hydrologic Reliability

The existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. As noted before, the net savings that would be realized for this alternative is simply the reduction in water required to lock a vessel through Pedro Miguel Locks. With 1 ft reduction for each filling of Pedro Miguel Locks, the proposed Raise Miraflores project would add approximately 0.7 lockages per day with existing demands. Based on the criterion set forth in Section 4, this increase is not considered adequate; therefore, this project was not recommended for further study.

Project Costs

GENERAL

No cost information was developed for this alternative since the potential aide to navigation was found to be very small.

Pertinent Data

Table 26 - 2 presents pertinent data for operating the proposed Raise Miraflores project.

Table 26 - 2 Pertinent Data for Revised Operating Option

MIRAFLORES LAKE	
Elevation of normal operating lake level	55.5 ft (16.92 m) MSL
Elevation of maximum flood storage lake level	56 ft (17.07 m) MSL
Elevation of minimum operating lake level	53 ft (16.15 m) MSL
EMBANKMENTS	
Dam	
Type of dam	Rock dams and Hydraulic fill
Top elevation of dam	70.0 ft (21.34 m) MSL
Overall length of dam	2,700 ft (823 m)
Saddle dam (at abandoned French Canal)	
Type of saddle dam	Natural
SPILLWAY	
Type of Spillway	Gated
Type, No. and size of gates	8 Stony gates – 19 ft (5.79 m) high and 45 ft (13.72 m) wide
Total length at flow surface	360 ft (110 m)
Maximum discharge	100,000 CFS (2,830 CMS)

RAISE MIRAFLORES LAKE

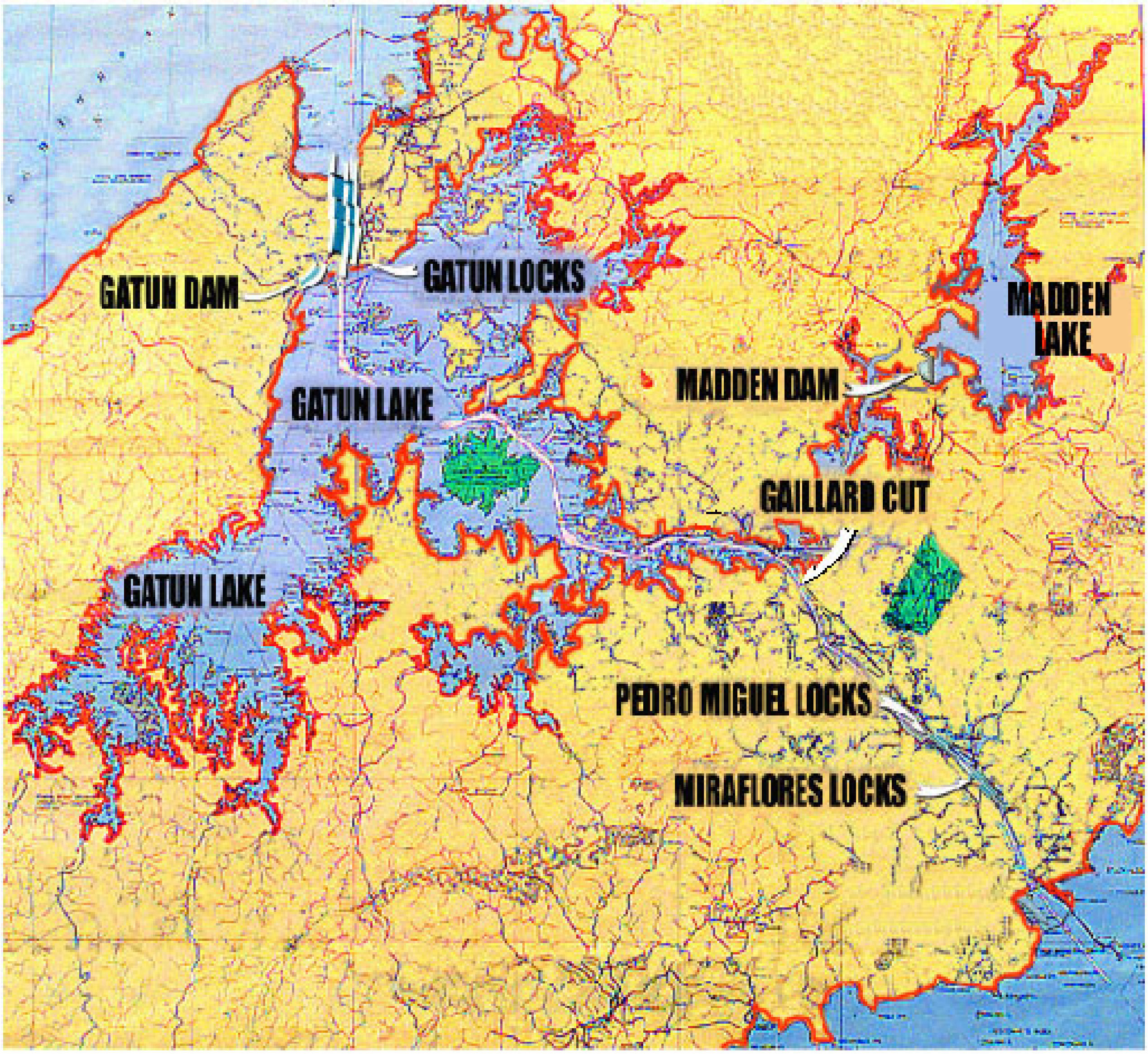


Plate 26 - 1   Project Location Map

RAISE MIRAFLORES LAKE

Plate 26 - 2 Existing Features Map

SECTION 27

PUMP STORAGE TO MADDEN LAKE

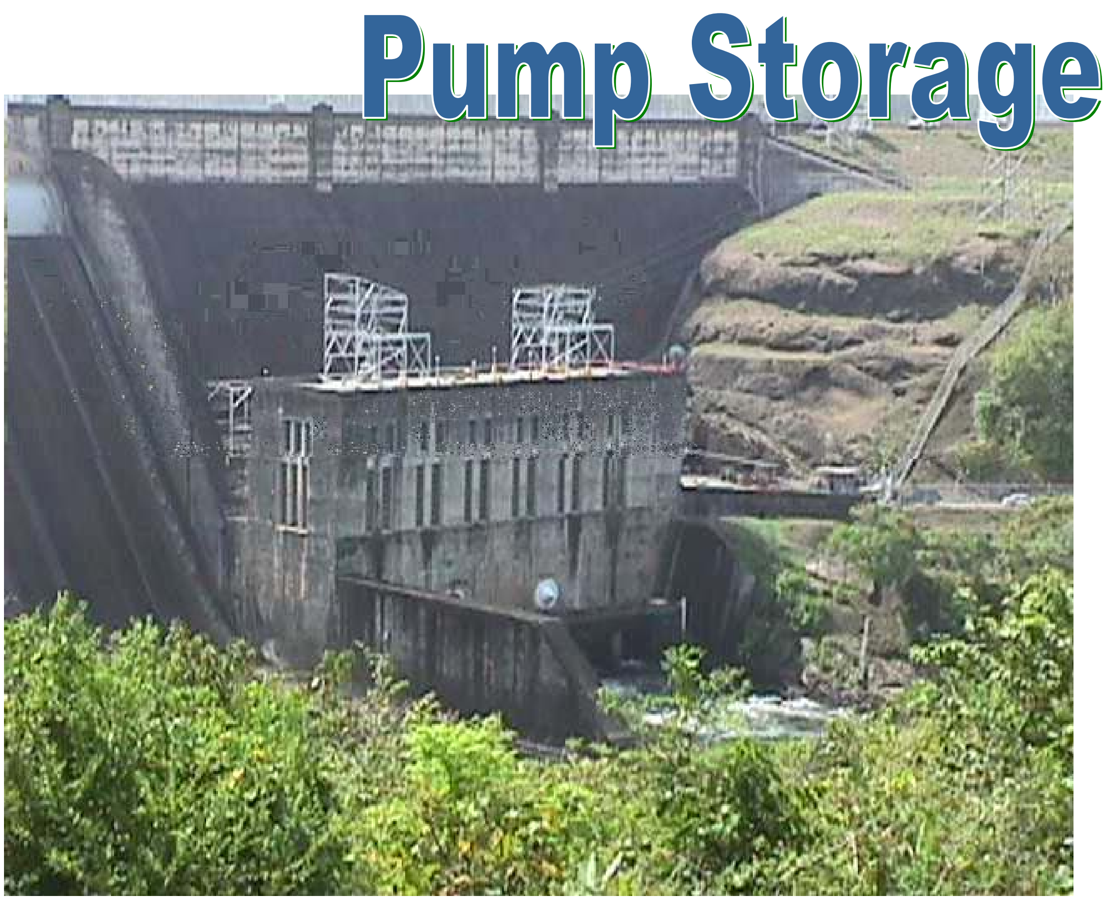


TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein would include modifying Madden Dam with pumpback capability. Water would be pumped from Gatun Lake to Madden Lake. Water impounded in Madden Lake would be transferred to the Panama Canal watershed as needed to support canal operations.

Madden Dam is located on the Chagres River 0.8 km above the site of the original Village Alhajuela. Plate 27 - 1 shows the location of the Madden Dam project. The dam is located approximately 19.3 km upstream from the Panama Canal and 40.2 km from Panama City. It is a gravity dam of concrete consisting of an overflow spillway section across the river, flanked by mass concrete non-overflow dam sections. These non-overflow sections extend to the canyon walls and the dam is continued north and south by earth and rock fill embankments with reinforced concrete cores. The concrete gravity dam is 296.9 m long between the abutments and its height is 67 m, with the foundation at elevation 15.2 m MSL. The dam and spillway contain four 30.5 m long drum gates, 6 low level sluiceways and two pipe outlets with needle valves.

Each drum gate is a 326.59 MT steel structure, roughly triangular in cross-section. Each is anchored and hinged at its upstream corner to the concrete dam. The drum gates are raised and lowered to control the water level of Madden Lake.

The present maximum operating lake elevation of Madden Lake is 76.8 m MSL and minimum elevation is 57.9 m MSL. Water from the Madden basin would be stored within those limits along with water pumped from Gatun Lake. The features impacted by this proposed project would be the Madden powerplant. Some structural modifications of the powerplant would be required to accommodate a pump turbine or add a pump to the system. The 24 MW of installed capacity would be increased to 64 MW and modified with pump-back capability. This proposal will not impact the available flood storage in Madden Lake. The Madden Lake drainage area is 1,026 km^2. The lake surface area is 50.2 km^2 at elevation 76.81 m. Available active storage of Madden Lake between elevations 57.91 and 76.81 m MSL is 651 MCM. According to the Madden Flood Control Manual, storage below 57.91 m MSL is reserved for the Republic of Panama M&I use only; however, M&I water can be withdrawn when the lake levels are above this limit. (See Flood Control Manual, page 1-7)

The proposed Pump Storage to the Madden Lake project was weighed against the technical objectives stated in Section 4 of this report and found to be lacking in the fundamental purpose for which these alternatives are intended.

1. The volume of water produced by this project would not be enough to significantly impact the reliability of the Panama Canal water supply (less than one lockage per day).

2. The technical viability of the development is questionable. In order to minimize spillage at Gatun Lake, by balancing the Madden and Gatun pump-storage system, would require implausible accurate weather forecasting tools. Additionally, power to the pumps would likely be supplied by hydropower which is counter productive in a water supply system

3. From an operational standpoint, a pump-generation system maximizes hydropower production. This study is intended to increase the available water supply to meet future navigational demand. Without increasing storage at Gatun Lake or Madden Lake, this

proposal would only transfer water back and forth between the two projects. No additional storage capacity is realized within the system. There could be some benefit by pumping back excess water from the Gatun basin into Madden Lake. The comparison of hydrologic records indicate that the dry and wet periods of the two basins are coincident and offer little opportunity to store excess water at Madden Lake. When Gatun Lake is drawn down so is Madden Lake, and when Gatun Lake is full so is Madden Lake. The alternative was considered operationally infeasible considering the small amount of increased water storage capacity realized.

The only benefit derived by the installation of this project would be the increased amount of hydropower that could be produced. The plan for development of the Pump Storage to Madden Lake will not be pursued further and will be eliminated from the list of technically viable projects to be subjected to further scrutiny in this report. No formal economic or environmental analyses will be made of this alternative. This alternative does not meet three of the four assessment criterions, which are to provide at least one lockage per day, technically viable and operationally practical. Therefore, further consideration of this alternative is not recommended.

Current Conditions and Study Objective

The primary function of Madden Dam is to augment the reserve water supply for operation of the Panama Canal system. Secondary functions include the production of hydropower and flood control for the Chagres River. The current normal operating scenario at Madden Lake allows the pool to fluctuate from a maximum normal pool elevation of 76.81 m MSL down to low of 57.91 m MSL. High water levels above this maximum put the existing structures and embankments in jeopardy proportionally to the water level rises in times of flooding. The original upper operating pool limit was set at elevation 73.15 m MSL during the rainy season, and was later raised to meet the higher demands for hydropower and lockage water to elevation 76.20 m MSL. Therefore, the amount of flood storage at Madden Lake was reduced by 143 MCM. The upper operating pool limit was later raised to elevation 76.81 m MSL, reducing the amount of flood storage at Madden Lake by an additional 30 MCM. The 1991 Panama Canal Flood Control Plan established maximum permissible operating for Madden Reservoir at 77.72 m MSL and states that this level should only be exceeded temporarily during periods of extreme floods. The available flood storage at Madden Lake between elevations 76.81 and 77.72 m MSL is now 47 MCM. Plate 27 - 2 shows an aerial view of the Madden Dam and Lake.

During the rainy season, the lake is allowed to fill to between elevations 76.20 and 78.03 m MSL. After the first of November each year, the lake is maintained between elevations 76.8 m MSL and 78.6 m MSL, except during periods of major flooding. When the floods come, the discharge from the spillway is limited to 1,416 CMS during major floods until the lake level reaches elevation 79.25 m MSL at which point emergency flood procedures are implemented allowing flows to exceed 1,416 CMS. After the first of December each year the lake is filled, if possible, to elevation 78.03 m MSL allowing extended free flow over the tops of the fully raised drum gates

The objective of this study is to increase the time during the driest years over which the full draft could be maintained through Gatun Lake and Gatun and Pedro Miguel Locks by reallocating water within the Panama Canal watershed so that more water would be available during the dry season for lockages. The most desirable pump storage scheme would provide these advantages while causing the least impact on existing facilities and requiring the least in added facilities. The existing operating facilities, the impacts expected on each, and the new construction required by pump storage are summarized below under Project Features.

Hydrologic Considerations

The dam is located on the Chagres River in a narrow gorge near the Village of Alhajuela, nearly 15.1 km northeast of Gamboa. The Rio Chagres flows southwestward into Madden Lake from the mountains of the Panama and Colon Province border. The headwaters of the watershed begins at elevation 700 m MSL approximately 45 km above Madden Dam and fall to elevation 76.8 m MSL, normal pool level at Madden Lake. The distribution of the average annual rainfall over the Rio Chagres watershed varies from a high of 3,050 mm at the middle watershed area and decrease to a low of 2,800 mm in east and west edge of the watershed. The Madden Lake would receive runoff from approximately 1,025 km^2 of the watershed. Rainfall runoff produces an average annual flow of 73 CMS at the proposed dam site.

The average monthly outflow for Madden Lake were computed as the sum of power releases, spills, leakage, and M&I water supply as appropriate. Lake elevation data were converted to storage data using the elevation-capacity table. Lake evaporation, expressed in flow units, was computed using average monthly elevation, elevation-area curves and evaporation in cm. The monthly net inflow and total inflow (with adjustments for evaporation) was computed for Madden Reservoir based on change-in-storage and total outflow (releases plus M&I water supply). These data represent the derived local flow into Madden Reservoir, which is required for canal capacity studies using HEC-5 simulation and other analysis tools. PCC provided all the pertinent flow data required to generate the monthly flow data sequence.

Lake Operation

Operating Madden Lake consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 76.81 m MSL down to the minimum operating lake level at elevation 57.91 m MSL, with 642.26 MCM of useable storage. The maximum flood lake level would be at elevation 77.72 m MSL. The volume between the maximum flood lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows.

Operating Gatun Lake consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 26.73 m MSL down to the minimum operating lake level at elevation 24.84 m MSL, with 801.84 MCM of useable storage. The maximum flood storage lake level would be at elevation 26.67 m MSL. The volume between the maximum flood storage lake level and the normal operating lake level would be used to store floodwaters and reduce peak flood flows.

Under the proposed Pump Storage to Madden Lake alternative, the objective would be to capture excess water that would normally be lost through the Gatun spillway and not used for canal operations by pumping it to Madden Lake. This concept assumes that storage will be available in Madden Lake when excess water is available in Gatun Lake. This case rarely occurs.

This operational scheme would maintain Gatun Lake at or near the top of normal pool. When rainfall in the basin exceeds water supply needs, the water would be pumped up to Madden Lake until the top of normal pool is reached in Madden Lake. No pumping would occur when both lakes are at normal pool. If this were allowed, it would impact the flood control operation. The benefit comes from pumping potential spill water at Gatun Lake into Madden Lake. This operation requires sophisticated forecasting ability to enable the Panama Canal system managers to initiate pumping at Madden Lake before spilling begins. However, water can only be pumped into Madden Lake if storage is available.

The parallel hydrologic characteristics and pattern of the two basins complicates the operation. The wet and dry seasons of the two basins coincide. Therefore, filling and drawdown will occur during the same time of the year. Any amount of water pumped back must reside in the normal pool storage between elevation 76.81 m MSL and 57.91 m MSL. Additionally when Madden Lake is drawn down and storage is available for pumping water back to Madden Lake, Gatun Lake does not normally experience excess rainfall.

The powerhouse could operate as a peaking hydropower plant with pumpback occurring during off-peak hours. The pumps would be sized to pump in 10.5 hours the volume of water needed for 8.5 hours of generation. Applications of Madden Lake as a peaking plant assumes that excess energy would be available from the power grid during the off-peak hours and would not necessarily provide benefits to canal operations.

Project Features

GENERAL

The primary structures and facilities appurtenant to, and potentially affected by any change in the operation of Madden Lake can be grouped according to general type as follows: Spillway, Concrete Dam, Powerhouse, and Embankments. These features are addressed in the following articles.

SPILLWAY

Existing spilling facilities

The spillway facilities of Madden Lake include Madden spillway, two 2.59 m diameter outlet pipes equipped with needle valves, and six 3.05 by 1.73 m rectangular sluiceways controlled by gates. (Reference 23). The existing spillway crest at Madden Dam is 121.9 m in length and is arranged in four sections that are separated by piers supporting concrete bridge arches, providing for highway communication across the dam. Each of the 30.5 m sections of this spillway has a variable crest (or drum type) gate by which the level of the reservoir may be controlled for a height of up to 6.7 m above the crest of the dam. (Reference 12). The crest of the spillway is at elevation 70.71 m MSL and the top of the drum gates is at elevation 77.4 m MSL.

Present spilling procedures and capabilities

Currently, the maximum permissible operational level at Madden Lake is 77.72 m MSL. If lake elevation exceeds 79.25 m MSL it will overtop the core walls of saddle dam No. 5, and enter private lake shore property. At about 80.47 m MSL, the water will enter through a window opening above the powerhouse penstock trashracks.

Maximum discharge through Madden Spillway with the Madden Lake level at 80.16 m MSL is 7,420 CMS.

Sluiceway flow is regulated by two sluice gates of the sliding type, which are arranged in tandem. The upstream emergency valves are protected from debris by a semi-circular trashrack, and are located 9.8 m from the upstream face of the dam. The others, also called service valves are 2.44 m farther downstream.

To prevent cavitation, sluice gates No. 1 through No. 4 can only be opened 70 percent. Sluice gates No. 5 and No. 6 can be fully opened. (Reference 1).

MADDEN HYDROPOWER PLANT

The Madden powerplant has 24 MW of installed capacity. It consists of three generators of 3 MW each and three generators of 5 MW each. Installing pump generation at Madden Lake would require structural modification tailrace channel dredging or construction of a re-regulation dam. The bottom of the turbine draft tube opening is at elevation 24.08 m MSL and top at elevation 26.21 m MSL. Gatun Lake does not backup to Madden Lake at elevations below 26.21 m MSL. Pump draft tubes are required to be fully submerged at the tailrace. This would require lowering the draft tube by excavation and lengthening the existing tube so that the tunnel remains submerged below Gatun Lake minimum pool of 24.84 m MSL. The second option involves dredging a channel deep and wide enough to allow Gatun Lake to back up to Madden Dam and enable pumpback down to elevation 24.84 m MSL. Thirdly, constructing a re-regulation dam would provide the required tailrace elevation to submerge the draft tubes and provide temporary storage. The proposed Madden Pump Storage alternative requires 68 MW of pump generator capacity. This allows 99 CMS to be pumped from Gatun Lake for 10.5 hours over an average head of 41.8 m. Additional energy would be generated because of the pump storage operation and increased installed capacity.

Sources of Construction Material

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Hydrologic Reliability

The existing HEC-5 model of the Panama Canal system was modified to include a pumping unit at Madden Lake.

HEC-5 model simulations were conducted for both the existing Panama Canal system and the system operating with the proposed higher Gatun Lake level. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record.

The existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8

would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability of the Pump Storage to Madden project, with current demands, would be less than existing 99.6 percent.

The hydrologic characteristics of the two drainage basins coincide. Therefore, filling and drawdown will occur during the same time of the year. When storage is available in Madden Lake water is not available in Gatun Lake. The system will not realize a net gain in storage capacity.

The powerhouse could operate as a peaking hydropower plant with pumping of water back to Madden Lake during off-peak hours or when excess energy is available. The pumps could be sized to pump in 10.5 hours the volume of water needed for 8.5 hours of generation. Operating in this manner would only be beneficial if there is a need to supplement energy capacity during peaking periods.

Without additional water supplies, the hydrologic reliability of the Panama Canal system would decrease. With the construction of the proposed Pump Storage to Madden Lake project, the existing high hydrologic reliability would not improve. This alternative was not recommended for further study.

Pertinent Data

Table 27 - 1 presents pertinent data for Pump Storage to Madden Lake proposed project.

Table 27 - 1 Pertinent Data for Pump Storage to Madden Lake

GENERAL	
Dam site, above mouth of Rio Chagres	
Drainage area above dam site	1,025.6 km^2
Average annual flow at dam site	73 CMS
LAKE	
Elevation of normal operating lake level	76.81 m MSL
Elevation of maximum flood storage lake level	77.72 m MSL
Elevation of minimum operating lake level	57.91 m MSL
Area at normal operating lake level	5,020 ha
Area at maximum flood storage lake level	5,175 ha
Area at minimum operating lake level	1,865 ha
Top clearing elevation	
Lower clearing elevation	
EMBANKMENTS	
Dam	
Type of dam	Concrete gravity
Top elevation of dam	83.36 m MSL
Fixed crest width	14.3 m
Height above lowest foundation	67 m
Overall length of dam	289 5 m
SPILLWAY	
Type of Spillway	Gated ogee
Total length	140.21 m
Number of Gates	4
Gate dimensions	30.48 by 5.49 m
Elevation of spillway crest	70.71 m MSL
Elevation of top of gates (fully depressed)	70.71 m MSL
Elevation of top of gates (fully raised)	76.81 m MSL
Maximum discharge	7,420 CMS
Sluice Gates	
Number of Gates	6
Gate dimensions	1.73 by 3.05 m
Centerline elevation of inlet	28.96 m MSL
Centerline elevation of outlet	28.86 m MSL
HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	6
Capacity of each unit	3 – 3 MW and 3 – 5 MW
PUMP REQUIREMENTS	
Average Head	41.8 m
Flow Capacity	99 CMS (3,500 CFS)
Power Required	68 MW

PUMP STORAGE TO MADDEN LAKE

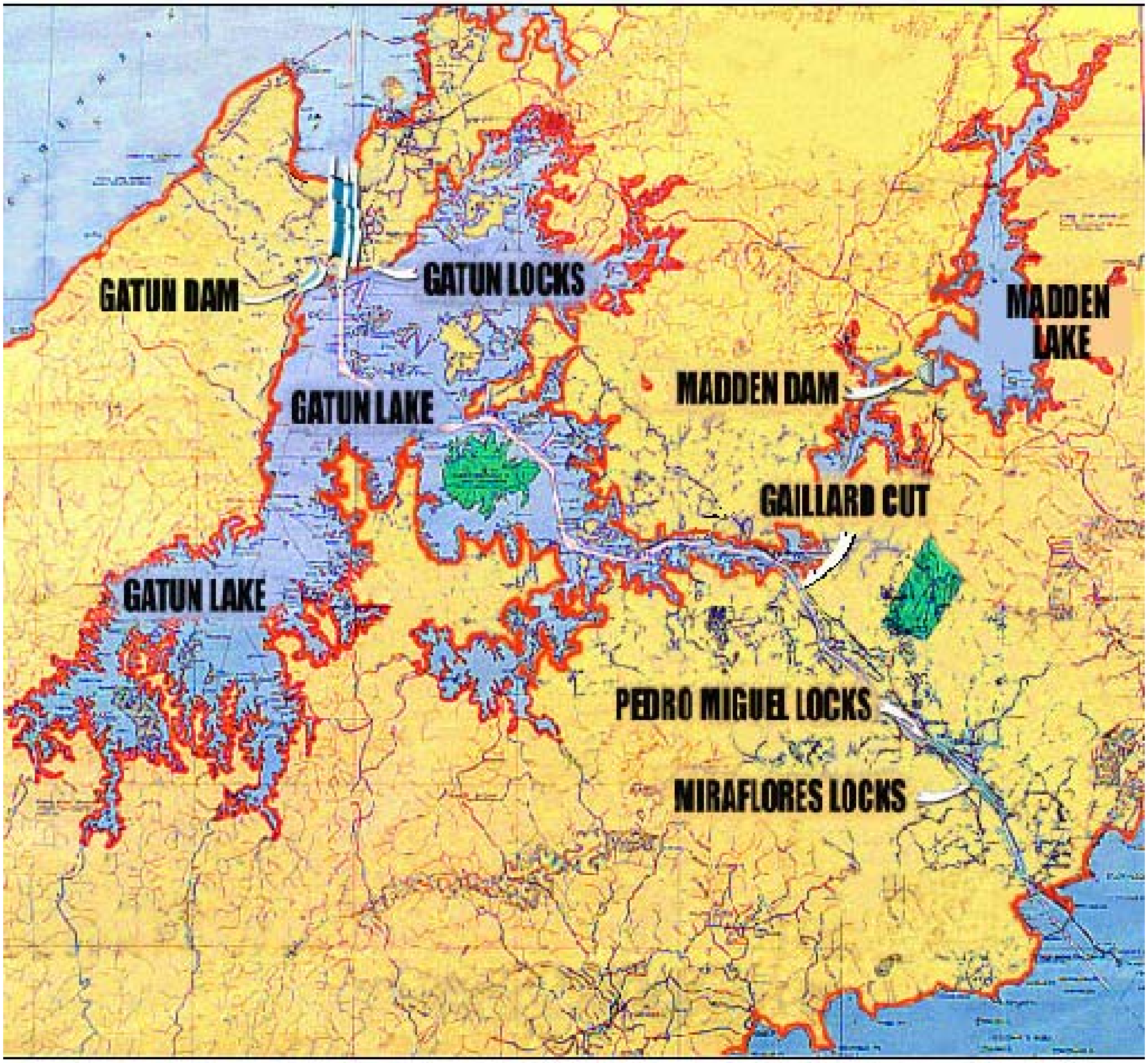


Plate 27 - 1 Project Location Map

PUMP STORAGE TO MADDEN LAKE

Plate 27 - 2 Proposed Feature Map

SECTION 28

PUMP GROUNDWATER TO GATUN LAKE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

Synopsis

This proposal consists of pumping groundwater to provide additional lockage water for operating the Panama Canal. The areas proposed for groundwater production are watersheds adjacent to the Panama Canal watershed. These areas include the northeast portion of the Colon Province, the northeast portion of the Cocle Province, and the southeast and southwest portions of the Panama Province. Pumping water from the Panama Canal watershed was not considered because, over time, the water produced would reduce the volume of surface and groundwater flowing into the canal naturally by almost an equal amount.

Two operating options are considered possible for pumping groundwater to Gatun Lake. Option 1 would consist of pumping groundwater into the Panama Canal watershed itself. Option 2 would consist of pumping groundwater to the communities that are now withdrawing water from the Panama Canal, and eliminate the withdrawals.

Because of the meager amount of groundwater available from the volcanic rock in the watersheds adjacent to the Panama Canal basin, a large number of wells (estimated at 11,000) would be required to supply the volume of water required for a single lockage. Due to the excessive cost of constructing and maintaining the piping required to connect this large number of wells, groundwater should not be considered a viable source of water to supplement Panama Canal operations. Additionally, because most surface waters are not potable, the rural population of Panama currently relies heavily on groundwater. Large well fields producing water for canal operations in rural areas would reduce productive yield of any existing system producing water for domestic consumption and would impact any future efforts. This would be unacceptable to the local population since it effectively eliminates any ready source of potable water.

Based upon the technical and operational difficulties associated with this proposed project, no formal cost, economic or environmental analyses will be made of this alternative. A rough order of magnitude cost estimate was performed. The average annual construction costs, excluding interest during construction, annual operation and maintenance and major replacement costs would amount to more than $550,000,000. Assuming that the development sequence for this alternative is as long as the proposed Rio Pacora project (8 years), the average annual benefits would not exceed $20,000,000.

This alternative should not be recommended for further consideration.

Hydro-geology

The aquifers from which the groundwater would be pumped consist of volcanic rocks of the Canaza Tucue Formation, the Panama Formation, the Playa Venado Formation, and the El Valle Formation. Producing wells from these formations would produce meager to small quantities of water. The maximum well yields are on the order of 20 LPM. The best yields are from wells located along fractures in the rocks, especially those at locations near rivers and lakes.

Project Features

GENERAL

This proposal consists of pumping groundwater to provide additional lockage water for operating the Panama Canal or to replace water drawn from the Lakes for other purposes. Two operating options are considered possible. Option 1 would consist of pumping groundwater into the Panama Canal watershed itself. Option 2 would consist of pumping the groundwater to the communities that are now withdrawing water from the Panama Canal, to eliminate the withdrawals.

WELLS

The wells for the system would generally be rock wells consisting of a cased upper portion and an uncased hole drilled into rock. The average yield from such wells should be about 20 LPM [taken from Figure C - 2 and Table C - 1 in Water Resources Assessment for Panama (see Appendix A)]. Average well depths would be about 50 m. Static water levels are estimated to be at a depth of about 5 m, and average drawdowns when pumping should be about 15 m. Minimum spacing between wells of 250 m would be required to avoid mutual interference. When in operation, it was assumed that each well would be pumped 16 hours per day. At this rate, 11,000 wells would be required to produce the water equivalent to one lockage approximately 55 million gallons (208,180 M^3).

Table 28 - 1 Well Summary

Average well depth	50 m
Maximum yield / well	20 LPM
Yield / day / well	19,000 l
Drilling cost per well	$7,000

PUMPING AND DISTRIBUTION

The pumping and distribution system required for using groundwater to supplement water for navigation was investigated based on several assumptions. The area of consideration is assumed mountainous and undeveloped. It is anticipated that the water wells would be installed in three well fields and that each of the three fields would be similar. Each of the well fields would pump into a zone header and the zone header would connect to a mainline header. For distribution purposes, each well field was considered to consist of one-third of the total estimated number of wells (11,000), i.e. approximately 3,700 wells. As indicated above, the spacing of the individual wells was assumed 250 m.

A connection or grid of wells with this spacing would require 9.6 by 105 m of piping per zone. The mainline header used to connect the three zones was assumed to be 8 km in length. An above ground steel pipeline supported by ring girders was evaluated for this effort. It would be suspended between supports with minimum spacing of 30 m.

If indeed the area for well field development is mountainous, it is imperative that pipeline velocities be limited to approximately 1.2 MPS or less to prevent hydraulic transients (water hammer) that could create extreme pressure conditions leading to catastrophic pipeline failure. Pipeline diameters carrying water from the well zone (collector piping) would be about 1,150 mm and the mainline conducting water to the lake at 1,980 mm. These pipeline sizes are based on the velocity stated above, and generally include one size collector pipe (1,150 mm) for an entire zone.

As mentioned earlier for an Option 2, the pumping of groundwater to the cities in lieu of Gatun Lake is not expected to reduce the amount of drinking water treatment required versus existing surface water treatment. From literature data referenced earlier, the Gatun Lake is estimated to have total dissolved solid ranges of less than 500 mg/l and most likely less than 200 mg/l on average. Groundwater will have a higher total dissolved solid ranges, approximately 300 to 750 mg/l. Hardness levels for Gatun Lake is expected to be less than 60 mg/l and sometimes as high as 120 mg/l. On the other hand, groundwater wells may have values ranging from 120 to 400 mg/l, which is likely to require an additional softening process to lower these values. It is also reported in the same literature that many shallow wells in the area have significant biological contamination. It is likely, for protection of health, the treatment for groundwater in shallow wells would receive as near a complex treatment as does the surface water with one addition: lime softening. Softening is necessary to reduce the impact caused by significantly hard water on the water system distribution and M&I users. In summary, it is not anticipated that the treatment of groundwater would be significantly less (and may be more complicated) than current treatment of surface water. Additional treatment facilities were not considered for Option 2, since this water would replace water normally withdrawn from the lakes.

Sources of Construction Material

The various components of the well installation including screens, pipe stems, valves, cement, pumps, and distribution piping are available within the Republic of Panama.

Real Estate Requirements

The areas proposed for groundwater production are watersheds adjacent to the Panama Canal watershed. These areas include the northeast portion of the Colon Province, the northeast portion of the Cocle Province, and the southeast and southwest portions of the Panama Province. Construction of this proposed project, including real estate for access roads, would require acquisition of approximately 11,000 ha in the remote areas of these provinces.

Development Sequence

Planning studies would be accomplished to evaluate the various features of each proposed well site. Each potentially viable site would be evaluated to assure that the wells presented would provide the water required to make it functional. Project implementation would begin with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, including the access roads, would be acquired initially. Lands for the well sites, staging areas, disposal areas, and pipeline distribution would then be acquired. The wells would be constructed, developed and added to the distribution system.

Project Costs

A rough order of magnitude cost estimate was developed for this alternative. Since specific features for the two options were not defined, costs for both were assumed to be in the same order of magnitude. Well pumps were assumed to operate at approximately 222 m total dynamic head at 23 LPM discharge capacity. A value of $0.070 / kWh is used for electrical consumption costs. Pipeline costs are estimated at $1,300 / m for well zone piping and $2,600 / m for mainline piping. Right-of-way development was placed at $625,000 / km.

The estimated construction cost to achieve one additional lockage per day using a groundwater pumping system is approximately $4.6 billion with a daily electrical consumption cost of $14,000 per lockage. The cost breakdown is as follows:

Table 28 - 2 Pumping and Distribution Summary

Item	Costs ($)
Well Zone Construction (Total for 3 zones)	3,797,000,000
Mainline Piping Construction	21,000,000
Right-of-way Development - entire project	593,000,000
Subtotal	4,411,000,000
Electrical Construction Total (5% of subtotal)	220,550,000
Construction Total	**4,631,550,000**

With a first cost of almost $4.6 billion and only one additional lockage, it is apparent that the benefit cost ratio for this alternative will be much less than one. The average annual construction costs, excluding interest during construction, annual operation and maintenance and major replacement costs would amount to more than $550,000,000. The development sequence for this alternative is as long as the proposed Rio Pacora project (8 years), which also produced approximately one lockage. Therefore, the average annual benefits would not exceed $20,000,000 and the benefit to cost ratio would be on the order of 0.04. Based on this information, this alternative should not be recommended for further consideration.

Pertinent Data

Table 28 - 3 presents pertinent data for the proposed project.

Table 28 - 3 Pertinent Data for Pump Groundwater Alternative

WELL DATA	
Estimated maximum well yield	20 LPD
Estimated maximum well depth	50 m
Average assumed static water depth	5 m
Average assumed well drawdown	15 m
Assumed optimum well spacing	250 m
Daily operating time	16 hr
Total number wells required per lockage	11,000
Steel Piping	
- Collector piping	1,150 mm diameter
- Mainline piping	1,980 mm diameter
WELL PUMPS	
- Operating head	222 m
- Discharge capacity	23 LPM
REAL ESTATE	
Well Fields and pipelines	11,000 ha

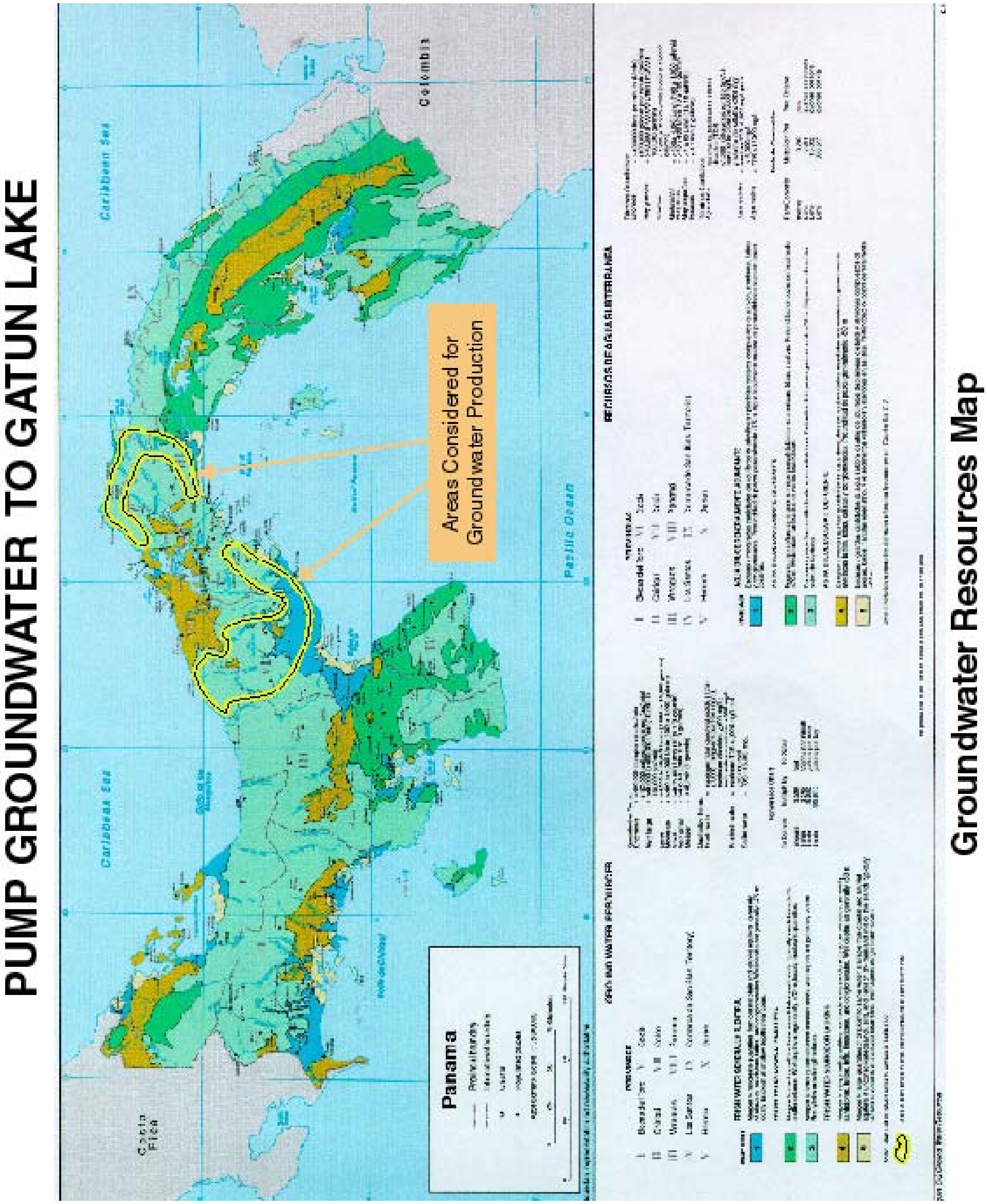


Plate 28 - 1 Groundwater Resources Map

SECTION 29

Pump Storage from Cocle del Norte Lake

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein would include a dam and lake on the Rio Cocle del Norte, a dam and lake on the Rio Toabre and a dam and lake on the Rio Caño Sucio. An open channel, cut through the watershed divide, would connect the Toabre Lake and the Caño Sucio Lake. Water would be pumped from Cocle del Norte Lake storage to Toabre Lake by a pump / turbine unit installed in the Rio Toabre Dam. Water from these lakes would be passed via a tunnel from the Caño Sucio Lake to the Indio Lake. The Indio Lake would be connected to the Panama Canal watershed at Gatun Lake via a second tunnel. Water impounded in these three lakes would be transferred to the Panama Canal watershed as needed to support navigation. See Figure 29 - 1 for a profile of the lake systems. This alternative will be referred to as the Pump Storage from Cocle del Norte Lake project throughout the remainder of this section.

The Rio Cocle del Norte watershed is located to the west of the Panama Canal watershed with the Rio Caño Sucio and Rio Indio watersheds between them. The proposed Rio Cocle del Norte dam site would be approximately 15 km inland from the Atlantic Ocean, and approximately 7 km downstream of the confluence of Rio Cocle del Norte and Rio Toabre. The Rio Cocle del Norte project would have a normal operating pool at elevation 65 m MSL operating down to elevation 50 m MSL. The structures for this proposed project would consist of a mass concrete gravity dam with a gated spillway and a hydropower plant (See Section 6 of this report for details of the Rio Cocle del Norte development).

The Rio Toabre basin is an eastern tributary to the Rio Cocle del Norte that is located approximately 70 km west of the Panama Canal. The Rio Toabre flows into the Rio Cocle del Norte approximately 17 km inland from the mouth of the Rio Cocle del Norte. The development plan presented herein includes a normal operating pool at elevation 100 m MSL with operating withdrawal down to elevation 90 m MSL. The structures for this proposed project would consist of an earth and rock fill dam, uncontrolled spillway and a hydropower plant with pump-back capability. The plan assumes that the Caño Sucio Lake project would be incorporated into this development. (See Section 9 of this report for details of the Rio Toabre development.)

The Rio Indio watershed is located adjacent to the western side of the Panama Canal watershed. The structures for this proposed project would consist of a rock fill dam, two saddle dikes, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and other outlet works. The tunnel would transfer water from Indio Lake to the Panama Canal watershed as needed for canal operations (see Section 5 of this report for details of the Rio Indio development).

The total project first costs of the proposed Pump Storage from Cocle del Norte Lake project are estimated to be $839,160,000. This cost includes the Rio Cocle del Norte, Rio Toabre, and Rio Caño Sucio Dams and the associated lakes, powerplants, pump back facilities at Rio Toabre Dam, and any modifications to other features included in other projects which are attributable to the addition of the Pump Storage from Cocle del Norte Lake alternative. The power required for pumping water from Cocle del Norte Lake to Toabre Lake was balanced against the power production capacity at Rio Cocle del Norte Dam in order to avoid any net increase in demand to the existing national power production system.

The Pump Storage from Cocle del Norte Lake project would provide additional water, equivalent to approximately 25.29 lockages per day, for canal operations up to the year 2070. This would contribute measurably to the reliability of the Panama Canal to serve its customers as future demands increase and it would greatly reduce the need for imposing draft restrictions, which results in light loading of vessels during periods of low water availability. Additional benefits would be realized in the form of increased hydropower. This number of additional lockages far exceeds the maximum capacity of the existing lock systems and could be used to accommodate any canal expansion that might take place in the future. Construction of the proposed Pump Storage from Cocle del Norte Lake would continue the existing high hydrologic reliability as demand for lockages increases above 180 percent of current demand levels.

The amount of hydropower energy that could be produced by the hydropower plants in the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water increase. With the inclusion of the hydropower plant at the proposed Rio Cocle del Norte and the Rio Toabre Dams, the system could produce additional megawatt hours of hydropower during high flow periods. However, much of this would be offset by energy required for the pumping operations dry periods.

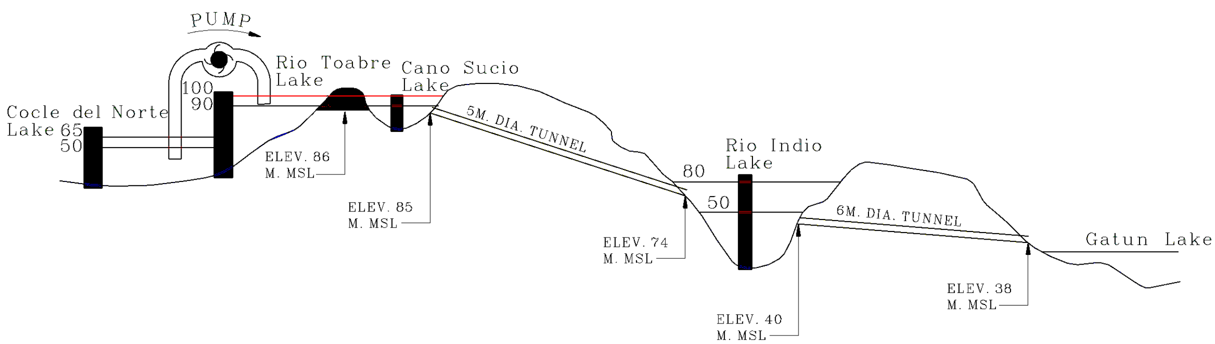


Figure 29 - 1 System Profile

Site Selection

The proposed Rio Cocle del Norte, Rio Toabre, and Rio Indio dam sites were chosen with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dams and minimizing the number of saddle dams required to contain the lakes. To maximize the water impounded, it was desirable to locate the dams as far downstream in the watersheds as possible. In choosing a site for the dam, the ideal location was where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow.

The site chosen for the proposed Rio Cocle del Norte Dam would be approximately 15 km inland from the Atlantic Ocean and approximately 7 km downstream from the confluence of Rio Cocle del Norte and Rio Toabre. This site would accommodate construction of a dam with a normal operating lake level at elevation 65 m MSL and a maximum flood storage lake level at elevation 69 m MSL. Plate 6 - 1 in Section 6 shows the location of the proposed Rio Cocle del Norte project.

The site chosen for the proposed Rio Toabre Dam would be approximately 30 km inland from the Atlantic Ocean and would be approximately 16 km upstream of the confluence of the Rio Cocle del Norte and Rio Toabre. This site would accommodate construction of a dam with a maximum operating lake level at elevation 100 m MSL and a maximum flood storage lake level at elevation 104 m MSL. The proposed Rio Caño Sucio dam site would be approximately 25 km inland from the Atlantic Ocean. This site would also accommodate construction of a dam with a maximum operating lake level at elevation 100 m MSL and a maximum flood storage lake level at elevation 104 m MSL.

The site chosen for the proposed Rio Indio Dam would be approximately 25 km inland from the Atlantic Ocean and would be near Cerro Tres Hermanas. This site would accommodate construction of a dam with a normal operating lake level at elevation 80 m MSL and a maximum flood lake level at elevation 82.5 m MSL.

Plate 29 - 1 shows the location of the proposed Rio Cocle, Rio Toabre, Rio Caño Sucio and Rio Indio projects. See Sections 5 and 9 of this report for details concerning the development of the Rio Indio and Rio Toabre-Rio Caño Sucio projects.

Hydrologic Considerations

Development of the hydrologic data for each project is well documented in the project sections (see Sections 5, 6 and 9). However, revisions were required for the Rio Cocle del Norte flow sequence. The site chosen for the proposed Rio Cocle del Norte Dam would be approximately 7 km downstream from the confluence of Rio Cocle del Norte and Rio Toabre. Streamflow records for Rio Cocle del Norte at El Torno and Rio Toabre at Batatilla hydrologic stations were combined to represent the dam inflow for Rio Cocle del Norte alternatives described in Sections 6, 7 and 8. However, those alternatives did not include the Rio Toabre Dam. For this alternative, discharge at the Rio Cocle del Norte dam site is extrapolated from recorded and correlated stream flow data for the Rio Cocle del Norte at El Torno hydrologic station only. Discharges from the Rio Toabre Dam will flow directly into the Cocle del Norte Lake.

Rainfall runoff produces an average annual flow of 109 CMS at the Rio Cocle del Norte proposed dam site, 39 CMS at Rio Toabre proposed dam site, and 25 CMS at Rio Indio proposed dam site.

Because of the proximity of the projects to Gatun Lake, and because of the absence of site-specific information, the monthly evaporation rates established for Gatun Lake were considered appropriate for the evaporation rates of Cocle del Norte, Toabre, Caño Sucio, and Indio Lakes.

Geologic Considerations

Refer to Sections 5, 6, and 9 for specific project geologic discussion.

Lake Operation

As described in Section 6, Cocle del Norte Lake at 65, two operating options were considered for periods when water would be transferred from Cocle del Norte Lake to the Panama Canal watershed for canal operations. Cocle del Norte Lake at 65 project with Option 1 was selected for combination with the Toabre / Caño Sucio Lake system. Operating Option 1 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 65 m MSL down to the minimum operating lake level at elevation 50 m MSL, with 1,960,560,000 M^3 of useable storage. The maximum flood storage lake level would be at elevation 69 m MSL. The volume between the maximum flood storage lake level and the normal operating lake level would be used to store floodwaters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Cocle del Norte downstream of the dam.

Toabre and Caño Sucio Lakes would be connected by a channel and would be operated as one lake. One operating option was considered in this study for periods when water would be transferred from the combined Toabre and Caño Sucio Lakes to the Panama Canal watershed for canal operations. The water surface of the Toabre / Caño Sucio Lake would fluctuate from the maximum operating lake level at elevation 100 m MSL down to the minimum lake operating level at elevation 90 m MSL, providing 468 MCM of useable storage.

As described in Section 5, Rio Indio, two operating options were considered for periods when water would be transferred from Indio Lake to the Panama Canal watershed for canal operations. Indio Lake Option 2 was selected for combination with the Pump Storage from Rio Cocle del Norte project. This option would allow the water surface of Indio Lake to fluctuate from elevation 80 m MSL down to elevation 50 m MSL, providing 993 MCM of useable storage.

Water would be transferred from Cocle del Norte Lake to Toabre Lake and then to Indio Lake for release to the Panama Canal watershed for use in canal operations. The normal operating lake level at Toabre Lake would be higher than at the Cocle del Norte Lake. Operation of the linked system of lakes, Cocle del Norte Lake, Toabre Lake, Indio Lake, and the Panama Canal watershed, would require a unique approach. The water in storage at the Indio Lake would have to be transferred to the Panama Canal watershed initially. Water could then be transferred from Toabre Lake while minimizing the spillage at Indio Lake. As Toabre Lake is lowered, water from Cocle del Norte Lake would be pumped to replenish the transferred water. The required energy for the pumping operation is not available on the existing electrical grid system; therefore Rio Cocle del Norte Dam would generate energy simultaneously to supply power for the Toabre pumps. This would require releasing and pumping water from the Cocle del Norte Lake at the same time. The pump / turbine units at Rio Toabre Dam could be used to produce hydropower during periods of sufficient water supply to the canal system. Rio Cocle del Norte Dam would store water during excess generation at the Rio Toabre project to provide additional supply of water for the pumping operations. The pumping and generation operation would require a delicate balance to first provide additional water to the Panama Canal system and maximize the hydropower potential.

Table 29 - 1 shows the lake levels for operation of this alternative.

Table 29 - 1 Lake Operating Levels

Lake Level	Cocle del Norte	Toabre and Caño Sucio	Indio
	(m MSL)		
Normal Operating Lake Level	65	100	80
Minimum Operating Lake Level	50	90	50
Maximum Flood Lake Level	69	104	84

Project Features

GENERAL

Refer to Sections 5, 6 and 9 for details of the structures for these proposed projects not included below. The following paragraphs provide a description of required changes to the proposed structures and improvements for the Pump Storage from Rio Cocle del Norte project.

Performance of the design was only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. The PCC received separate documentation that contained assumptions and design calculations for the reconnaissance level investigations of these structures. Further development of this project into the planning studies would require accomplishment of optimization of the project features and improvements.

EMBANKMENTS

Rio Cocle del Norte Dam

The dam at Rio Cocle del Norte would be a mass concrete gravity structure with a gated ogee crest spillway containing two gate bays. It was assumed that the base of the dam would be recessed approximately 10 m into the foundation across the full length of the dam. The dam would be stepped up the valley walls at the abutments. Foundation grouting would be required across the entire base of the dam and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

The hydropower plant penstocks would be constructed in the mass concrete gravity structure adjacent to the spillway. A series of low-level sluiceways would be constructed in the spillway to provide for diversion of the Rio Cocle del Norte flows during construction and to allow for emergency drawdown of the lake. Minimum flows were assumed to be released through the gated spillway; however, multilevel intakes with outlets into the spillway tailrace channel could be incorporated for water quality releases.

Rio Toabre and Rio Caño Sucio Dams

The proposed Rio Toabre Dam would be an embankment with the top at elevation 105 m MSL and with a crest width of 13 m. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam at its highest point would be approximately 90 m high, and the overall length would be 1,130 m.

The proposed Rio Caño Sucio Dam would be an embankment with the top at elevation 105 m MSL and with a crest width of 13 m. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam at its highest point would be approximately 20 m high, and the overall length would be 185 m.

The actual side slopes and crest width would be determined during further study and would be contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. See Section 5 for typical embankment sections.

SPILLWAYS

Rio Cocle del Norte Spillway

The two gated spillway bays at the Rio Cocle del Norte Dam would be designed to pass the entire design flood for the lake. The spillway bays would be located near the center of the existing channel. The spillway crest would be at elevation 50 m MSL. Each spillway bay would be fitted with mechanically operated gates measuring 17 by 15.5 m. Tainter gates with torque tube and wire rope gate lifting devices, operated by electric motors mounted on the top of the spillway piers, would be used. For periodic maintenance of the gates, a bridge would be placed across the top of the spillway to facilitate the placement of stoplogs between the spillway piers. Typical sections of the concrete dam and spillway are presented on Plates 6 - 5 and 6 - 6 in Section 6 of this report.

Rio Toabre Spillway

At the proposed Rio Toabre Dam, an uncontrolled ogee spillway with a length of 219 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 3,391 CMS at a maximum flood storage lake level at elevation 104 m MSL. The spillway design discharge was equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway would be located within the abutment adjacent to the right end of the dam and would consist of a mass concrete sill section embedded in the natural rock. A sloped and / or stepped, natural rock cut tailrace channel would return flow to the existing stream. The tailrace channel would extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. See Plate 9 - 2 of Section 9 for the location of the spillway. A typical section through spillway would be similar to that shown for the Rio Indio project, see Section 5.

Rio Caño Sucio Dam Spillway

At the proposed Rio Caño Sucio Dam, an uncontrolled ogee spillway with a length of 74 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 1,141 CMS at a maximum flood storage lake level at elevation 104 m MSL. The spillway design discharge was equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway would be located within the abutment adjacent to the left end of the dam and would consist of a mass concrete sill section embedded in the natural rock. A sloped and / or stepped, natural rock cut tailrace channel would return flow to the existing stream. The tailrace channel would extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. See Plate 9 - 2 of Section 9 for the location of the spillway. The spillway profile would be similar to that shown for the Rio Indio project, see Section 5, although it would be much smaller at this location.

IMPOUNDMENTS

The lake formed by the proposed Rio Cocle del Norte Dam would have a normal operating lake level at elevation 65 m MSL. The surface area at the normal operating lake level would be approximately 17,940 ha. With the minimum operating lake level at elevation 50 m MSL, the surface area would be approximately 10,730 ha. At the maximum flood storage lake level at elevation 69 m MSL, the surface area would be approximately 20,090 ha. At the top of dam at elevation 70 m MSL, the surface area would be approximately 20,640 ha.

The lake formed by the proposed Rio Toabre Dam would have a maximum operating lake level at elevation 100 m MSL and would have a surface area of approximately 4,850 ha. At the minimum operating lake level, elevation 90 m MSL, the surface area would be 3,220 ha. At maximum flood storage lake level, elevation 104 m MSL, the surface area would be approximately 5,830 ha. At the top of dam, elevation 105 m MSL, the surface area would be approximately 6,115 ha.

The lake formed by the proposed Rio Caño Sucio Dam would have a maximum operating lake level at elevation 100 m MSL and would have a surface area of approximately 1,355 ha. At the minimum operating lake level at elevation 90 m MSL, the surface area would be 245 ha. At maximum flood storage lake level, elevation 104 m MSL, the surface area would be approximately 2,040 ha. At the top of dam, elevation 105 m MSL, the surface area would be approximately 2,235 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas required for construction of the dams and associated structures, inter-basin transfer facilities, hydropower plants, access roads, and disposal and staging areas. For the Rio Cocle del Norte project, clearing only would be required for the 7,210 ha in the lake area between normal operating lake level at elevation 65 m MSL and the minimum operating lake level at elevation 50 m MSL, and for the transmission lines. For the Toabre and Caño Sucio Lake areas, clearing only would be required on the 2,740 ha in the cumulative lake area between the maximum operating lake elevation at 100 m MSL and the minimum operating lake elevation at 90 m MSL.

INTER-BASIN TRANSFER FACILITIES

The Rio Cocle del Norte project proposed in Section 6 consisted of an inter-basin transfer tunnel excavated beneath several watersheds to connect the proposed Cocle del Norte Lake with Indio Lake. The finished tunnel would be concrete lined, 7.6 m in diameter, and approximately 18 km in length. Pumping of storage from Cocle del Norte Lake to Toabre Lake would eliminate the need for the inter-basin transfer tunnel. The 3 m finished diameter inter-basin transfer tunnel included in the proposed Rio Toabre project between Caño Sucio Lake and Indio Lake would need to be enlarged to a 5 m finished diameter to pass the combined flows from Toabre Lake and Cocle del Norte Lake at elevation 65 m MSL. The maximum capacity of this tunnel would be 153 CMS, and it would have invert elevations at its inlet and outlet ends of 85 and 74 m MSL respectively. This would result in a slight lengthening of the tunnel over that indicated in the Rio Toabre evaluation, See Section 6. The additional cost of this tunnel resulting from changes in diameter and length would be directly attributable to the Pump Storage from Rio Cocle del Norte project and are included in the accompanying construction cost estimate as changes in the Rio Toabre facilities.

PUMP HYDROPOWER PLANTS

The proposed Rio Toabre Dam would support installation of a 22 MW hydropower plant (refer to Section 6). For the Pump Storage from Cocle del Norte Lake alternative, the Rio Toabre Dam would require a 122 MW hydropower pump-generator plant. The power required for pump back capability at the Rio Toabre was balanced against the power production capacity at the Rio Cocle del Norte project in order to avoid any net increase in demand to the existing national power production system. The pumping from Cocle del Norte Lake would transfer water to Toabre Lake for canal operation and hydropower production. The Rio Cocle del Norte, Rio Toabre and Rio Indio hydropower facilities would be designed and configured to function as part of the national power grid. A 115 kV transmission line would be constructed to carry the energy to a connection with the grid near La Chorrera, connecting from there back through Rio Caño Sucio, Rio Toabre, and Rio Cocle del Norte hydropower facilities. The estimated electrical output and assumed plant configurations are included in the Pertinent Data listing at the end of this section.

OUTLET WORKS

Outlet works for the Rio Cocle del Norte Dam are described above in the Spillway section. An outlet works system at the Rio Toabre Dam would provide for diversion of the Rio Toabre during construction. After completion of construction, it would be used to supply water for production of hydropower, allow for emergency drawdown of the lake after it is raised and placed in service, facilitate the pumping of water from Cocle del Norte Lake to Toabre Lake and allow minimum flow to pass by the dam.

These water handling facilities would consist of two 8 by 8 m horseshoe-shaped tunnels passing through the dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures. The diversion tunnel would be approximately 1,100 m in length. It would have an inlet invert elevation at 17 m MSL and an outlet invert elevation at 15 m MSL. The diversion tunnel would serve in combination with a cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of approximately 1,789 CMS at the site without regulation from the dam. The cofferdam would measure 15.5 m above the upstream invert of the tunnel. A separate 0.9 m diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be approximately 1,100 m in length and it would have an invert elevation of 15 m MSL. Intake for minimum flow would be through individually gated water quality intake ports located at various levels in the intake structure. The elevations of these intakes would be established during environmental water quality investigations made during subsequent phases of study. The capacity of the minimum flow conduit would be 4.0 CMS. The hydropower intake would also be elevated to prevent silt from entering the power units. At the downstream end of the tunnel, a bulkhead structure would be installed to close the construction diversion and to divert lake water into the hydropower penstock. The closure would be configured so that it could be removed in the event that the Toabre Lake had to be drawn down. The intake structure would be similar to that depicted for the Rio Indio site, see Section 5.

At the Rio Caño Sucio Dam, an outlet works system would be required only to provide minimum flows to the Rio Caño Sucio downstream of the dam. Diversion of the Rio Caño Sucio flows during construction could be provided by initially installing the Caño Sucio to Indio tunnel and by providing for flood releases through the divide between the Rio Caño Sucio and Rio Toabre basins to the west. The Caño Sucio to Indio tunnel and the channel connecting Caño Sucio to Toabre Lakes would also allow for emergency drawdown of the lake after it is raised and placed in service.

These water-handling facilities would consist of a 406 mm outlet pipe passing through the dam, an intake structure located in the lakeside face of the dam, and various gates and water conduits. Intake for minimum flow would be through individually gated water quality intake ports located at various levels in the intake structure. The elevations of these intakes would be established during environmental water quality investigations made during subsequent phases of study. The minimum flow outfall piping would be approximately 140 m in length. It would have an outlet invert elevation at 83 m MSL. The capacity of the minimum flow conduit would be 0.74 CMS.

ACCESS ROUTE

Access to the lake sites and the various construction sites must be provided from the main population centers on the Atlantic and Pacific coasts, Colon and Panama City respectively.

The route chosen for this study would originate at the Rio Indio dam site using the access routes that were constructed to reach the Rio Indio dam site. It would cross the Rio Indio below the dam then proceed westward and southward to the outlet end of the Caño Sucio-Indio inter-basin tunnel on the Rio Uracillo. From there, the route would extend westward to the inlet end of the tunnel, then westward to the Rio Caño Sucio dam site, westward to the Toabre-Caño Sucio channel cut, then north and west to the Rio Toabre dam site. The entire route would cover approximately 32 km through mountainous terrain and would require 8 stream crossings. This part of the route and the features it would connect are shown on Plate 9 - 1 of Section 9.

The route would then proceed generally northwestward by new roads to the Rio Cocle del Norte dam site and to the other construction areas. Note that this route, as well as the secondary access to the inter-basin tunnel outlet noted above, assumes that the Rio Indio project would be in place prior to the construction of the Rio Caño Sucio, Rio Toabre, and Rio Cocle del Norte projects.

This new corridor into the interior of the country west of the Panama Canal would also be of benefit to those living in that region by providing roadway access to the main centers of commerce.

Sources of Construction Material

Rock removed from the spillway sites at Rio Toabre and Rio Caño Sucio Dams would be used as fill in the embankment portion of the dams. Impervious materials for the core section might have to be obtained from outside the project area; however, for this study, it was assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that insufficient impervious materials are available, then other materials such as roller compacted concrete should be considered for construction of the dam.

For the Rio Cocle del Norte, Rio Toabre and Rio Caño Sucio Dams, foundation grouting might be required across the entire base of the dams and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would have to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Pump Storage from Cocle del Norte Lake project would be located in the Cocle and Colon Provinces. Construction of this proposed project would require approximately 21,640 ha. Table 29 - 2 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 29 - 2 Real Estate Requirements for Cocle del Norte Lake

Project Feature	Land Required (ha)
Lake	20,640
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	21,640

The proposed Rio Toabre and Rio Caño Sucio dam sites are located in the Cocle, Colon and Panama Provinces. About 5,600 people inhabit the Rio Cocle del Norte area, with concentrations in the towns of Coclecito and Cutevilla. Farms and ranches occupy approximately 40 percent of the Cocle del Norte project area. The Rio Toabre and Rio Caño Sucio areas have a dispersed population of approximately 800 people throughout the area. People are concentrated in the towns of El Guayabo o Toabre Abajo and El Valle de San Miguel, El Caraño, Las Maravillas, Santa Maria (or Caño Sucio), Riecito Abajo, and approximately 11 smaller settlements. Farms, ranches, some teak and tobacco plantations of various sizes occupy approximately 80 percent of the land in the Rio Toabre and Rio Caño Sucio project areas. There are also some mineral and ore deposits in the impoundment areas. Approximately 9,700 ha would be required for construction of this proposed project. The amount of land required for the various project features is shown in Table 29 - 3.

Table 29 - 3 Real Estate Requirements for Toabre / Caño Sucio Lake

Project Feature	Land Required for Rio Toabre (ha)	Land Required for Rio Caño Sucio (ha)	Total Land Required (ha)
Lake	6,100	2,200	8,300
Dam site	200	100	300
Staging area	200	100	300
Housing and facilities	200	0	200
Disposal area	400	200	600
Total	7,100	2,600	9,700

The proposed Rio Indio project would be located in the Cocle, Colon, and Panama Provinces. Construction of this proposed project would require acquisition of approximately 5,600 ha. Table 29 - 4 shows the amount of land required for the various project features.

Table 29 - 4 Real Estate Requirements for Indio Lake

Project Feature	Land Required (ha)
Lake	4,600
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	5,600

Relocations

Rio Cocle del Norte

The lake would be located in a sparsely settled region with few roads and utilities. This area is devoted primarily to subsistence farming, pineapple growing, and ranching. Structures and individuals located in the lake area below elevation 70 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. Other relocations associated with the proposed project would be minimal.

Rio Toabre with Rio Caño Sucio

The lake would be located in a sparsely populated region with few roads and utilities. Relocations associated with the proposed construction would be moderate. Structures and individuals located below elevation 105 m MSL within the lake would require relocation due to the normal lake inundation and the need to secure the lake perimeter for flood considerations. The significant villages within the proposed lake area, noted above under Real Estate

Requirements, would require relocation of each entire village, including not only dwellings but service facilities such as schools, churches, and public utilities.

Rio Indio

The lake would be located in a sparsely populated region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. Structures and individuals located in the lake area below elevation 85 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. The required relocations would include the five towns in the lake area (El Limon, Los Uveros, La Boca de Uracillo, Aguila, and Tres Hermanas), approximately 30 other small settlements (just a few structures), and numerous isolated structures. The five towns all have elementary schools, churches, electricity, and limited telephone coverage.

Development Sequence

For the economic evaluation of this project, it was assumed that the planning for the Rio Cocle del Norte, Rio Toabre and Rio Caño Sucio projects would begin during the construction of the Rio Indio project. Construction of the Rio Toabre-Rio Caño Sucio project would be started immediately following completion of the Rio Indio project followed by the construction of Rio Cocle del Norte project.

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed for its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising and award phase, and through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, would be acquired initially. Lands for the dam sites, staging areas, disposal areas, and lakes would then be acquired.

Access roads would be constructed to the dam sites and the inter-basin transfer tunnel inlet and outlet sites. Once highway access to the sites has been established, a camp would be built to house workers during construction.

Environmental programs would begin shortly before starting construction. The relocation of all towns, settlements and isolated structures within the Cocle del Norte and the Toabre-Caño Sucio lake areas would be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project would continue throughout the construction phase.

Construction of the Rio Toabre and the Rio Caño Sucio Dams would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. The channel connecting the Toabre and Caño Sucio Lake areas would be constructed first. The Rio Caño Sucio dam site would then be isolated using upstream and downstream cofferdams and the Rio Caño Sucio flows would be diverted to the Rio Toabre. The Rio Caño Sucio Dam foundation would then be excavated and grouted, and the dam and minimum flow structure would be constructed. Excavation for the inter-basin transfer tunnel, the Rio Toabre Dam intake structure, the diversion tunnel for construction at the Toabre dam site, and the spillways at both sites would proceed simultaneously. Where possible, materials removed from the excavations would be placed directly into the earth and rock fill portions of the dams. Once the intake structure and diversion tunnel at Rio Toabre were completed, the dam site would be isolated using upstream and downstream cofferdams, which would eventually become part of the main dam, and the stream would be diverted through the tunnel. The Rio Toabre Dam foundation would then be excavated and grouted, and the dam constructed. Concurrently with construction of the dam, the hydropower plant site downstream of the dam would be excavated, and the powerhouse construction would be started. The power transmission lines would be constructed during this time frame also. Upon completion of the Rio Toabre Dam and the inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped using the head gates in the Toabre intake structure, and lake filling would begin. Simultaneously with this operation, the downstream gate and flow separation structure would be constructed to provide for closure of the diversion tunnel and diversion of the tunnel flows to the hydropower penstock(s). The Rio Toabre Dam minimum flow conduit would be installed through the diversion tunnel at this time. Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Concurrent with the construction of Rio Toabre Dam, the Rio Cocle del Norte Dam construction would begin with the clearing and grubbing of the construction sites and the clearing of the lake area, followed by excavation for the dam and appurtenant structures. The concrete gravity dam would be constructed in two stages. The first stage construction would begin with stream flows being routed around the construction area in an excavated, open channel and construction of the first stage cofferdam. The dam foundation would then be excavated and grouted, and the portion of the dam within the first stage cofferdam would be constructed. Concurrently with construction of the dam, the hydropower plant site downstream of the dam would be excavated and the powerhouse construction would be started. Work on clearing and construction for the electric power transmission lines would begin at this time. With completion of the first stage dam and hydropower plant construction, the cofferdam would be removed and stream flows would be diverted through the low level sluice. A cofferdam would be constructed to protect the second stage construction area. The remaining gravity dam foundation work and dam construction would be completed. The spillway gates and operating machinery, and the hydropower units, would be installed concurrently with the second stage dam construction. Upon completion of the dam and the inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped and reservoir filling would begin. Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

The timing of the construction efforts would be planned to minimize the construction time. Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 10 years, from initial planning to lake filling. Figure 29 - 2 depicts the development sequence of the various project features.

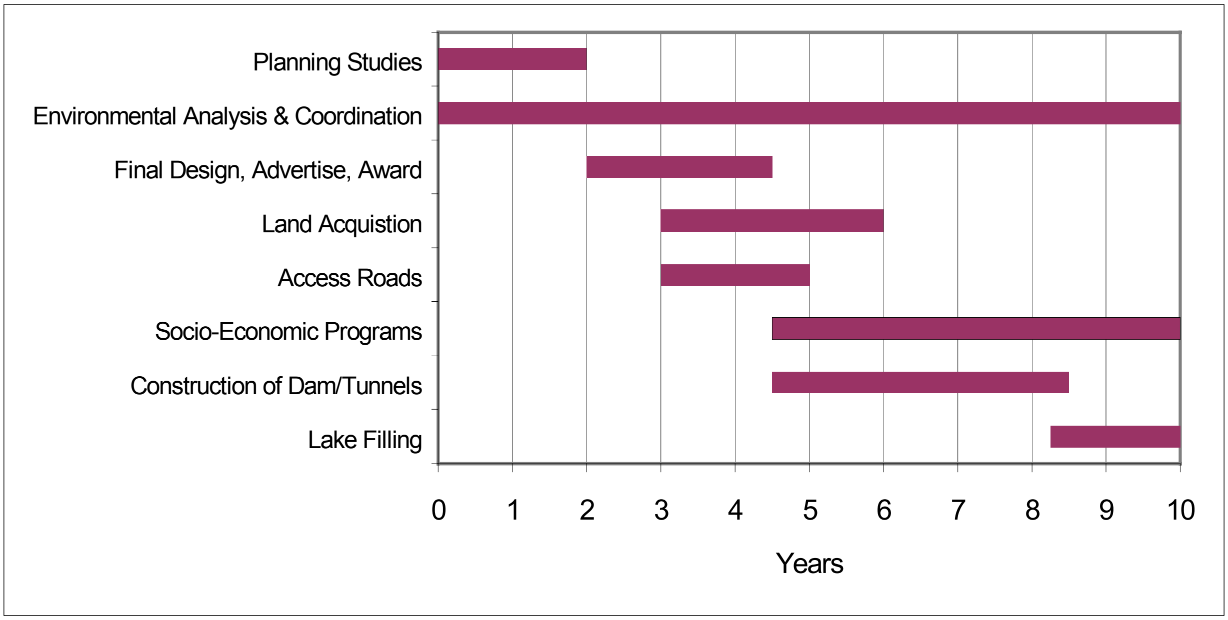


Figure 29 - 2   Development Sequence

Hydrologic Reliability

In order to determine the effect of the proposed project on the hydrologic reliability of the Panama Canal, the alternative was evaluated as linked with the Panama Canal watershed. A HEC-5 model was constructed with the Cocle del Norte Lake, Toabre / Caño Sucio, and Indio Lakes linked to the Panama Canal model. Water stored in Cocle del Norte Lake was pumped to Toabre / Caño Sucio Lake as needed. Then water was supplied to Gatun Lake when shortages were expected using the Indio Lake as a conduit. Excess flows in the Rio Cocle del Norte and Rio Toabre / Rio Caño Sucio were still released down the Rio Cocle del Norte, taking advantage of the hydropower generation at both dams when possible. Minimum flow requirements were deducted from the waters made available to the Panama Canal watershed and released down the Rio Cocle del Norte and Rio Caño Sucio.

HEC-5 model simulations were conducted for both the existing Panama Canal system and the system operating with the proposed alternative providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record. Figure 29 - 3 presents the resulting hydrologic reliability for two configurations with demands increasing up to 180 percent of current demands. These configuration are: (1) the existing system, and (2) Cocle del Norte Lake with operating lake level varying between elevations 65 and 50 m MSL, Toabre Lake with operating lake level varying between elevations 100 and 90 m MSL, and Indio Lake with operating lake level varying between elevations 80 and 50 m MSL.

The horizontal axis along the bottom of Figure 29 - 3 reflects demands as a ratio of the 5-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 29 - 3, the existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability with a demand ratio of 1.0 would be 100 percent, and the hydrologic reliability with a demand ratio of 1.8 would be 99.71 percent. Table 29 - 8 displays the number of lockages associated with various levels of reliability.

With the construction of the proposed Pump Storage from Cocle del Norte Lake project, the existing high hydrologic reliability could be continued as demand for lockages increases up to at least 80 percent above current demand levels equivalent to approximately 30.95 lockages per day. This study only addressed demand levels that would be required to meet the needs of the Panama Canal system through the year 2070, which approximated 25.29 additional lockages above the year 2000 demand levels. This project is capable of providing even more than required before the reliability drops below 99.6 percent.

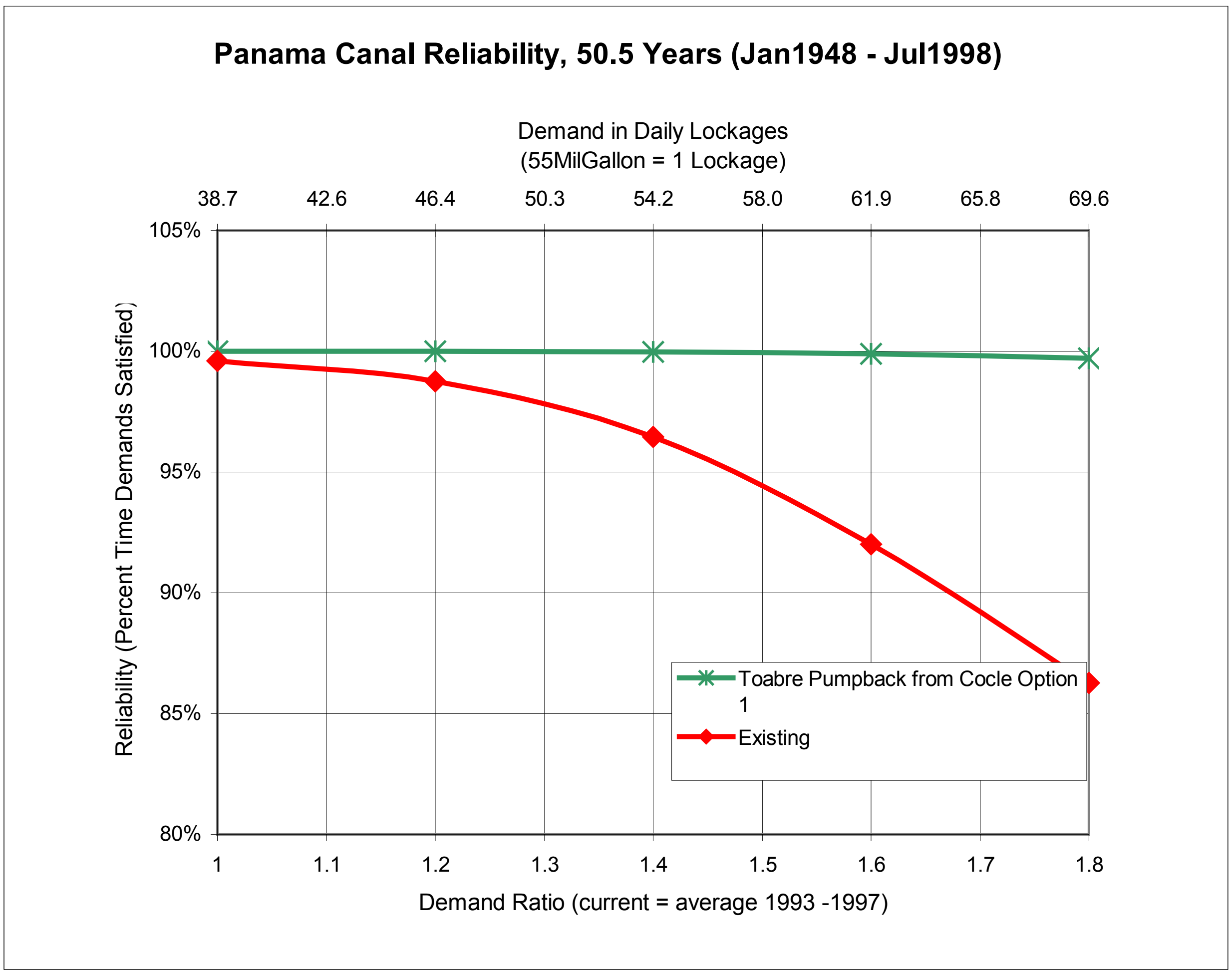


Figure 29 - 3 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts shown on Plate 29 - 1, and were primarily assembled from individual estimates made for the various component projects which would comprise this alternative. New costs were developed for the pump-generation units required by this alternative. The unit prices applied to these quantities were based on: historical information from previous estimates prepared for similar construction in the Republic of Panama, previous estimates for similar construction in the Southeastern United States, information gathered from U.S. Army Corps of Engineers, Mobile District, Construction Division personnel in the Republic of Panama, and the publication, Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1979.

Engineering and design is estimated to be 12 percent and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent was included contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $839,160,000. Table 29 - 5 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 29 - 5 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	78,350,000
Access Roads	18,427,000
Clearing and / or Grubbing	9,752,500
Diversion Tunnel	63,811,328
Inter-basin Transfer Toabre to Caño Sucio	659,750
Inter-basin Transfer Tunnel [1/]	18,305,370
Inter-basin Transfer Tunnel [2/]	40,984,506
Cofferdam	14,839,624
Dam	120,332,781
Spillway	55,311,320
Channel	415,000
Intakes	12,050,746
Pump turbines	92,000,000
Hydropower Plants	24,520,030
Transmission Lines	9,680,000
Subtotal	559,439,955
E&D, S&A, Field Overhead	111,881,991
Contingencies	167,831,987
Total Project First Costs	839,159,933 **approximately** 839,160,000

[1/] The difference in costs to enlarge the inter-basin transfer tunnel connecting Caño Sucio Lake and Indio Lake from a 3 m finished diameter tunnel to a 5 m finished diameter tunnel are included.
[2/] The difference in costs to enlarge the inter-basin transfer tunnel connecting Indio Lake and the Panama Canal watershed from a 3 m finished diameter tunnel to a 6 m finished diameter tunnel are included.

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Indio project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 11 that would include a station manager, a multi-skilled supervisor, 3 leaders (Electronics / Instrumentation, Electrical and Mechanical), 5 craftsmen, and 1 laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the proposed project. The part-time staff would consist of three mechanics and three electricians. The annual costs of the staff are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $400,000 per year for the main project facilities.

Major Replacements
The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 100 years. To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it was assumed that specific items would cost the same as at present. No allowance was made for salvageable fixed parts. Table 29 - 6 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements would be $728,500 and the average annual replacement costs would be $88,000.

Table 29 - 6 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	10,345,500	35,800
Bridges	50	1	1,687,500	5,800
Intake				
Head Gates	50	1	3,201,900	11,100
Minimum Flow Gates	50	1	90,000	300
Stoplogs	50	1	477,750	1,700
Trashracks	50	1	155,250	500
Access Stairs	50	1	67,500	200
Pump-Turbines	50	1	138,000,000	477,500
Hydropower Plant				
Turbines and Generators	33	1	4,200,000	99,800
Station Electrical Equipment	33	1	1,170,000	27,800
Switchyard Equipment	33	1	810,000	19,200
Miscellaneous Plant Equipment	33	1	696,000	8,800
Transmission Lines	50	1	11,550,000	40,000
Total			172,451,400	728,500
Average Annual Replacement Costs				88,000

Annual Costs

The project first costs for the proposed Pump Storage from Cocle del Norte Lake project are estimated to be $839,160,000, and it includes $61,477,000 to enlarge the inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed from a 3 m finished diameter tunnel to a 6 m finished diameter tunnel and modify the intake structure to the tunnel. The total project first costs also include the $245,868,000 costs for the Rio Indio project (see Section 5) and are estimated to be $1,085,028,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. It was assumed that the 6 m finished diameter inter-basin transfer tunnel from Indio Lake to the Panama Canal watershed would be constructed at the Rio Indio project instead of the 3 m finished diameter inter-basin transfer tunnel. Interest on the total project first costs of $777,683,000 ($839,160,000 - $61,477,000) was computed from mid-year throughout the 10-year development period from initiation of Planning and Design until the lake was filled. Interest during construction for the Rio Indio project including the enlarged inter-basin transfer tunnel at the Rio Indio project was computed from mid-year throughout its 17-year development period until lake filling was complete at the Rio Cocle del Norte project. The interest during construction at 12 percent would be $406,645,000 for Rio Cocle del Norte / Rio Toabre / Rio Caño Sucio, and $614,902,000 for Rio Indio for a total interest during construction of $1,021,547,000. These costs were added to the total project first costs for total project investment costs of $2,106,575,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $253,667,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 29 - 7 contains a summary of the $255,714,000 total annual costs.

Table 29 - 7 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Rio Cocle del Norte, Rio Toabre & Rio Caño Sucio	777,683,000
Total Project First Costs – Rio Indio	245,868,000
Enlarged Tunnel and Modify Tunnel Intake at Rio Indio project	61,477,000
Interest During Construction – Rio Cocle del Norte, Rio Toabre & Rio Caño Sucio	406,645,000
Interest During Construction – Rio Indio	614,902,000
Total Project Investment Costs	2,106,575,000
Annual Average Investment Costs	253,667,000
Operation and Maintenance Costs	
Staff Costs - Rio Cocle del Norte, Rio Toabre & Rio Caño Sucio	500,000
Staff Costs - Rio Indio	500,000
Ordinary Maintenance Costs - Rio Cocle del Norte, Rio Toabre & Rio Caño Sucio	420,000
Ordinary Maintenance Costs - Rio Indio	320,000
Major Replacement Costs - Rio Cocle del Norte, Rio Toabre & Rio Caño Sucio	88,000
Major Replacement Costs - Rio Indio	219,000
Total Average Annual Costs	255,714,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Section 4. The following paragraphs present the results of the economic investigations for the proposed Pump Storage from the Cocle del Norte Lake project. The 50-year planning period for this proposal is 2016 to 2066.

The proposed Pump Storage from the Cocle del Norte Lake project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 29 - 8 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages were obtained from the data used to develop Figure 29 - 3. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 29 - 8 Panama Canal Hydrologic Reliability
(Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Rio Cocle del Norte [1/] (%)
1	2000	38.68 [2/]	99.60	100.00
	2010	45.11	98.91	100.00
1.2		46.42	98.76	100.00
	2015	46.82	98.64	100.00
	2020	47.61	98.41	100.00
	2025	48.52	98.14	100.00
	2030	49.55	97.83	99.99
	2035	50.72	97.48	99.99
	2040	52.02	97.10	99.99
	2045	53.49	96.65	99.99
1.4		54.15	96.45	99.98
	2050	55.13	95.89	99.97
	2055	56.98	94.83	99.95
	2060	59.05	93.65	99.92
	2065	61.37	92.32	99.89
1.6		61.89	92.02	99.89
	2070	63.97	90.47	99.84
1.8		69.63	86.27	99.72

[1/] Rio Cocle del Norte - the lake fluctuates from the normal operating lake level at elevation 65 m MSL down to the minimum operating lake level at elevation 50 m MSL

[2/] 2000 Daily Demand is Average of 1993-1997

With the proposed Pump Storage from the Cocle del Norte Lake project, there would be no water supply shortages for navigation. The demand for the M&I purposes will always be met first. As these demands increase, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Pump Storage from the Cocle del Norte Lake project, all demands for water supply for navigation would be met over the planning period. With a hydrologic reliability of 99.6 percent, the project would increase the amount of water supplied by more than 25.29 equivalent lockages. The 99.6 percent hydrologic reliability would occur after the year 2070 with an equivalent daily average number of lockages of 63.76. Benefits for this amount of additional water would be attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The average annual benefits for water supply would be $207,543,000. Table 29 - 9 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Pump Storage from the Cocle del Norte Lake project in operation, the annual benefits for meeting shortages, and the average annual benefits.

Table 29 - 9 Benefits for Additional Water Supply for Navigation

Year	Shortages Under Existing System	Remaining Shortages	Annual Benefits ($)
2017	8.45	0	174,348,000
2020	8.93	0	184,110,000
2030	10.87	0	224,201,000
2040	13.34	0	275,147,000
2050	16.45	0	339,266,000
2060	20.37	0	419,966,000
2066	23.21	0	478,573,000
Average Annual Benefits			207,543,000
With the Pump Storage from the Cocle del Norte Lake alternative, the system will provide 63.97+ lockages, or will satisfy 100 percent of the forecast demands through 2070 or 30.95 more lockages than the existing system.			

With the proposed Pump Storage from the Cocle del Norte Lake project, the reliability of the system to provide all of the water demanded for navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Pump Storage from the Cocle del Norte Lake project would be $16,041,000. Table 29 - 10 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 29 - 10 Average Annual Reliability Benefits For Navigation

Year	**Daily Average Number of Lockages**	**Value Per Lockage** ($)	**Annual Benefits For Navigation** ($)
2017	40.0	2,260,000	11,959,000
2020	40.0	2,260,000	13,105,000
2030	40.0	2,260,000	17,861,000
2040	40.0	2,260,000	23,905,000
2050	40.0	2,260,000	33,646,000
2060	40.0	2,260,000	51,756,000
2066	40.0	2,260,000	65,457,000
Average Annual Benefits			16,041,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was based upon the growth in population. The PCC provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day. An equivalent lockage is 55 million gallons of water. One equivalent lockage was added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Pump Storage from the Cocle del Norte Lake project, the current costs to the PCC to process finished water of $0.69 per 1,000 gallons, the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability would be $2,546,000. Table 29 - 11 displays the population forecast, the resulting number of equivalent lockages per day, the annual benefits for increased reliability, and the average annual benefits for M&I water supply.

Table 29 - 11 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2017	2,008,000	7.14	1,434,000
2020	2,141,000	7.61	1,676,000
2030	2,688,000	9.55	2,869,000
2040	3,384,000	12.02	4,823,000
2050	4,259,000	15.13	8,546,000
2060	5,360,000	19.05	16,557,000
2066	6,746,000	23.97	24,069,000
Average Annual Benefits			2,546,000

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Pump Storage from the Cocle del Norte Lake project, the system could produce net additional megawatt hours of hydropower. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, the project would have benefits of $19,617,000. Table 29 - 12 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 29 - 12 Average Annual Benefits For Hydropower Generation

Year	Net Generation (MWh)	Annual Benefits For Hydropower ($)
2017	281,406	20,029,000
2020	279,582	19,899,000
2030	272,198	19,375,000
2040	262,905	18,716,000
2050	257,321	18,326,000
2060	249,310	17,786,000
2066	243,164	17,362,000
Average Annual Benefits		19,617,000

SUMMARY OF ANNUAL BENEFITS

As shown in Table 29 - 13, total average annual benefits for the proposed Pump Storage from the Cocle del Norte Lake project would be $245,747,000.

Table 29 - 13 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	207,543,000
Navigation – Reliability	16,041,000
M&I - Reliability	2,546,000
Hydropower	19,617,000
Total	245,747,000

To perform an analysis of benefits versus costs, a common point in time was selected. This common point was at the completion of the filling of the proposed Pump Storage from the Cocle del Norte Lake project, the end of the year 2016. In these analyses, it was important to note that the average annual benefits or average annual costs were the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Pump Storage from the Cocle del Norte Lake project would be to develop the Rio Indio project first (2001 – 2010) and then the Pump Storage from the Cocle del Norte Lake project second (2007 – 2016).

The benefits attributable to the proposed Rio Indio project would begin to accrue in 2010 when that lake is filled. Thus, the Rio Indio project benefits for the period 2010 to 2016 were escalated by the project discount rate, 12 percent, in order to estimate their total present worth of $1,685,278,000 in the year 2016. The average annual benefits for the proposed Rio Indio project that accrue during the construction of the proposed Pump Storage from the Cocle del Norte Lake project are estimated to be $202,936,000. The benefits for the proposed Pump Storage from the Cocle del Norte Lake project are estimated with the assumption that the Rio Indio project would use its operating Option 2. Although the discharge tunnel would be larger, the proposed Rio Indio project would be operated for the period 2010 through 2016 just as if the proposed Pump Storage from the Cocle del Norte Lake project was not to be constructed.

To estimate the interest during construction, similar calculations were made for the costs of each proposed project. For the proposed Rio Indio project, interest during construction was taken from year 2001 to year 2016 and the interest during construction for the proposed Pump Storage from the Cocle del Norte Lake project was taken from the year 2007 to the year 2016. Additionally, there would be added costs for the larger inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed that would only be required if the proposed Pump Storage from the Cocle del Norte Lake project were to be constructed. Those amounts were subtracted from the cost estimate for the proposed Pump Storage from the Cocle del Norte Lake project and added to the cost estimate for the proposed Rio Indio project. The revised estimated average annual costs for the Rio Indio portion of the overall project would be $112,103,000.

Total average annual benefits and average annual costs were then estimated, and the ratio of benefits to costs and the net benefits (net of costs) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. Table 29 - 14 provides the benefit to cost ratios and the net benefits.

Table 29 - 14 Economic Evaluation

Item	Value
Average Annual Benefits	
Rio Indio	$ 202,936,000
Rio Cocle del Norte	245,747,000
Sum	$ 448,683,000
Average Annual Costs	
Rio Indio	$ 112,093,000
Rio Cocle del Norte	143,621,000
Sum	$ 255,714,000
Benefit to Cost Ratio	1.8
Net Benefits	$ 192,969,000

For this proposed project, the operating scheme used in the simulation model does not draw the pool elevation down to the minimum elevation. Therefore, there is additional storage for which beneficial uses could be made. Since the proposed project meets all of the total demand for water over the planning period, there are no quantifiable remaining benefits to be estimated. The operating scheme could be revised to allow for additional hydropower production for which benefits could be estimated. The unused storage could also be used for increased forecast demands of navigation or M&I water uses. Should those forecast demands be increased, the net benefits for this proposed project would also be increased.

Internal Rate of Return

An internal rate of return analysis for the project was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For the Pump Storage from the Cocle del Norte Lake project, the internal rate of return would be 20.7 percent.

Incremental Evaluation of Hydropower

Since the generation of hydropower would be provided through the conjunctive use of storage, an analysis of the incremental benefits and costs for this purpose was accomplished. The first costs of the Lands and Relocations and the Clearing and / or Grubbing, which were associated with hydropower, as well as the costs of the Hydropower Plants and the Transmission Lines were taken from Table 29 - 6. The portion of annual operation and maintenance costs associated with hydropower generation were derived from the data included in Table 29 - 7. The construction costs are estimated to be approximately $198,956,000. Interest during a two-year construction period is estimated to be $24,233,000 for a total hydropower investment cost of $223,189,000. The portion of annual operation and maintenance costs for hydropower were assumed to be $350,000 for staff, $300,000 for ordinary maintenance and $81,000 for major replacement. The total average annual costs for hydropower would be $27,627,000. The average annual benefits are estimated to be $19,617,000. The average annual benefits do not exceed the average annual costs for the Pump Storage from the Cocle del Norte Lake project. The benefit to cost ratio is 0.7. It should be noted, however, that hydropower was valued at the current costs of production for the PCC. This value might underestimate the economic value of any additional hydropower generating capacity. Additional effort should be expended in any future planning studies to determine the economic value of added hydroelectric power generation.

Socio-Economic

The socio-economic impacts of the project could be substantial. The relocation of the towns of Coclecito, Cutevilla and others would be an important issue. The average monthly income of some families in the project area is less than $100 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to create the impoundments. The relocation of agricultural and ranching activities would also be a substantial issue. The impoundments would also substantially impact the potential to mine the mineral ore resources.

On a per hectare basis, the revenues from power generation would be greater than those produced by the current agricultural activity. During construction, the influx of workers could create a temporary demand for additional housing, which could result in an increase in housing values in the vicinity of the dam site. However, after completion of the project, the workers would leave, the housing demands would drop, and the housing values could drop to pre-construction levels. Currently, most residents have access to public schools and health centers. During construction, these services should continue to be available and additional public and community services may be offered. After construction, these services would remain available at the normal level.

To construct the dams, some existing roads would be improved and some new roads would be built; however, the unpaved roads within the impoundment area would be significantly reduced, which would change the traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads would increase. However following completion of construction, the traffic volumes would decline. Noise levels would increase during construction and could negatively impact noise-sensitive receptors; however, after construction, noise levels should return to pre-construction levels.

The communities that could receive the people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land and working areas. Construction of the dam would permanently displace people and disrupt community cohesion through the division of communities, separation of families, and loss of livelihood.

Environmental Setting

The project would include a dam and lake on the Rio Cocle del Norte, a dam and lake on the Rio Toabre and a dam and lake on the Rio Caño Sucio. An open channel cut through the low ridge between the two basins would connect the Toabre and Caño Sucio Lakes. Flow from these lakes would be passed via a tunnel to Indio Lake from Caño Sucio Lake. Indio Lake would be connected to the Panama Canal watershed at Gatun Lake via a second tunnel. Water impounded in these three lakes would be transferred to the Panama Canal watershed as needed to support navigation. The project consists of a mass concrete gravity dam on the Rio Cocle del Norte, an earth and rock fill dam on the Rio Toabre and a rock fill dam on Rio Caño Sucio, uncontrolled ogee spillways on the Rio Toabre, the Rio Caño Sucio, a gated concrete spillway on the Rio Cocle del Norte Dam, inter-basin transfer facilities, two hydropower plants, and outlet works. The hydropower plant at the Rio Toabre Dam would be a pump / generation unit.

The project area encompasses the areas to be flooded as well as the areas downstream from the dam sites. This area is sparsely populated. It is characterized by rolling hills, low coastal regions, and scenic water falls. The Rio Toabre is located west of the Panama Canal and flows northward from the Continental Divide into the Rio Cocle del Norte and then to the Atlantic Ocean. The Rio Caño Sucio is located west of the Panama Canal, but east of the Rio Toabre basin, and flows northward from the Continental Divide into Rio Miguel de la Borda, and then northeastward into the Atlantic Ocean. The combined Rio Cocle del Norte, Rio Toabre and Rio Caño Sucio watershed above the dam is approximately 2,400 km^2. Impoundment areas cover approximately 29,000 ha and consists of approximately 30 percent of forested land, 20 percent of pasture land (used by ranchers), 20 percent of cropland, 25 percent of newly slashed and burned land, and 5 percent of mining land. The transmission lines, tunnel portals, and roads associated with the project could also have environmental impacts and would be sited to minimize those impacts.

LAND USE

The project area encompasses the areas to be flooded as well as the areas downstream from the dam sites. About 5,600 people inhabit the Rio Cocle del Norte area, with concentrations in the towns of Coclecito (population 1,150) and Cutevilla (population 300). Farms and ranches occupy approximately 40 percent of the project area. There are also mineral and ore resources in the region.

The population in the Rio Toabre and Rio Caño Sucio areas is approximately 800 people, dispersed throughout the area, with concentrations in the towns of El Guayabo o Toabre Abajo and (population – 150) El Valle de San Miguel (population – 250), El Caraño (population (population - 100), Las Maravillas (population - 70), Santa Maria (or Caño Sucio) (population - 60), Riecito Abajo (population - 50), and approximately 11 smaller settlements. Farms and ranches of various sizes as well as some teak and tobacco plantations occupy approximately 80 percent of the land in this project area. Also in this region there are some mineral and ore deposits in the impoundment areas.

INFRASTRUCTURE

Several towns have schools, cemeteries and churches. All towns depend on the rivers or groundwater wells for their water supply. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the rivers. Disposal of domestic waste is the responsibility of individual homeowners: each home has an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses attributable to the present waste disposal methods. There are a limited number of paved roads around Coclesito. The project area is traversed by unpaved horseback riding trails that link various communities. No major industries or poultry or beef processing plants are located in the project area. The dirt roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

About 80 percent of the lands along the rivers are covered with forests that could support diverse wildlife populations. The forests extend to the upper mountainous areas above the impoundment areas; however, as a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations in the Rio Toabre and Rio Caño Sucio watersheds. There are some contiguous forests in the lowlands west of Coclesito within the Rio Cocle del Norte impoundment area.

ANIMALS ON ENDANGERED LIST

ANAM by its Resolution 002-80 on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although none have been identified to date, some animals and other species of concern on the threatened and / or endangered list may be found in the project area.

AQUATIC HABITAT

The rivers in the project area have characteristics typical of streams in mountainous regions. The waters are clear and cool, and the beds range from sand to boulders, with numerous riffles, runs, and pools and with accumulations of large boulders and rocks downstream from the dam sites. The rivers appear to support some fish and other aquatic communities; however, information about these communities in the project area is limited.

WETLANDS

The wetlands consist of forested riparian habitat and are limited by the relatively steep topography of the project area to the immediate vicinity of the stream banks. The width of the riparian habitat within the impoundment area varies from approximately 10 to 75 m. Approximately 80 percent of the streams above and below the dam site along the Rio Toabre and its tributaries are bordered by forested riparian habitat. In the western section of the Rio Cocle del Norte impoundment area, the wetlands become part of the dense forest that extends towards the mountains.

AIR QUALITY

Air quality in the project area is generally good, except during slash and burn activities. At the end of the dry season in March or early April, sizable areas of established forests and secondary growth are burned and cleared to prepare the land for agricultural use. Based on observations in the project area, the amount of forested land burned varies annually.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The El Cope National Park covers 25,000 ha in the highlands of the Rio Cocle del Norte project area. The late General Omar Torrijos owned a home in Coclesito, which is now a museum. Some Pre-Columbian cultural resources, identified by archaeological surveys, are located in the impoundment areas. It should be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in the impoundment area would be substantial, since forest with relatively high quality terrestrial habitat cover about 8,700 ha of the impoundment areas. With the creation of the lakes, migration routes of some species could be adversely affected. The only forests that would remain in the vicinity of the Cocle del Norte, Toabre and Caño Sucio Lakes and the drainage basins would be confined to the higher elevations.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered animals cannot be determined at this time, because it is not known which listed species occur within the proposed project area. The Meso-American Biological Corridor is also promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity should be positive, because construction of the dam should result in an increase in the volume of stored fresh water in surrounding areas during the dry season. The releases would be made at appropriate intervals and in amounts that would help significantly reduce problems with water quality and temperature downstream, and also minimize flooding.

WATER QUALITY

The impacts downstream from the dam sites could be positive. The water should contain less silt due to minimum normal flows and should provide people downstream higher quality water.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on downstream aquatic faunal communities should be minor, because the dam would be designed to allow releases of water from different reservoir levels, which could reduce problems with water quality and temperature downstream. The dams would act as large sediment traps, which should cause the released water to have low turbidity; therefore, siltation is not expected to be a problem. The impacts of interference with the migratory movements of natural stream fishes are unknown. Streambed degradation below the dam should be minor due to minimum normal flow rates.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed lakes would depend on water level fluctuations, which are anticipated to vary seasonally. Fluctuations would cause much of the shore to be covered with mud, where neither aquatic nor terrestrial plant communities could thrive. Rooted aquatic plants tend to grow as deep as light penetration allows.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the rivers and their upstream tributaries could be important. If aquatic fauna are able to thrive in the new reservoir, they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. If the new reservoirs are responsibly managed and stocked with game fish by the Aquaculture Department, they could provide good opportunities for recreational and subsistence fishing. Increase in fish populations could cause a corresponding increase in piscivorous predators, such as crocodiles, caimans, otters, and herons, among others. Some manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well, but several riverine native species that formerly occupied the impoundments have disappeared.

WETLANDS

The impacts to wetlands could be significant, even though the wetlands are limited to forested riparian areas. However, owing to the topography of the project area, a number of wetlands could be impacted by the project. It is possible that even though the reservoir water levels would fluctuate, new wetlands could develop in the littoral zones.

AIR QUALITY

During construction of the dams, dust and emissions from equipment could impact the air quality in the project area. Upon completion, the air quality could improve because the slash and burn activities are discouraged by the Panamanian government.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The impacts of the project on cultural resources and historic properties could be moderate. The project area is relatively large and is known to contain Pre-Columbian sites; therefore, the presence of cultural resources is highly probable. Prior to construction, surveys would be conducted to locate cultural resources and historic properties, and the important sites would be preserved or salvaged as appropriate.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of this alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an SIA. The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities.
  - Employment.
  - Land Use.
  - Property Values.
  - Public and Community Facilities and Services (including utilities and schools).
  - Community and Regional Growth.
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population.
  - Community Cohesion.
  - Recreational Resources.
  - Mineral Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major types of terrestrial and aquatic habitat are identified and quantified.
- Conduct field studies to locate special habitat features, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Rio Cocle del Norte, Rio Toabre, Rio Caño Sucio, and Rio Indio project areas.
- Coordinate with local experts regarding terrestrial and aquatic habitats.

- Provide species inventory lists for each area, identifying their status as native or exotic and whether they are threatened and / or endangered species.
- Address cumulative effects downstream due to diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.

WATER QUALITY

- As only limited water quality data are available for the Rio Cocle del Norte, Rio Toabre, Rio Caño Sucio, and Rio Indio areas, additional information should be compiled on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria content of the water.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and / or properties.

Evaluation Matrices

In accordance with evaluation procedures described in Section 4, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Section 35. Tables 29 - 15 through 29 - 17 present the evaluation of the proposed Pump Storage from Cocle del Norte Lake project as related to developmental effects, environmental effects, and socio-economic effects.

Table 29 - 15 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I demands	10	10	100
	Supplements Existing System	10	10	100
	Satisfies Future Canal needs / expansion	10	10	100
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	2	6	12
	Feasibility of Concept	5	6	30
Operational Issues	Compatibility	3	6	18
	Maintenance Requirements	4	2	8
	Operational resources required	4	2	8
Economic feasibility	Net Benefits	5	9	45
	Total			421

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 29 - 16 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	2	8	16
Animals on Extinction List	1	10	10
Water Quantity Impacts – Lake	6	10	60
Water Quantity Impacts -- Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	3	8	24
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	6	6	36
Wetlands	2	4	8
Air Quality	5	3	15
Cultural Resources and Historic Properties	3	10	30
Total			345

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 29 - 17 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	1	7	7
Relocation of People	1	10	10
Relocation of Agricultural / Ranching Activities	1	6	6
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	5	5	25
Public / Community Services During Construction	6	4	24
Public / Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	3	5	15
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	1	8	8
Community Cohesion	1	8	8
Tourism	6	5	30
Total			302

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 29 – 18 through 29 – 21 present the pertinent data for the Rio Cocle del Norte, Rio Toabre / Rio Caño Sucio, and the Rio Indio projects.

Table 29 - 18 Pertinent Data for Rio Cocle del Norte Project

GENERAL	
Dam site, above mouth of Rio Cocle del Norte	15 km
Drainage area above dam site	1,600 km^2
RESERVOIR	
Elevation, top of flood storage lake	69 m MSL
Area at top of flood storage lake	20,090 ha
Top clearing elevation	70 m MSL
Lower clearing elevation	50 m MSL
Elevation of normal operating lake	65 m MSL
Elevation of minimum operating lake	50 m MSL
Area at normal operating lake	17,940 ha
Area at minimum operating lake	10,730 ha
DAM AND APPURTENANT STRUCTURES	
Dam	
Type of dam	Concrete Gravity
Top elevation of dam (nominal)	70 m
Overall length of dam	391 m
Height above lowest foundation	65.0 m
Crest width (nominal)	9 m
Volume of concrete dam (including spillway)	638,300 M^3
SPILLWAY	
Type of Spillway	Gated ogee with flip bucket
Number / Type Spillway gates	2 / vertical operating Tainter
Spillway gate dimensions	17 by 15.5 m
Total length at flow surface	34 m
Elevation of crest	50 m MSL
Maximum discharge	5,346 CMS
Width of piers	4 m
HYDROPOWER PLANT	
Type of hydropower plant construction	Reinforced concrete, outdoor
Number of units	4
Capacity of each unit	17 MW
Type hydraulic turbine	Vertical Francis

Table 29 - 19 Pertinent Data for Rio Toabre / Rio Caño Sucio Project

GENERAL	Toabre	Caño-Sucio
Dam site, above mouth of river	16 km	---
Drainage area above dam site	730 km^2	111 km^2
Average annual flow at dam site	39 CMS	7.4 CMS
LAKE		
Elevation of maximum operating lake level	100 m MSL	100 m MSL
Elevation of maximum flood storage lake level	104 m MSL	104 m MSL
Elevation of minimum operating lake level	90 m MSL	90 m MSL
Area at maximum operating lake level	4,850 ha	1,355 ha
Area at maximum flood storage lake level	5,830 ha	2,040 ha
Area at minimum operating lake level	3,220 ha	245 ha
Top clearing elevation	100 m MSL	100 m MSL
Lower clearing elevation	90 m MSL	90 m MSL
EMBANKMENTS		
Dam - Rock fill embankment		
Top elevation of dam	105 m MSL	105 m MSL
Fixed crest width	13 m	13 m
Height above lowest foundation	90 m	20 m
Overall length of dam	1,130 m	185 m
SPILLWAY		
Type of Spillway	Uncontrolled ogee	Uncontrolled ogee
Total length	219 m	74 m
Elevation of spillway	100 m MSL	100 m MSL
Maximum discharge	3,391 CMS	1,141 CMS
INTER-BASIN TRANSFER TUNNEL	**Sucio-Indio**	
Tunnel diameter	5 m	
Tunnel length	2.0 km	
Inlet invert	85 m MSL	
Outlet invert	74 m MSL	
Tunnel capacity	153 CMS	
HYDROPOWER PLANTS		
Rio Toabre Dam		
Type of hydropower plant construction	Reinforced concrete	
Number of pump-turbine units	4	
Capacity of each unit	28 MW	
CONSTRUCTION / POWERHOUSE DIVERSION	**(Toabre only)**	
Diversion length	1,100 m	
Horseshoe tunnel dimensions	(2) 8 by 8 m	
Inlet invert	17 m MSL	
Outlet invert	15 m MSL	
Cofferdam Height above tunnel inlet invert	15.5 m	

Table 29 – 19 Pertinent Data for Toabre / Rio Caño Sucio (continued)

MINIMUM FLOW CONDUIT	Toabre	Caño-Sucio
Conduit diameter	0.9 m	406 mm
Conduit length	1,100 m	140 m
Inlet invert	15 m MSL	85 m MSL
Outlet invert	15 m MSL	83 m MSL
Conduit capacity	4.0 CMS	0.74 CMS

Table 29 - 20 Pertinent Data for Rio Indio Project

GENERAL	
Dam site, above mouth of Rio Indio	25 km
Drainage area above dam site	381 km^2
Average annual flow at dam site	25 CMS
LAKE	**Option 2**
Elevation of normal operating lake level	80 m MSL
Elevation of maximum flood lake level	82.5 m MSL
Elevation of minimum operating lake level	50 m MSL
Area at normal operating lake level	4,280 ha
Area at maximum flood lake level	4,440 ha
Area at minimum operating lake level	2,360 ha
Top clearing elevation	80 m MSL
Lower clearing elevation	50 m MSL
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	83.5 m
Fixed crest width	13 m
Height	73.5 m
Overall length of dam	891 m
Saddle dam (North)	
Type of saddle dike	Earth / rock fill embankment
Top elevation of saddle dike	83.5 m MSL
Fixed crest width	13 m
Overall length of saddle dike	255 m
Saddle dam (South)	
Type of saddle dike	Earth / rock fill embankment
Top elevation of saddle dike	83.5 m MSL
Fixed crest width	13 m
Overall length of saddle dike	272 m
SPILLWAY	
Type of Spillway	Uncontrolled ogee
Total length	120 m
Elevation of spillway	80.0 m MSL
Maximum discharge	920 CMS
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	6 m
Tunnel length	5.2 km
Inlet invert	40 m MSL
Outlet invert	38 m MSL
Tunnel capacity	216 CMS

Table 29 - 20 Pertinent Data for Rio Indio (continued)

HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	2
Capacity of each unit	12.5 MW
Inter-basin Transfer Tunnel	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of unit	10 MW
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	1,500 m
Horseshoe tunnel dimensions	8 m X 8 m
Inlet invert	10 m
Outlet invert	7 m
MINIMUM FLOW CONDUIT	
Conduit diameter	1.2 m
Conduit length	800 m
Inlet invert	10 m
Outlet invert	8 m
Conduit capacity	2.5 CMS

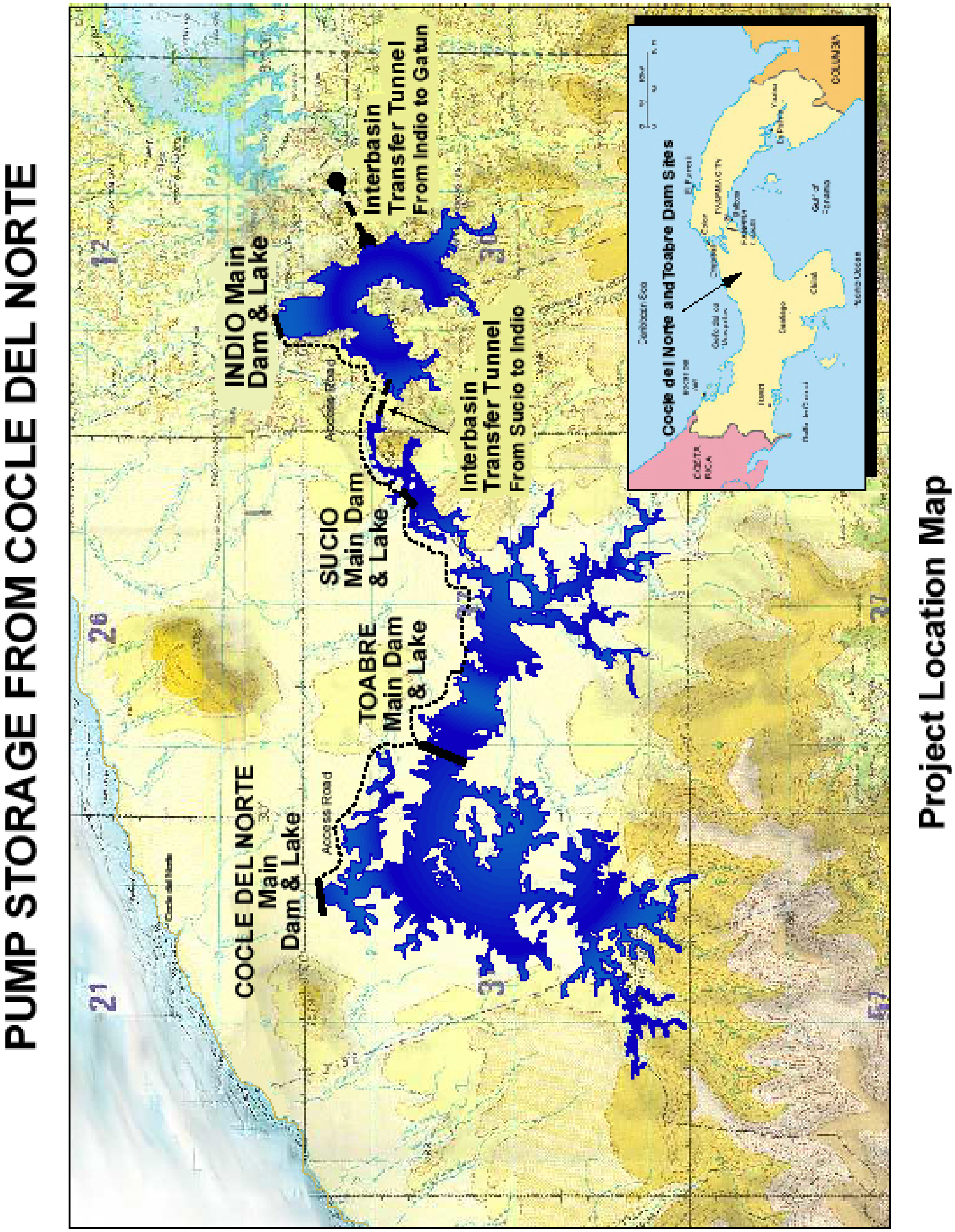


Plate 29 - 1   Project Location

SECTION 30

(At the Pacific Entrance to the Panama Canal)

Tide Gates

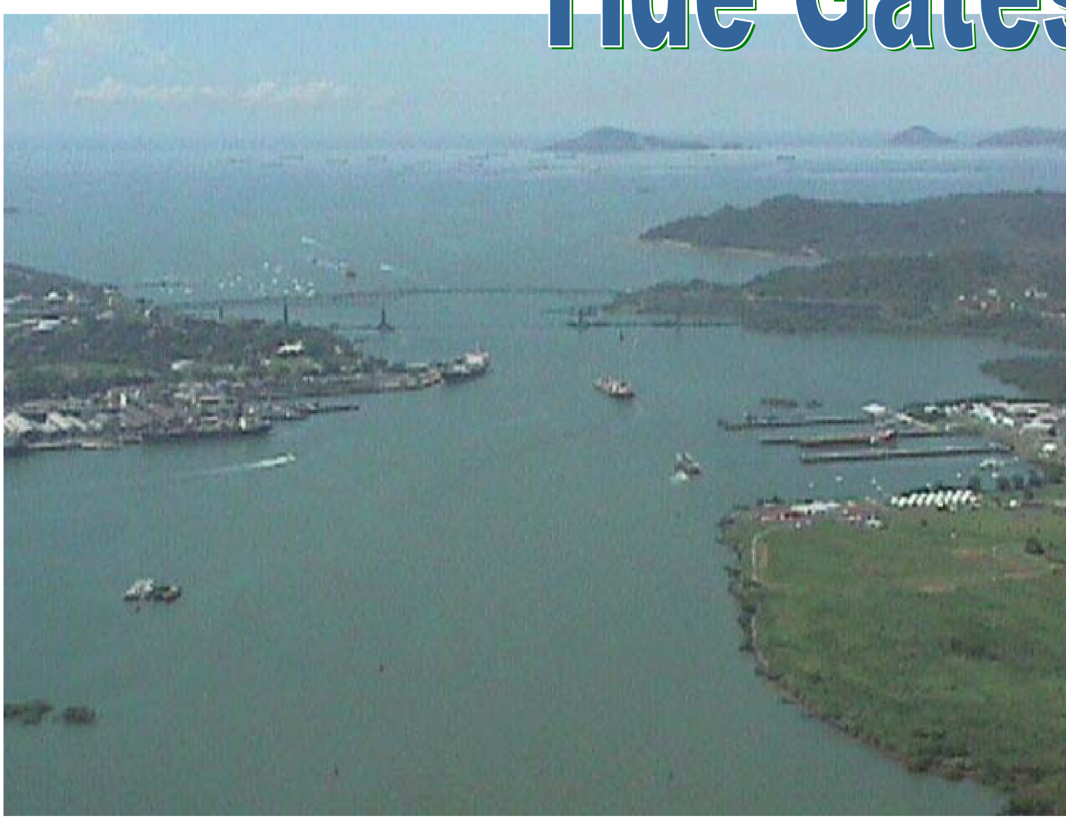


TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

Synopsis

The Tide Gates alternative would result in a revised minimum operating elevation of approximately mean sea level at the lower end of Miraflores Locks. The only structures impacted by this proposal would be Miraflores Locks. The net effect of a tidal dam installed below Miraflores Locks would be to provide more thorough usage of available water for navigation through this structure. There would be no net change in the total water usage in the Pacific descent of the Panama Canal, since the water saved at Miraflores Locks would have to be either stored in Miraflores Lake or spilled at Miraflores Spillway. Miraflores Lake is so small and has such limited storage capacity that the latter would occur.

The proposed Tide Gates alternative would not contribute to the hydrologic reliability of the Panama Canal since no net water savings would be realized.

The plan for the development of the Tide Gates was not pursued further and was eliminated from the list of technically viable projects to be subjected to further scrutiny in this report because it failed to meet the minimum criteria of one lockage. No formal cost, economic or environmental analyses were made of this alternative.

Location

In order to reduce loss of lockage water from the lower Miraflores Lock caused by tide fluctuations, it was proposed that a tide control structure be installed at some point downstream from Miraflores Lock to retain the operating pool at some optimum level for lockage. In order to provide sufficient maneuvering space and ship anchorage area below Miraflores Locks, this facility would need to be positioned within the Pacific leg of the Panama Canal at a point between the Bridge of the Americas and Culebra Island. Plates 30 - 1 and 30 - 2 show the location of this proposed project and a potential location and orientation for the tide dam.

Hydrologic Considerations

The hydrologic situation existing at Miraflores Locks is dominated by the extreme tidal fluctuations experienced at the Pacific end of the Panama Canal. Spring tide at this location can vary from approximately 3.35 m above to 3.05 m below mean sea level. Neap tide could show as little as 2 m total variation between tide levels. Also, the Pacific tide at this location is diurnal (exhibiting two high and two low tides in each tidal day of approximately 25 hours).

Geologic Considerations

The Tide Control Structure is proposed to be located in an area that is primarily underlain by sedimentary rocks of the La Boca Formation. Igneous and volcanic rocks (basalts, dacites and tuffs) are also present in the area. In depressions below the present high-tide level, Pacific muck overlies the igneous, volcanic and sedimentary rocks. Near the existing channel south of Miraflores Locks, the muck has been found to depths exceeding 12 m.

The igneous and volcanic rocks are probably high quality. The sedimentary rocks of the La Boca Formation consist mainly of siltstones, sandstones, conglomerates, and clay shale. The sediments of the La Boca Formation are relatively impervious, but are considered low quality with respect to slope stability. The Pacific muck can be dredged with ease but is very poor for foundation purposes.

Existing Facilities

From Gatun Lake, the Panama Canal passes approximately 14.5 km through the Gaillard Cut to Pedro Miguel Locks. The average water surface elevation from Gatun Lake through the Gaillard Cut is approximately 25.9 m MSL. At Pedro Miguel Locks, the water level is lowered to the level of Miraflores Lake. The Panama Canal passes through the full length of Miraflores Lake to Miraflores Locks, Dam and Spillway. Here the water level is lowered through Miraflores Locks to the level of the Pacific Ocean.

Pedro Miguel Locks are a single lift structure having a nominal 33.53 by 304.8 m footprint. The adopted nominal standard footprint for the Panama Canal is actual length 360 m, center to center of operating gate pintles. The nominal lift through Pedro Miguel Locks is approximately 9.45 m, which varies slightly with changes in the level of Gatun and Miraflores Lakes.

Miraflores Locks are a double lift lock system having an upper chamber identical in footprint to that at Pedro Miguel. The lower chamber is only 329 m long from center to center of operating gate pintles and has walls extending to elevation 9.75 m MSL, making the lower chamber somewhat smaller in total volume than the upper chamber. Because of the extreme tidal variation, and in the interest of economy of construction, it was decided that the lower chamber should only be large enough to contain that prism of water that would be passed from the Miraflores upper chamber at approximately mean tide, with normal operating pool level (assumed for design at 16.66 m MSL) in Miraflores Lake.

Miraflores Lake is a relatively small reservoir with no storage capacity. It is very sensitive to the injections of water through Pedro Miguel Locks and its pool elevation is limited by the upper lock wall elevation at Miraflores Locks.

Water Movement – Southern Descent

In developing the water movement data for use in these analyses the gross lock chamber dimensions and resulting volumes were used. These were extracted from original design documents. The water surface elevations used were those in Paper No. 14, General Design of the Locks, Dams and Regulating Works of the Panama Canal, by Brigadier General Harry F. Hodge, published by Neal Publishing Company, San Francisco, CA, 1916. Currently experienced water levels and operational procedures may vary slightly from those assumed in the original design of these facilities, but the net effects of the movement of water through the locks from Gatun Lake to the Pacific would be the same.

It was determined that, except for the very lowest levels of the tide cycle, the passage of water from Pedro Miguel Locks through Miraflores Locks requires that water be spilled at Miraflores. This is the net effect of the relatively smaller lower chamber at Miraflores Locks in reducing the total volume capacity of Miraflores Locks. Miraflores Locks will simply not contain all of the water passed through Pedro Miguel during all but the very lowest tides.

Despite the apparent inefficiencies of water usage at Miraflores Locks, this is not the controlling water usage factor on the Pacific leg of the Panama Canal. The total water usage is controlled by Pedro Miguel Locks. With Miraflores Lake at elevation 16.31 m MSL, and with Gatun Lake held at its mean operating pool level, 25.9 m MSL, the prism of water passed with each ship passage through the locks at Pedro Miguel is greater than can be used at the Miraflores Locks. The lower ranges of Pacific tide levels have the net effect of depleting Miraflores Lake as successive lockages are passed through Miraflores Locks creating the need for water to be artificially supplied to Miraflores Lake through dummy lockages from Pedro Miguel Locks.

The tides below Miraflores Locks were studied in an effort to determine the frequency of these losses and a numerical analysis was made to apply the tidal fluctuations to the water losses and thus approximate a cumulative loss estimate over time. The results show the trends described in the paragraphs above.

Tide Gates Alternative

The installation of a tide dam and gates at the Pacific entrance to the Panama Canal to regulate the tidal effects on water usage at Miraflores Locks would allow the Miraflores Locks to make more efficient use of the water reaching this site. The numerical analyses of the southern descent of the canal indicate that water equivalent to 0.7 lockages could be saved at Miraflores Locks. If there were any place to store this water above the locks, this would actually be the case. However, since Miraflores Lake is very small and is, by necessity, operated over a very narrow range of elevations (16.31 to 16.61 m MSL) this apparent water savings would be forfeited, passing over the Miraflores Spillway. While there would be a minimal advantage in avoiding the dummy lockages that occur at extremely low tide levels, the overall advantage would be small if other measures were not taken to store or reclaim the excess water passed to Miraflores Lake through Pedro Miguel Locks.

Alternative Measures

From these studies it is apparent that the only way to effectively alter the water usage in the Pacific descent of the Panama Canal would be to, (1) alter the vertical storage available in Miraflores Lake, (see Section 26 of this report, or (2) to devise a means of reclaiming the waters that pass through Pedro Miguel Locks and not used for navigation at Miraflores Locks.

Considering the numerical analyses performed for the study of the potential effectiveness of a tide dam, it is estimated that, with the operating pool levels held within their current elevation ranges and allowing for tidal variation effects at Miraflores Locks, the average amount of water that now goes unused for navigation downstream of Pedro Miguel Locks is shown in Table 30 - 1. If means were incorporated to retain or reclaim this water, it could be a substantial water savings to the canal. It is recommended that further study be made into the alternative of pumping excess water back from Miraflores Lake to the Gaillard Cut at Pedro Miguel Locks in the interest of reclaiming the water which now passes unused over the Miraflores Spillway.

Table 30 - 1 Estimated Savings Available at Pedro Miguel Locks per Tide Day

Elevations (ft MSL)		Pacific Tide Variation	Sum Passing Miraflores Spillway	
Gatun Lake	**Miraflores Lake**		**(AF)**	**Lockages**
82	53.5	Minimum	234	1.39
		Average	275	1.63
		Maximum	316	1.87
85	53.5	Minimum	485	2.87
		Average	530	3.14
		Maximum	575	3.41
87.5	53.5	Minimum	701	4.15
		Average	746	4.44
		Maximum	791	4.69
Note: One lockage assumed to equal 55 million gallons.				

Pertinent Data

Table 30 - 2 presents pertinent data for operating tide ranges and lake levels for Gatun Lake and Miraflores Lake offered for the Tide Gates Structure project.

Table 30 - 2 Pertinent Data

GENERAL	
Maximum Tide Range (approximately)	+3.35 to –3.05 m MSL
Minimum Tide Range (approximately)	+1.75 to –1.25 m MSL
LAKE OPERATING LEVELS	
Gatun Lake	25.9 to 26.67 m MSL
Miraflores Lake	16.31 to 16.63 m MSL
NOMINAL LOCK FOOTPRINT DIMENSIONS	33.53 by 304.8 m

TIDE GATES AT PACIFIC APPROACH

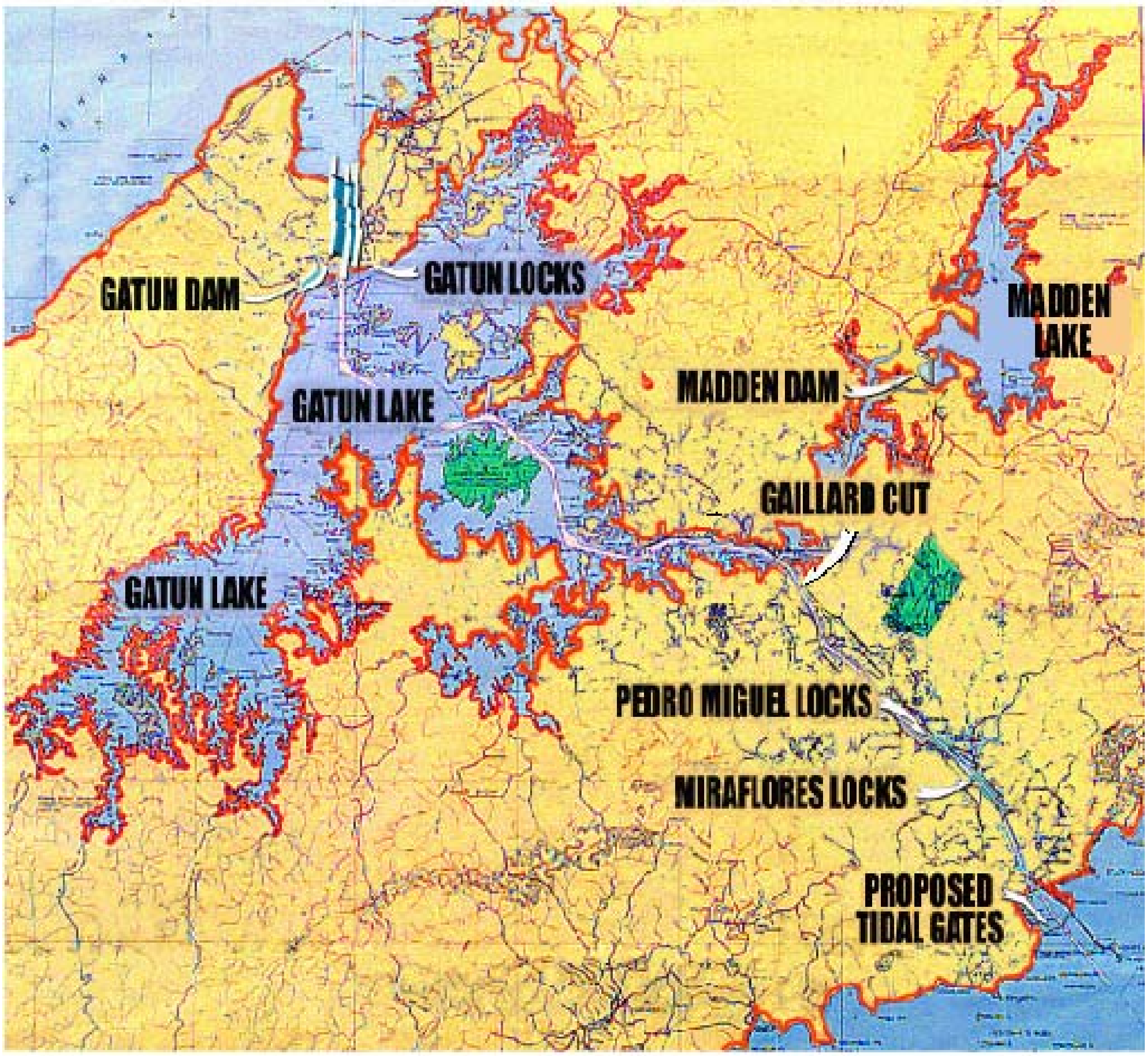


Plate 30 - 1 Project Location Map

TIDE GATES AT PACIFIC APPROACH

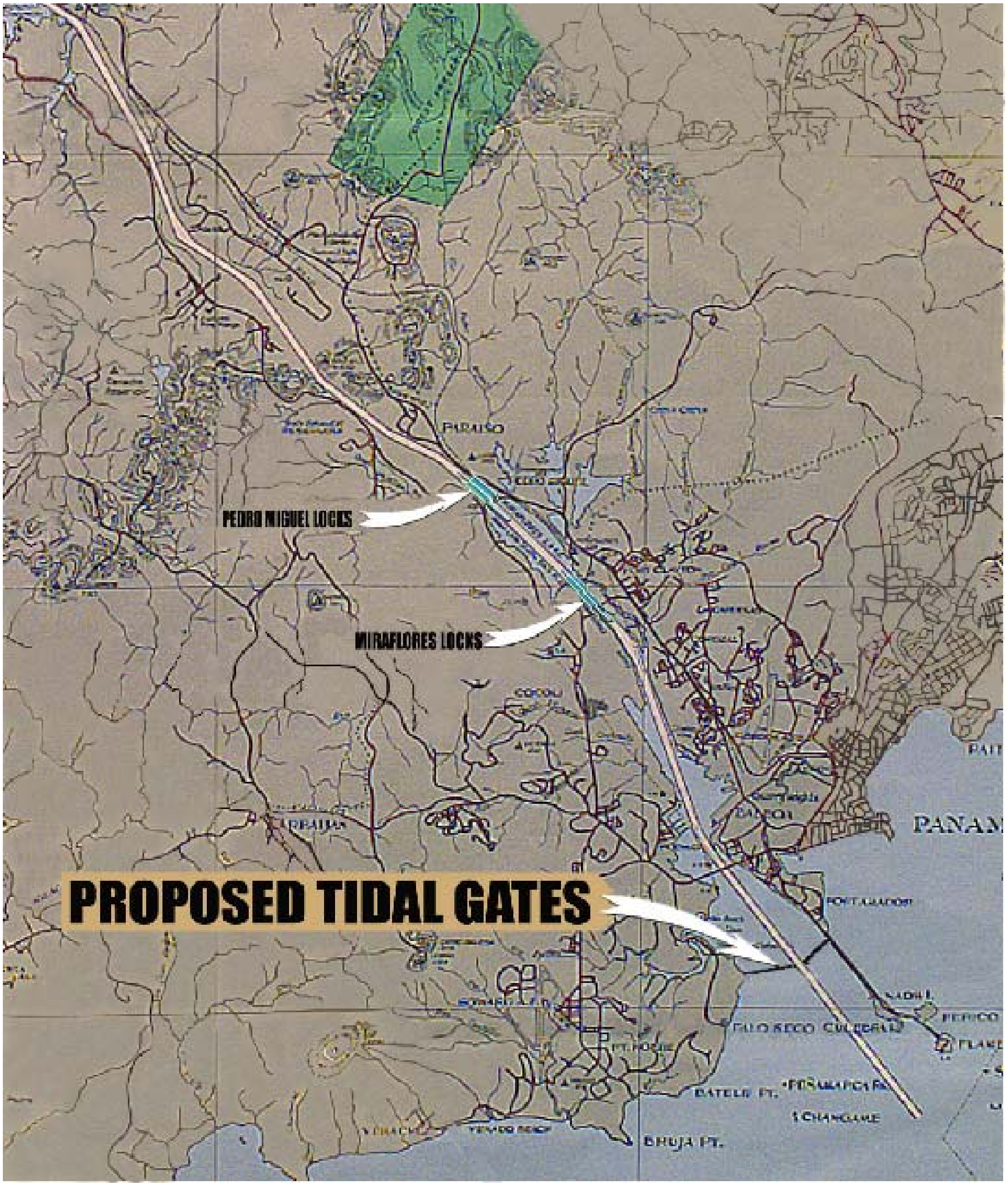


Plate 30 - 2 Project Feature Map

SECTION 31

Lower Gatun Lake and Eliminate Upper Locks

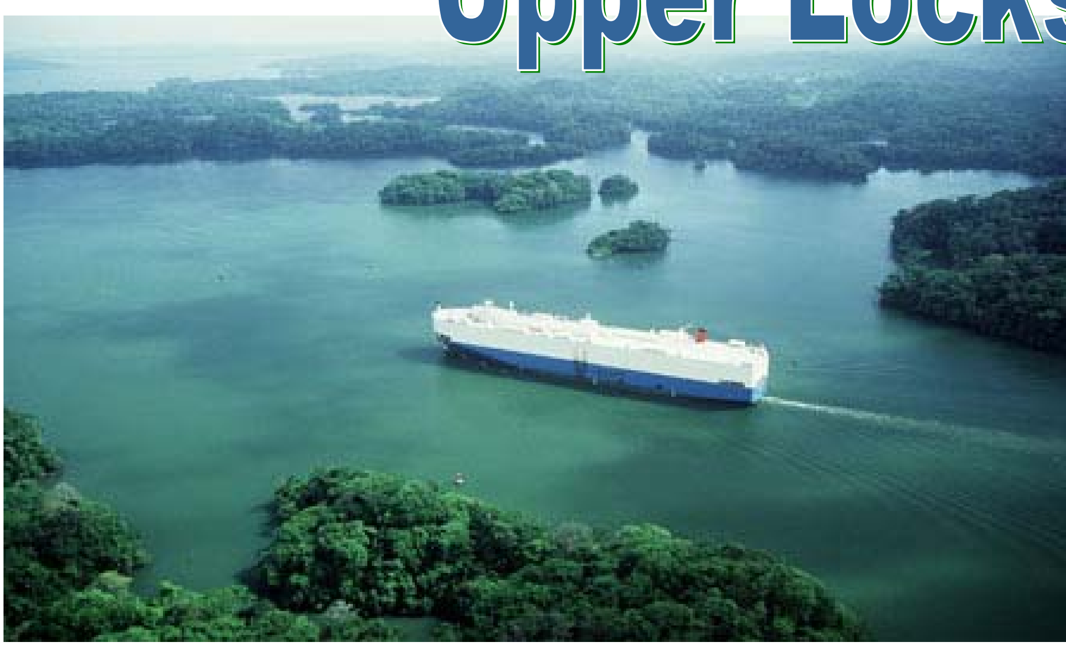


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein proposes a drastic modification of the configuraton of the Panama Canal and its supporting lakes. This plan would isolate the navigation channel with dams extending parallel to the navigation channel from the Gaillard Cut within Gatun Lake to Gatun Dam and permanently lower the water surface of the navigation channel from elevation 87.5 ft (26.76 m) MSL to elevation 55 ft (16.76 m) MSL. The plan would require deepening of the navigation channel by 30 ft (9.14 m). The plan would also include major modification to Gatun Locks including the elimination of the upper lock chambers and removal of a major portion of the east and west lock walls, and the center guide wall. It would also require the complete removal of Pedro Miguel Locks.

This alternative would divide Gatun Lake into a lake east of the Panama Canal and a lake west of the Panama Canal. In conjunction with this alternative, the spillway at Gatun Dam would be replaced by a smaller one located at the west end of the existing Gatun Dam. Another small spillway would be constructed east of Gatun Locks at the Canoa Saddle Dam.

Efforts to simulate this alternative with a monthly model was inconclusive and the degree that the proposed Lower Gatun Lake project would contribute to the hydrologic reliability of the Panama Canal to serve its customers is unclear. The HEC-5 model, with a monthly time step, could only provide indicators. A daily model is needed to accurately simulate the operation of this alternative. That level of analysis is beyond the scope of this effort.

This alternative could possibly decrease the travel time for vessels through the Panama Canal thus increasing the canal capacity. However, it is uncertain whether the much smaller reservoir contained between the side channel dams (as compared to Gatun Lake) would be manageable under operating conditions. Under this alternative, rather than having a large lake at the apex of the canal, the navigation channel itself would comprise the apex. It would be similar to Miraflores Lake, because of its relatively small volume, it would be very reactive to water loss caused by lockages and uncontrolled inflows. The small lake comprised of the navigation channel and Miraflores Lake would have to receive constant inflows from the adjacent remaining portions of Gatun Lake. Madden Lake would not provide water to the remaining portions of Gatun Lake but would release directly into the navigation channel. This would further complicate the operation of the system. Though the two portions of Gatun Lake could be operated over a much wider elevation range than is now possible, they would receive inflow from only about 44 percent of the current Gatun drainage basin. The remaining Gatun Lake would retain approximately 86 percent of the existing storage. This would reduce the water available for operation of the canal during times of drought or low flow. This would pose extreme operational difficulties and require constant monitoring and manipulation of the side channel inflows to regulate the navigation channel water level.

Construction activities associated with the proposed Lower Gatun Lake project would impose extreme operational difficulties because of the very disruptive nature of the construction required. Though it is not possible to identify all of the disruptions, it is clear that removal of the lock at Pedro Miguel and the upper chambers at Gatun Locks and the required rework of the remaining features, would certainly require some disruption of traffic, perhaps even requiring that the canal be shut down completely for extended periods of time. Similarly, the very large excavation and fill placement efforts through Gatun Lake and the Gaillard Cut would likely cause occasional disruptions if not complete closure of the Panama Canal.

The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. With the loss in storage and controlled drainage area, initial modeling efforts indicate that the current reliability could not be maintained. The apparent exorbitant cost to deepen the channel and remove the locks further mitigates against this plan. With essentially very little or no added benefits and a significant investment, the benefit-cost ratio would be much less than unity.

The amount of hydropower energy that could be produced by the hydropower plants in the system of Gatun Lake would likely decline if this plan is implemented. The hydropower plants proposed in this plan would be smaller and less productive than those now in place because the available flows would be smaller.

The rough order of magnitude estimate of the first cost for this project is $3,269,000,000 and it does not appear that the reliability would be significantly increased.

For these reasons, the proposed Lower Gatun Lake alternative is not recommended for development at the feasibility level and will not be subjected in this study to detailed cost, economic or environmental analysis.

Project Configuration

In considering the lowering of Gatun Lake others have proposed that the lake be altered in various ways.

The study by Lopez Moreno y Asociados, S.A., The Interoceanic Canal, The Panamanian Alternative, November 1981, proposed that the lake be sacrificed completely and other reservoirs to be constructed, both inside and outside the Panama Canal basin, to restore the water supply for navigation. This would involve construction of no less than eight dams and lakes to replace the water for Panama Canal operations lost with the virtual draining of Gatun Lake. It would also leave many individuals and several villages without means of access to the Panama Canal or M&I water supply. Many sites in the upper reaches of the lake would not have access to the lake were it permanently lowered. Many depend on the lake for transportation and subsistence.

In Study of Alternatives to the Panama Canal 1993, it was proposed that the navigation channel be isolated with side dams and lowered in place with the portions of Gatun Lake remaining outside the side dams. The Gatun Lake would be maintained at elevation 85 ft (25.91 m) MSL with side dams cordoning the lowered channel through the lake. Control structures would regulate the flow of lake waters to the Panama Canal and control flood flows through the lakes.

Either plan would be quite disruptive to Panama Canal operations, requiring that the upper lifts at Gatun Locks be removed, and that Pedro Miguel locks be removed altogether.

Because the second alternative noted above would be contained entirely within Gatun Lake, because it would leave the lake virtually intact, and because it would be the least disruptive to the existing lake system and would, therefore, require the least in peripheral water supply reservoir construction, this plan was selected for detailed analysis in this study. Plate 31 –1 depicts the proposed plan.

Hydrologic Considerations

The new Gatun Lake would receive run-off from only 44 percent of the original surface drainage of Gatun Lake. The remaining 56 percent would drain into Madden Lake or would be uncontrolled and run directly into the isolated navigation channel and Miraflores Lake. During the rainy season, almost all of the excess water from the uncontrolled areas would be spilled at Miraflores Spillway. The new Gatun Lakes would retain approximately 85 percent of the existing lake storage. The 1.5 million AF of storage would still be very significant; however, the reduced inflow would lengthen the refill time.

The hydrology and storage available to Madden Lake would not be changed. However, the manner in which these waters are introduced into the Panama Canal would be altered considerably. Under the current arrangement, water from Madden Lake is introduced into the canal above Pedro Miguel Locks through the original Rio Chagres channel. These waters are then allowed to comingle directly with local drainage to Gatun Lake contributing to the highest and largest storage level in the system. Under the revised plan described herein, these waters would enter the navigation channel at the same location but would be separated from the Gatun Lakes, entering into the navigation channel at a level below the lakes. This would require that the discharges from Madden Lake be much more closely controlled during normal operation times, and during flood stages would require that all flows from Madden Lake be discharged to the south over the Miraflores Spillway. The Miraflores Spillway has ample capacity to carry the higher flows, but this would constitute a marked change in operation from the current conditions.

Geologic Considerations

Two distinct geological zones underlie the proposed area for deepening the Panama Canal. These zones consist of the Gatun Lake area to the north, and the Central Divide area to the south.

The Gatun Lake Zone includes the area between the Gatun Lake and Gamboa at the confluence of the Panama Canal with the Chagres River. The geologic bedrock underling this zone consists of the Oligocene aged Caimito, Bohio and Bas Obispo Formations, with minor occurrences of the Caraba and Gatuncillo Formations. The Caimito and Bohio Formations are sedimentary in origin and include rock types ranging from tuffaceous sandstones and siltstones to limestones and conglomerates. These sedimentary rocks are considered to be medium hard and normally excavatable by ripping, with only limited use of explosives. The Bas Obispo Formation, however, is volcanic in origin and includes such rock types as agglomerate, tuff, basalt and andesite. These volcanic rocks are considered hard, generally requiring blasting for excavation. Due to fact that the necessary excavation is underwater, blasting will probably be required for both the sedimentary and volcanic rocks.

The Central Divide Zone is located between Gamboa and the Pedro Miguel Lock. The bedrock in this zone is divided into two sections by the Rio Limon Fault, which is aligned north-south and is located approximately 2 km to the south of Gamboa. The geologic formations on the northwestern side of the fault are the same Oligocene formations found in the Gatun Lake Zone, while southeast of the fault the formations are early Miocene. Five Miocene aged formations are represented in the Central Divide Zone, as well as extrusive and intrusive (dikes and plugs) basalt. The represented formations include the Las Cascada Formation (agglomerate and tuff), the La Boca Formation (mudstone, siltstone, sandstone and tuff), the Culebra Formation (sandstone and siltstone), the Cucaracha Formation (clay shale or tuff), and the Pedro Miguel Formation (fine to coarse grained agglomerate). The clay shale of the Cucaracha Formation is soft to very soft, the sediments of the Las Cascada, La Boca and Culebra Formations are soft to medium hard, while the rocks of the Pedro Miguel Formation are generally medium hard to hard, and the basalts are generally very hard. The sediments of the Cucaracha Formation have a well-known history of stability problems, whereas only small to moderate landslides have been noted in sediments of the Las Cascada, La Boca, and Culebra Formations. Blasting is expected to be necessary for excavation of basalts and rock of the Pedro Miguel Formation, and since the excavation will be underwater, at least the moderate use of explosives will probably be necessary for excavation of the sediments of the other formations.

Lake Operation

With the navigation channel lowered according to the plan described above, and therefore dividing Gatun Lake into two lakes, one to the east and one to the west of the navigation channel, operation of the canal scenario would change totally from the current situation. The main difference in the operation of the canal under either scenario would be the limited storage in the navigation channel portion, which would require rapid and precise control of the water surface level through coordinated releases from the two remaining portions of Gatun Lake and Madden Lake. Under the present conditions, the large Gatun Lake receives flows from Madden Lake and all the other streams in the watershed and helps to maintain the water level of the navigation channel. The lake is large enough to absorb the basin inflows and provide large quantities of water from storage during low water periods without significant variations in its water level. Because of Gatun Lake, the Panama Canal can remain fully functional during all but the most extreme conditions of very high or very low water levels. With the new configuration, the navigation channel portion would be very sensitive to inflows and withdrawals for operation of the locks and would require constant operation of the outlet structures from Gatun and Madden Lakes.

The lake area to the west of the lowered navigation channel would be operated in much the same way as the existing lake, with water levels being controlled through a new spillway located at the west end of Gatun Dam. A new spillway would be required because the embankment that isolates the navigation channel would take the existing spillway. This portion of the Lake would drain approximately 39 percent of the Gatun watershed. A hydraulic structure with low level sluices would be constructed in the embankment that separates the navigation channel and west lake to allow controlled releases of water to the navigation channel for lockages.

The lake area to the east of the navigation channel would also require installation of a new outlet spillway through which to control the lake level. For this study, it was assumed that the spillway would be installed at the current site of the Canoa Saddle Dam. The eastern portion of the lake would receive flow from approximately 5 percent of the Gatun watershed.

Both remaining portions of Gatun Lake would, of course, be operated to provide water for operation of the Panama Canal. However, several very important sources of water would flow directly into the Panama Canal where there would be no storage. These flows would be passed over the spillway at Miraflores Dam and would be lost. These areas include flood flows from Madden Lake and Rio Chagres basins, the Caño Quebrado arm of Gatun Lake, and the smaller Rio Frijoles Basin that lies between the Rio Chagres and the eastern arm of Gatun Lake. This would amount to approximately 56 percent loss in the controlled drainage area.

The remaining portions of Gatun Lake could be operated over a much wider range of elevations than is now possible allowing much more of the existing storage in the lakes to be used for navigation. However, because of the losses in captured runoff, this would provide for virtually no increase in hydraulic reliability.

Project Features

GENERAL

The structures for this proposed project would consist of earth and rock fill dams on either side of the lowered channel through Gatun Lake, water inlet structures at intervals along the length of these dams, a new gated spillway at Gatun Dam, a gated spillway at the site of the Canoa Saddle Dam, and channel excavation through Gatun Lake and the Gaillard Cut down to elevation 7 ft (2.13 m) MSL. This alternative would also include demolition and reconfiguration of the upper lock chambers at Gatun Locks, and complete removal of the locks at Pedro Miguel.

Performance of the design was only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. The PCC received separate documentation that contained assumptions and design calculations for the reconnaissance level investigations of these structures. Further development of this project into the planning studies would require optimization of the project features and improvements.

EMBANKMENTS

The dams on either side of the lowered channel would be earth and rock fill embankments with the top at elevation 90 ft (27.43 m) MSL, and with a crest width of 7 m. The embankments would be constructed by depositing cohesive materials into the lake waters along the alignment of the proposed dam until the stacked material reached its natural angle of repose and consolidation within the subgrade had stabilized. The assumed side slopes would be 15 horizontal on 1 vertical. The dams would vary in height varying from approximately 45 ft (13.72 m) to approximately 70 ft (21.34 m) high, and they would extend along either side of the channel from their abutments at high ground near Gatun Locks to high ground near the inlet to the Caño Quebrado arm of Gatun Lake near Punta Caño Quebrado on the west and Punta Bohio on the east. Further study would be required to determine the actual side slopes and the crest width would be contingent upon the need for vehicular access along the embankments, the quality of the fill, and the detailed design of the embankment

CHANNEL

The current overall navigation channel width and depth would be maintained in the lowered channel. It was assumed that this channel would be excavated to a template having a bottom width of 732 ft (223 m) and side slopes of 1 horizontal on 5 vertical in rock and 5 horizontal on 1 vertical in softer lake bottom materials. The channel would follow the same alignment as that now in service and would maintain the current channel width and depth. The current channel bottom is at elevation 37 ft (11.28 m) MSL. With Gatun Lake at elevation 85 ft (25.91 m) MSL the channel depth is 48 ft (14.63 m) and the minimum clearance through Gatun locks, is 41.67 ft (12.70 m). With Gatun Lake lowered to elevation 55 ft (16.76 m) MSL and maintaining the same channel depth and lock sill clearance, the revised channel bottom would be at elevation 7 ft (5.49 m) MSL and the highest lock sill elevation allowable would be 13.33 ft (4.06 m) MSL.

The total excavation effort for this alternative would be divided into reaches, according to the effort involved and variations in the excavation template required. The respective reaches are:

- Gaillard Cut, Pedro Miguel Locks to Gamboa, channel deepening in rock only;
- Gamboa to Punta Caño Quebrado, regular overburden with rock below, 50-50 split assumed for quantities;
- Punta Caño Quebrado to Punta Bohio, normal water depths, regular overburden with rock below, 50-50 split assumed for quantities;
- Punta Bohio to Gatun Locks, deep water, regular overburden with rock below, 50-50 split assumed for quantities.

The stability of the hillsides beyond the Gaillard Cut is believed to be questionable by this project and the deepening could subject the cut to landslides. A detailed study of this instability must be performed in subsequent feasibility studies.

Overburden dredging would be required from Gamboa to Gatun Locks. It was assumed that under-water drilling and blasting would be required throughout. The materials removed would be transported by bottom dump barges and deposited in designated areas of the lake. Thus, the excavation would need to be accomplished before the navigation channel is lowered.

LOCKS

In conjunction with this effort, the upper locks at Gatun Lake and the entire lock at Pedro Miguel would be removed.

Gatun Lock Modification Sequence would be approximately as follows:

1. Grout upstream center guide wall foundation (220 ft of gravity wall, pile wall to be removed upon completion of lock side wall replacement work, and new soft nose to be constructed).

2. Remove upper two sets of primary and one set secondary lock gates (Nos. 23,24,27,28,31,32,35,36,39,40)

3. Install upstream west side cofferdam and dewater upper two lock chambers.

4. Remove west lock wall backfill to second main valve monolith (app. 1,200 ft below upper lock gate pintle).

5. Remove west wing walls and lock wall to the first interior gate monolith.

6. Remove lock floor from upper end to first interior miter gate sill; critical elevation in this reach is +13.33 ft (4.06 m) MSL at finished upper (now first interior) gate sills.

7. Modify gate monoliths and gate sill to accommodate gates for operation at new pool elevation and reinstall miter gates 23, 24, 27, and 28. Note: Requires modification of existing sidewall and center wall in place to provide lowered gate recess, lowered pintle, pintle ball, and sill. Must also reconstruct culvert intakes and assure that existing culvert stoplogs and valves would work under new intake configuration.

8. Install new upstream west side wing wall adjacent to first interior gate valve monolith.

9. Remove cofferdam and upper guide wall and excavate new west side lock approach.

The remainder of lock renovation must be done with the Panama Canal operating level lowered in order to keep Panama Canal open. Therefore, the new channel excavation and side dams must be completed and functional with all side channel inlet structures and the new spillways at Gatun and Canoa Dams in place and functioning. This being accomplished, the east lock chamber modification would follow stepwise approximately as noted above.

10. Repeat steps 2 through 9 above for east side lock chamber.

As this work is being pursued, the same general approach would be used to demolish the Pedro Miguel Lock.

SPILLWAYS

For this study, it was assumed that sufficient spillway capacity would be installed on each side of the canal to pass the design flood to the Atlantic Ocean without overtopping the dams. Drainage areas serving the respective channel reaches indicated that flows from approximately 30 percent of the Gatun drainage area would be passed from Madden Lake to the navigation channel, bypassing Gatun Lake altogether. The remaining 70 percent of the area would be divided between Gatun Lake East, Gatun Lake West, and the area draining directly into the Panama Canal. Variations in rainfall and runoff over these areas would indicate that the distribution of flows might be somewhat more even than the division of drainage areas would indicate, however this data were not readily available for this analysis. The Gatun East Lake would receive waters from approximately 105 mi^2 (272 km^2) and the Gatun West Lake would receive water from 471 mi^2 (1,178 km^2). Average annual rainfall varies from 129.9 in (3,300 mm), along the Atlantic Coast to 63 in (1,600 mm) along the Pacific Coast. In the upper mountain ranges above the Madden Dam, average annual rainfall reaches almost 157.5 in (4,000 mm). For the assigning of spillway capacities, it was assumed that the area to the west would supply approximately twice as much runoff during flood events as would the eastern area.

It would be desirable to retain the existing Gatun Spillway as a feature of the western section of Gatun Lake. However, because of the extremely deep water in this area, the west side channel dam would block the spillway. For this study, it was assumed that a new spillway having 4 gates, each 45 ft (13.72 m) by 19 ft (5.8 m) and having a concrete ogee crest at elevation 69 ft (21.03 m) MSL would be constructed at the west end of Gatun Dam. This is a much smaller spillway than is currently serving the entirety of Gatun Lake because of the much smaller drainage area remaining on the west side.

A new spillway would also be constructed at the site of the existing Canoa Saddle Dam immediately east of Gatun Locks to serve the eastern section of Gatun Lake. This spillway would require 2 gates, each 45 ft (13.72 m) by 19 ft (5.8 m) and having a concrete ogee crest at elevation 69 ft (21.03 m) MSL to pass the design flood flow for the very small portion of Gatun Lake remaining on the east side of the canal.

SIDE DAM CONTROL STRUCTURES

In addition to the major spillway structures, the Gatun Lake portion of the lowered canal would require that some means be provided to allow water from the two sides of Gatun Lake to flow into the canal. This would be done using gated sluice type inlet structures to allow close control of the inflows. Flow would be passed into the channel through a system of conduits beneath the side channel dams and emerging vertically into energy dissipation / diffusion structures. This type of outlet would be required to minimize cross currents in the navigation channel. Flow analyses indicate that approximately eight, 7 ft (2.13 m) diameter conduits. Three conduits would be located on the east side of the channel and five on the west side. These outlets would be required to supply sufficient water to keep the channel at its working level under operating conditions up to and including 1.8 times the current demand level.

IMPOUNDMENT

The lakes formed by the proposed division of Gatun Lake would have a normal operating lake level at elevation 87.5 ft (26.67 m) MSL, the current maximum operating level. The lake level would be allowed to fluctuate downward in a controlled fashion to a minimum operating lake elevation of 69 ft (21.03 m) MSL, as the water is required for navigation. This would provide approximately 1.5 million AF (1,900 MCM) of storage between elevations 87.5 (26.67) and 69 ft (21.03 m) MSL.

HYDROPOWER PLANTS

The flows that are excess to the needs of the Panama Canal operation at Gatun Dam and at the proposed Canoa Saddle Dam would support installation of hydropower plants at these locations. Also, as water is passed from the Gatun east and west lake areas into the lowered channel, these waters could be passed through hydropower units. Considering the reduced drainage areas, the division of the lake and the loss of flows from Madden Lake, possible powerplant capacities are shown in Table 31 - 1.

Table 31 - 1 Hydropower Plants

Plant Site	Gross Head		Approximate Plant Rating (MW)
	(ft)	(m)	
Gatun Dam	85	25.91	5
Canoa Dam	85	25.91	5
West Channel Dam	30	9.14	5
East Channel Dam	30	9.14	5

Sources of Construction Material

Earth and rock fill removed from the channel excavation would be used as fill in the channel side embankments. Impervious materials for the core section might have to be obtained from outside the project area. A review of the quantities of excavation and fill required for the entire channel project indicates that approximately 57 percent more fill material would be required than would be available from the excavation. This being the case, borrow from other underwater or upland sites would be required for construction of the side channel dams.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, could be used for manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The only real estate acquisition that should be required for accomplishment of this alternative would be the land for construction of the spillway outlet channels below the relocated Gatun Spillway and the new Canoa Spillway.

Relocations

As noted above, the powerplant at Gatun Dam would be relocated, along with the spillway, to a point near the west end of Gatun Dam. Many of the operation facilities located to the east of Gatun Locks would be within the area required for the reconfigured lock approach channel, and would be relocated.

There are many service facilities located within the Gaillard Cut, including the Canal Dredging Division facilities at Gamboa, which would be left high above the revised operating Panama Canal water level, were the upper level of the Panama Canal lowered to the degree outlined in this report. These facilities would, therefore, be abandoned and the essential ones rebuilt at other locations.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed for its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising, and award phase. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin with land acquisition and rights of way. The only land acquisitions required would be the outlet channels downstream of the new spillways at Gatun Dam and the Canoa Saddle Dam and the lands from which borrow material would be obtained.

Socio-economic programs would begin shortly before construction of the dam. Because this alternative involves primarily PCC property and facilities, the socio-economic efforts involved are assumed to be very minor.

Construction would begin with the dredging / excavation of the revised navigation channel and simultaneous construction of the main spillways at Gatun Dam and Canoa Saddle Dam. The side channel dams and inlet facilities would be constructed as the excavation progresses. The first phase of the lock demolition would be done during this time frame also. Since the locks demolition / modification would be the most restrictive to navigation of all the components of this alternative, requiring restriction to single lane canal operation for an extended period of time, and since the two phases of the locks demolition / modification must be done one immediately before and the other immediately after the lowering of the Panama Canal water level, this work should be started as late in the schedule as possible to confine this restriction to the shortest time possible. After the main spillways at Gatun Dam and Canoa Saddle Dam, the side channel dams and appurtenant structures, the channel excavation, and the first phase of lock demolition have been completed, then the water level in the Panama Canal would be lowered and the second phase of the lock demolition would begin. At the completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions, the type and scope of construction, and the necessity of keeping the canal open and fully functional the maximum time possible, it is estimated that development of this project could be completed in approximately 25 years, from initial planning to final configuration. Figure 31 - 1 depicts the development sequence of the various project features.

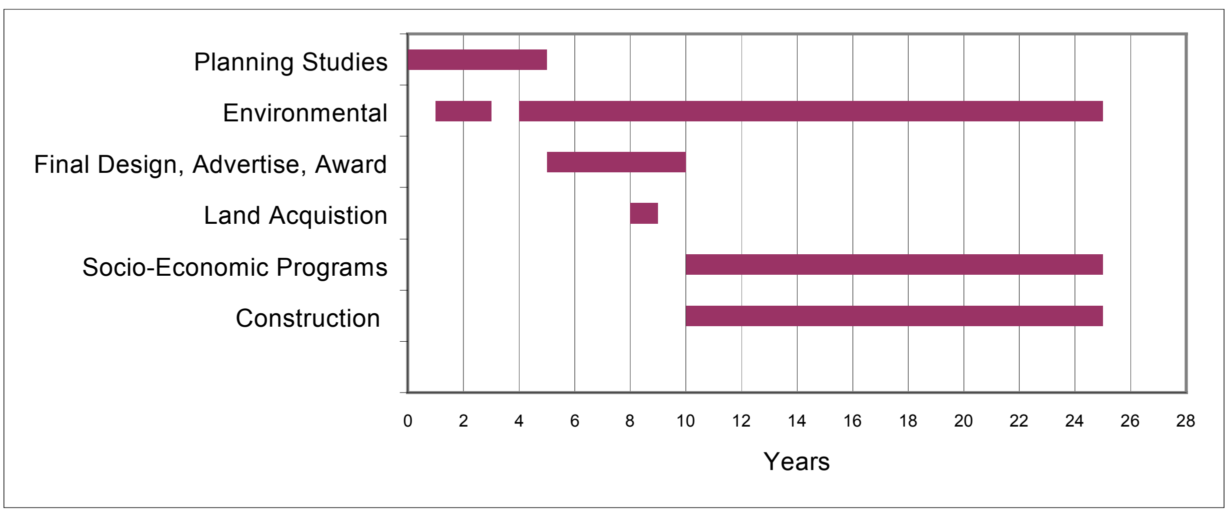


Figure 31 - 1 Development Sequence

Hydrologic Reliability

In order to determine the effect of the proposed alternative on the hydrologic reliability of the Panama Canal, the HEC-5 simulation model was modified to represent the Panama Canal separated from the remaining Gatun Lake. Madden Lake was configured to provide water directly to the Panama Canal. With a monthly time step and the relatively small storage in the canal portion, good model results were difficult to obtain. Because of the monthly time step, releases from Madden and Gatun Lakes were not accomplished in time to avert shortages in the canal. This created reliability percentages less than 99.6 percent. However, for higher demand levels the reliability was greater than existing conditions. Review of model results found that a daily model would be needed to accurately simulate the operation of this configuration. However, the monthly results could be used as an indicator of potential. The results indicate that the reliability of the system would not significantly increase and; therefore, benefits from the proposed project would likely be less than one lockage.

Given the criterion set forth in Section 4 that a project should provide at least one lockage, it is recommended that this alternative not be considered further.

Project Costs

GENERAL

A rough order of magnitude cost estimate is provided. The unit prices applied to these quantities were based on: historical information from previous estimates prepared for similar construction in the Republic of Panama, previous estimates for similar construction in the Southeastern United States, information gathered from U.S. Army Corps of Engineers, Mobile District, Construction Division personnel in the Republic of Panama, and the publication, Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1979.

An allowance of 25 percent was included in all construction features for contingencies. Engineering and design is estimated to be 12 percent and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $3,269,000,000. Table 31 - 2 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work. The costs for engineering and design, supervision and administration during construction, and field overhead (contractor facilities and construction camp) were included in the first costs of each item.

Table 31 - 2 Summary of Project First Costs

Principal Feature	Costs ($)
Access Roads	14,172,000
Clearing and / or Grubbing	3,102,000
Excavation of Navigation Channel	1,150,333,108
Channel Side Dams	1,320,554,953
Gatun Lock Modification / west lane	32,893,584
Gatun Lock Modification / east lane	32,893,584
Pedro Miguel Lock Removal / west lane	23,743,584
Pedro Miguel Lock Removal / east lane	23,743,584
Gatun Spillway Replacement	1,977,612
Canoa Spillway	2,741,174
Side Dam Inlet Structures	2,789,664
Powerplants	5,991,600
Switchyard	244,230
Subtotal	2,615,180,677
Contingencies	653,795,169
Total Project First Costs	3.268,975,847 **approximately** 3,269,000,000

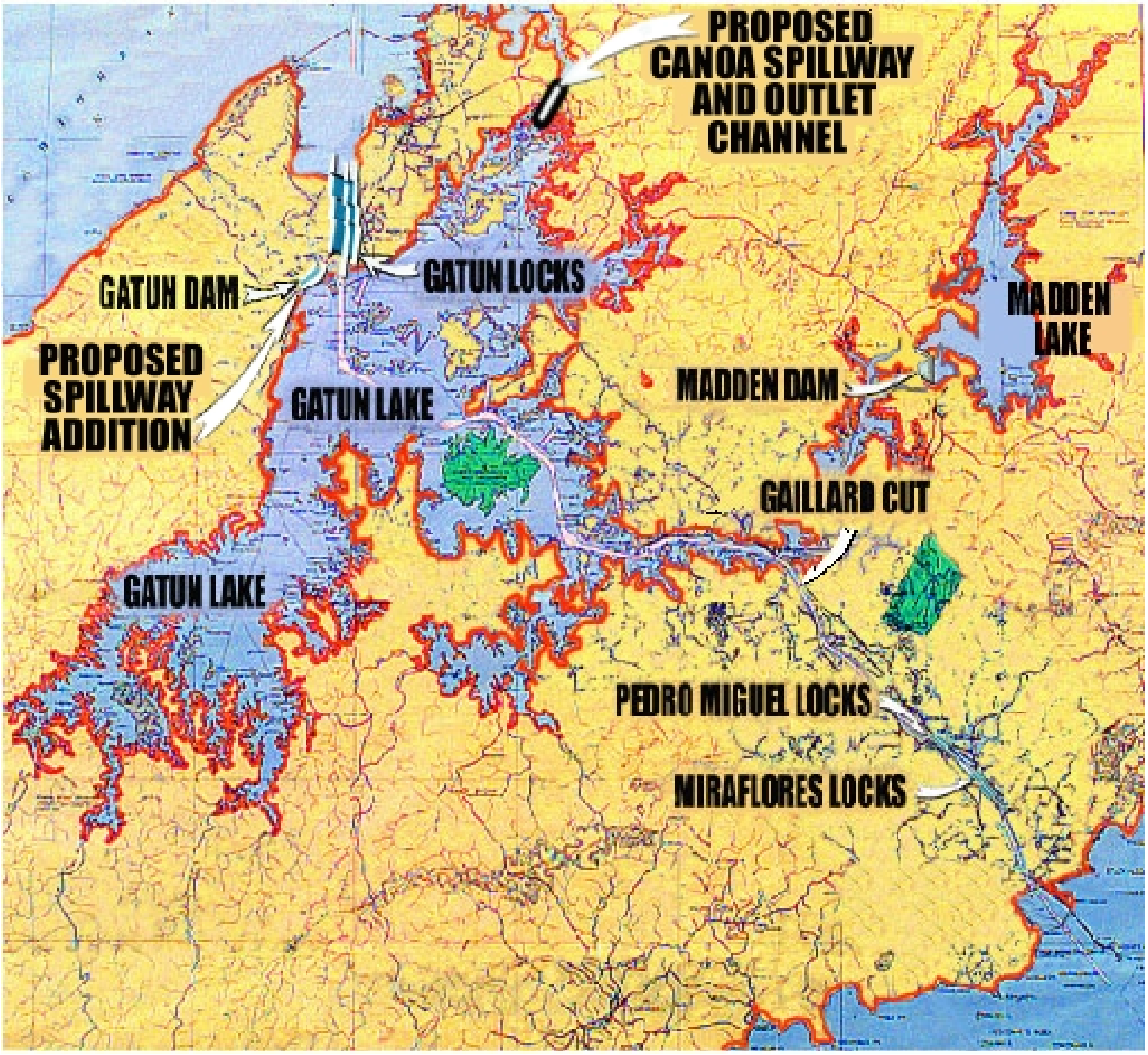
Pertinent Data

The Lower Gatun Lake alternative would create two separate lakes, one on the east side of the canal and another on the west side. These lakes would maintain current elevations but the canal would be lowered to elevation 55 ft (17.13 m) MSL. Miraflores Lake would become an integral part of the canal and Miraflores Spillway would control the Panama Canal lake level. Table 31 - 3 presents pertinent data for both lakes and the canal.

Table 31 - 3 Pertinent Data

GENERAL	
Total Drainage area into the West Lakes	471 mi^2 (1,469 km^2)
Average annual flow into the Lakes	259 CFS (7.3 CMS)
Total Drainage area into the East Lake	105 mi^2 (272 km^2)
Average annual flow into the Lakes	129 CFS (3.6 CMS)
Drainage area directly to Panama Canal	722 mi^2 (1,869 km^2)
Average annual local flow to Panama Canal	494 CFS (14 CMS)
LAKES	
Normal operating level for both lakes	87.5 ft (26.67 m) MSL
Maximum flood level for both lakes	91.5 ft (27.89 m) MSL
Minimum Operating level for both lakes	55 ft (17.13 m) MSL
Elevation of Canal normal operating level	55 ft (17.13 m) MSL
WEST SIDE SPILLWAY	
Total length	210 ft (64 m)
Net Length	180 ft (54.9 m)
Elevation of Crest	69 ft (21.03 m) MSL
Number of Gates	4
Type of Spillway	Gated – Ogee Crest
Maximum discharge	61,500 CFS (1,740 CMS)
EAST SIDE (CANOA) SPILLWAY	
Total length	100 ft (30.5 m)
Net Length	90 ft (27.4 m)
Elevation of Crest	69 ft (21.03 m) MSL
Number of Gates	2
Type of Spillway	Gated – Ogee Crest
Maximum discharge	30,750 CFS (870 CMS)
OUTLET STRUCTURES TO CANAL	
Type of structures	Gated sluices
Diameter of Sluices	7 ft (2.13 m)
Number of sluices in West Side	5
Number of sluices in East Side	3

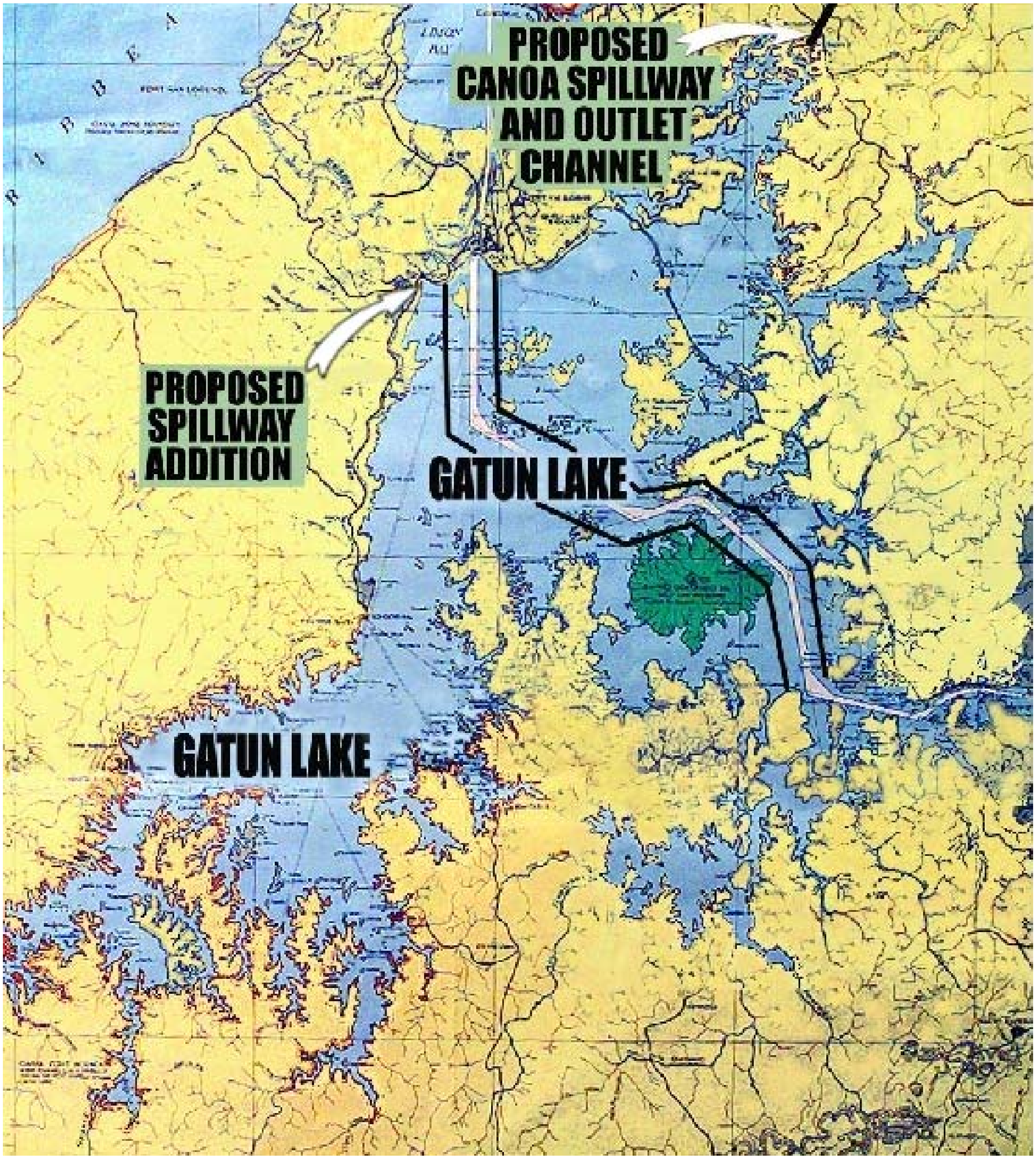
LOWER GATUN LAKE



Project Location Map

Plate 31 - 1 Project Location Map

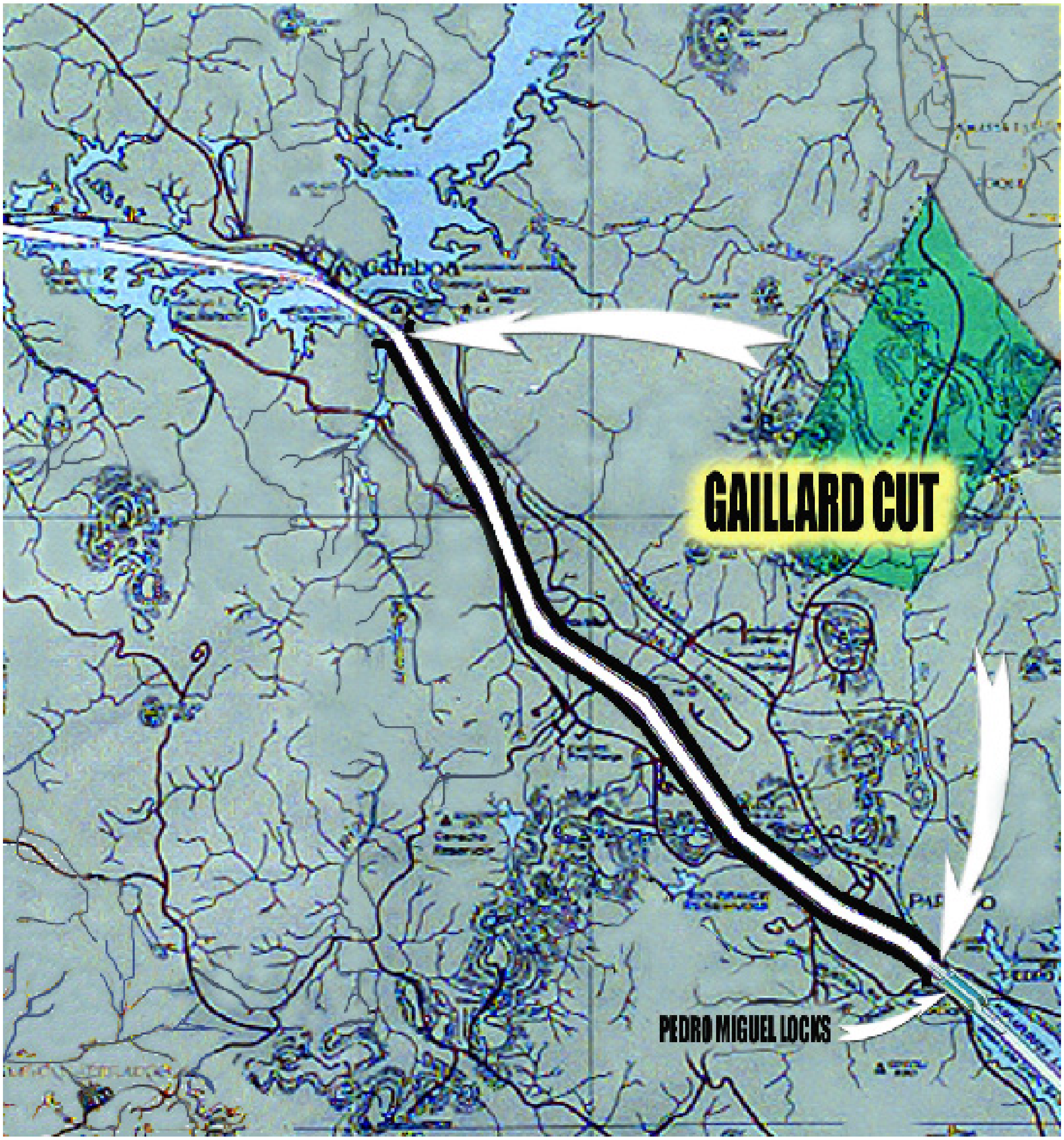
LOWER GATUN LAKE



Project Feature Map

Plate 31 - 2   Project Feature Map

LOWER GATUN LAKE



Gaillard Cut Feature

Plate 31 - 3 Gaillard Cut Feature

SECTION 32

REDUCE SEEPAGE AND EVAPORATION LOSSES FROM GATUN AND MADDEN LAKES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

Synopsis

SEEPAGE LOSSES

The areas where seepage losses might be occurring from the Gatun Lake consist of the main embankments of the Gatun Dam (by far the most important features) and saddle dams along the north, west, and southern boundary of the lake. The saddle dams are natural low ridges (23) or man-made embankments (4) which prevent reservoir water from spilling into adjoining drainage basins. Since any seepage losses from Madden Lake would drain into Gatun Lake, they were not considered in this alternative.

This proposal consists of reducing seepage from the Gatun Lake to provide additional lockage water for operating the Panama Canal. Some seepage is occurring through Gatun Dam and through some of the saddle dams located along the western boundary of the lake; however, the quantity is minor. The total documented seepage is less than 10 LPS. This amount is less than 14,400 LPD (0.4 MGD) or less than 0.7 percent of a lockage (55 million gallons). Due to the impervious nature of the saddle dams and the Gatun Dam foundation, any underground seepage is considered to be relatively inconsequential and would not significantly increase the computed quantities. Thus, reducing seepage from Gatun Lake is considered to be a totally inadequate solution for providing additional water for operating the Panama Canal.

EVAPORATION LOSSES

Gatun Lake is located at the apex of the Panama Canal and is the primary source of water for navigation. Not only does it provide water for the lockages but it also provides water for the main waterway for vessels passing from ocean to ocean. Gatun Dam is located at the Atlantic end of the Panama Canal between Gatun Locks and a range of hills on the west side of the valley. When the dam was completed, it was recognized as the largest in the world. The average annual rainfall for the northern region of Panama is 304.57 cm. Gatun Lake is located approximately 16.00 km from the Atlantic Ocean. A set of parallel locks, with three lifts each, located on the Atlantic side raises ships 85.00 ft (25.9 m) to Gatun Lake. At the southern end of Gatun Lake, the Gaillard Cut enables vessels to pass through the Continental Divide to Pedro Miguel Locks and Miraflores Locks which lower vessels to the Pacific Ocean.

Gatun Dam is 2.40 km long and 0.80 km wide. The surface area of Gatun Lake is 422.17 km^2 while the total drainage basin is 3,338.00 km^2. Normal upper pool is at elevation 87.5 ft (26.67 m) MSL and the tailwater is at sea level. The observed annual evaporation rate for Gatun Lake is 127.51 cm. This translates into a loss equivalent to approximately 7 lockages per day.

Madden Dam and Lake is located on the eastern side of the Panama Canal basin in the higher mountain ranges. The lake surface is approximately 252 ft (76.8 m) MSL and has a surface area of approximately 51.26 km^2. Madden Dam is a massive concrete structure consisting of a gated spillway, hydropower plant and an earth and rock fill section across the Chagres River. The dam is 220 ft (67.05 m) high and 950 ft (289.55 m) long. The eastern region of the Panama Canal basin receives much more rainfall than other areas; therefore, a significant portion of the water for the Panama Canal operations comes from Madden Lake. The observed annual evaporation rate for Madden Lake is 52.4 in (133.2 cm). This translates into a loss equivalent to approximately 0.8 lockages per day.

However, these losses are only critical during the dry season when the main source of water for navigation and M&I use is from storage in the lakes. Plate 32 – 1 depicts the general configuration of the lakes.

Public and private agencies reported 20 years ago that the use of chemicals to reduce evaporation was ineffective in the field setting because of the physical, biological and chemical factors. The alternative presented for Gatun and Madden Lakes would not be an effective method to reduce evaporation. The use of surface chemicals on Gatun and Madden Lakes would produce significant negative impacts on the biospheres of the lakes. In addition, a significant amount of chemical would be required to cover the lakes surfaces. The surface area of Gatun Lake, at elevation 85 ft (25.9 m) MSL, is approximately 423 MSM and Madden Lake, at normal lake elevation, is approximately 51.3 MSM. Accounting for voids and waste, this would require approximately 500,000 M^3 of hexadeconal to cover the surface with one application layer. Further consideration of this alternative is not recommended.

Project Features

REDUCE SEEPAGE LOSSES

General
This proposal consists of reducing seepage losses from Gatun Lake so as to provide additional lockage water for operating the Panama Canal. Two possible sources of seepage were identified. One source consists of seepage through the embankments of the main Gatun Dam and the other source consists of seepage through any of several saddle dams. See Plate 32 - 2 for location of the Gatun Locks and Dam and other features. The saddle dams are natural low ridges (23) or man-made embankments (4) which prevent reservoir water from spilling into adjoining drainage basins, and are located along the north, west, and southern margins of the lake.

Gatun Dam
The Gatun dam is located in a region of moderate hilly topography that is underlain by soft to moderately hard sedimentary rocks of Tertiary age. The higher topography in the area is directly underlain by clays and fine grained soil developed from intense weathering of the underlying rocks that occur at fairly shallow depths. The valleys are commonly filled with alluvial deposits that reach depths of up to 90 m. These deposits originated due to a general uplift of the land surface near the close of Tertiary time which caused the streams (Charges and Gatun Rivers included) to cut deep, narrow valleys into bedrock. Later, the land surface began to sink gradually and streams aggraded their channels, depositing material that was eroded from steep side slopes and higher elevations toward the center of the Isthmus. The Geologic Section taken along the axis of the dam, see Inspection of Panama Canal Flood Control Facilities Phase I. Volume IV, shows the distribution and general character of materials underlying the dam.

The Gatun spillway is founded on sound, moderately hard, argillaceous sandstone of the Gatun Formation of Miocene Age. Construction reports indicate that the rock was weathered only about a meter below the top of rock. No mention was made of jointing foundation. Apparently, great care was taken in preparing the foundation. The last 2 to 4 ft (0.6 to 1.2 m) above foundation grade was excavated by steam shovel and by hand to assure an undisturbed surface. The rock foundations were scrubbed with water jets to obtain a good bond with the concrete. A 1 ft (0.3 m) minimum thick concrete blanket was poured on the rock for a minimum of 233 ft (71 m) upstream from the structure to seal any openings and lengthen the seepage path under the spillway. No grouting was performed and no type of foundation drainage was provided.

The embankments of the Gatun Dam are a combination of rock and hydraulic fill. The embankments were constructed by placing two rock fill dams approximately 1200 ft (365.76 m) apart and then pumping hydraulic fill (clay material) into the interior to form the impervious section of the dam. Water from the hydraulic fill operation was allowed to flow from the embankment through horizontal drains with climbing vertical risers. In order to preclude stability problems due to the clay material upon which the dam was founded, as well as the material within the dam, the upstream and downstream slopes were constructed very flat, resulting in embankments which measured approximately 0.5 km across the base. Where the dam crossed the Chagres River the streambed was dredged to satisfactory sandy clay, and to original hard blue clay where it crossed the French Canal. A ditch about 19.7 ft (6 m) wide by 14.8 ft (4.5 m) deep was also cut across the valley along the dam axis, extending, with about half these dimensions, up the abutment slopes. The lowland of the valley was stripped for a width of 820 ft (250 m), with the excavation having a depth of 1 to 3.3 ft (0.33 to 1 m).

An extensive subsurface exploration program was conducted at the Gatun dam site consisting of borings as well as numerous test pits to determine the suitability of the foundation materials. In general, the material underlying the site from the surface down to the top of rock consists of clay with some sand. In the area of spillway hill beyond the west diversion, red clay averaging in thickness from approximately 10 to 20 ft (3 to 6 m) overlies the rock. This red clay was formed from decomposed rock and, with depth, it grades to a clay with a mixture of sand and decomposed rock. Brown sandy clay is found at the surface of the old gorges. This clay is an alluvial deposit and is composed of about 50 percent each of clay and sand, the sand grading from medium to superfine. Blue sandy clay underlies the brown sandy clay in the gorges and is considered the most permeable material that has any considerable extent. The blue clay and rotten wood found in the gorges consists of a large percentage of blue clay. In this material is found fine sand and decayed vegetation, the latter occurring in pockets and, when present, is in large proportion. The clay and shells in the gorges is an alluvial deposit of blue clay and sea shells, the larger percentage of which is clay and the remaining portion is composed of shells and sand. The stiff blue clay is an alluvial deposit of almost pure clay usually found just above the rock in the old gorges. It is very stiff and compact, and gradually grades into argillaceous sandstone. The clay, sand, and gravel is an alluvial and wash deposit containing small, angular fragments of hard rock found in the bottom of the old gorges, usually overlying the rock. It is found in pockets which, although extensive, does not extend in a continuous layer under the dam. In places it is compact and impervious to water, easily breaks down in a stream, and the wash samples show a very coarse gravel.

Saddle Dams

There are a number of low ridges along the boundary of the Gatun Lake that prevent reservoir water from spilling into adjoining drainage basins. These ridges are referred to as saddle dams and used here, is a general reference to both natural and constructed embankments that function as dams. The records document 27 existing saddles dams. There is some confusion as to which were constructed, however, it is believed that 4 were constructed and 23 are natural. The saddle dams vary considerably in elevation, length, slope, material and condition. Top elevations range from El. 93 (Caño No. 5) to El. 142 (Barro No. 1). Slopes range from 1.1 horizontal to 1 vertical (Caño No. 2, upstream) to 45 horizontal to 1 vertical (Arroyo No. 3, upstream).

The locations of the saddle dams are shown in Inspection of Panama Canal Flood Control Facilities Phase I. Volume IV, and a summary of the available engineering data are included in Table 32 - 1. In general, the material comprising the upper strata of each dam consists of impervious clay of varying thickness. Beneath the clay is a relatively thin stratum of decomposed rock that is underlain by sound rock (sandstone). The elevations for the top of sound rock, where known, are listed in Table 32 - 1. As can be seen in the table, in most cases, the top of rock elevation is above or only a few feet below the Gatun pool level.

Table 32 - 1 Saddle Dam Data

Saddle Name	Geographical Location	Length	Slopes Average (horizontal to vertical) U/S	D/S	Crest Elev. (m MSL)	Top of Rock Elev. (m MSL)
Lagarto 1	1.6 km NE of Cuipo	unknown	10 on 1	20 on 1	32.0	27.4
2	1.6 km NE of Cuipo	unknown	12 on 1	15.5 on 1	31.7	27.4
3	2.4 km NE of Cuipo	15 m	15 on 1	10 on 1	35.0	25.9
Caño 1	2 km North of Cuipo	100 m	6 on 1	6 on 1	35.0	24.7
2	2.2 km North of Cuipo	100 m	1.1 on 1	1.5 on 1	35.0	23.4
3	2.5 km North of Cuipo	unknown	4 on 1	4.7 on 1	31.7	23.5
4	2.9 km North of Cuipo	unknown	2.5 on 1	1.5 on 1	32.0	23.5
5	3.0 km North of Cuipo	unknown	14 on 1	13 on 1	28.4	22.8
6	3.62 km North of Cuipo	unknown	22 on 1	16 on 1	29.8	15.2
Arroyo 1	7.6 km SW of Escobal	107 m	11 on 1	35 on 1	35.6	27.4
2	7.4 km SW of Escobal	295 m	12 on 1	10 on 1	34.4	22.6
3	6.9 km SW of Escobal	205 m	45 on 1	16 on 1	35.6	26.2
4	6.6 km SW of Escobal	95 m	12 on 1	8 on 1	35.0	24.4
5	6.1 km SW of Escobal	unknown	11 on 1	17 on 1	32.9	19.8
6	5.8 km SW of Escobal	115 m	7.5 on 1	9 on 1	35.0	22.3
Gatun 1	U/S of 3rd Lock Excavation					
Escobal 1	1 km SW ctr of Escobal	70 m	38 on 1	4 on 1	35.0	27.4
2	0.56 km SW ctr of Escobal	unknown	9 on 1	60 on 1	35.0	25.6
3	1 km NE ctr of Escobal	unknown	4 on 1	12 on 1	35.0	25.3
Egronal 1	92 m E of Landing, Ft. Glck	45 m	unknown		39.3	36.6
Barro 1	3.2 km W of Sabanita Ck Pt	unknown	7 on 1	10 on 1	43.3	37.5
2	2 km W of Sabanita Ck Pt	unknown	unknown		31.7	Unknown
3	1.3 km W of Sabanita Ck Pt	unknown	unknown		31.7	Unknown
Canoa 1	0.8 km S of Sabanita Ck Pt	295 m	4 on 1	5 on 1	36.3	35.0
2	1.3 km S of Sabanita Ck Pt	unknown	unknown		36.3	Unknown
3	1.8 km S of Sabanita,	unknown	unknown		36.3	Unknown
Pedro Miguel	W. lock wall to Cartagena Hill	unknown	unknown		32.0	Unknown

DESCRIPTION OF PROPOSED USE OF SURFACE CHEMICALS TO REDUCE EVAPORATION

GENERAL

The use of surface chemicals to reduce evaporation was researched over 20 years ago by various public and private agencies. The Bureau of Reclamation in Salt Lake City, Utah and

Boulder, Colorado, experimented with the use of surfactants to reduce evaporation from dryland reservoirs. In addition, various power companies researched the use of hexadecanol to reduce evaporation. S. B. Engineers & Associates was a contractor for one of the power companies researching evaporation reduction. Both public and private agencies did not find the use of surface chemicals to be beneficial in a field-setting due to the effects on various biological, chemical, and physical factors.

Many types of chemicals that have specific gravity lower than water will float in freshwater or seawater. However, hydrodynamic processes, such as surface tension and turbulence, may affect the ability of various chemicals to float in both freshwater and seawater. For example, turbulence may either submerge a chemical that would normally float at the surface, or resuspend a chemical that would normally sink below the surface or to the bottom. Also, waters with high surface tension, such as waters containing discharge from a municipal sewage system, may either support particles with a density greater than water or keep an otherwise buoyant particle submerged. Physical factors, such as these, were found to affect the use of a chemical to reduce evaporation.

Hexadecanol Characteristics

The primary additive researched over 20 years ago was hexadecanol. Synonyms for hexadecanol are hexadecan-1-ol, cetyl alcohol, palmityl alcohol, n-cetyl alcohol, and n-hexadecanol.

Hexadecanol is a stable compound and incompatible with strong oxidizing agents, such as chlorine. It is a white waxy solid with a faint odor. The melting point and boiling point of hexadecanol is 49.3 and 344°C, respectively. The uses of hexadecanol include a foam stabilizer and water evaporation retardant (Widman, 1999).

Hexadecanol – Laboratory Setting

In a laboratory setting, five gallons of hexadecanol poured into a closed-system dispersed one-molecule thick over the entire surface area. Spherical microbeads having a uniform size in the range of 0.48 mm up to 1.4 mm diameter covered the surface area. Evaporation was reduced up to 90 percent as a result of the hexadecanol film.

Hexadecanol was evenly dispersed over the entire surface area when conditions were calm and stable. This closed-system setting does not consider the biological, chemical, and physical factors.

Hexadecanol – Field Setting

In a field setting, five gallons of hexadecanol was poured into an open-system dispersed throughout the surface area. Spherical microbeads ranging from 0.48 up to 1.4 mm in diameter formed patches across the surface area as a result of various physical factors. A small breeze over the surface area unevenly redistributed hexadecanol in one direction of the open-system. In addition, a ripple in the water broke the one-layer thick spherical microbeads, which resulted in open water patches where evaporation was not reduced. Physical factors resulted in no net reduction in evaporation by the use of hexadecanol.

Although hexadecanol is fairly inert, it was found that an increase in fauna mortality resulted from its use in an open-system. The spherical microbeads covering the water surface affected pelagic fauna. Studies determined that hexadecanol coated the gills of small fish species and disrupted gestation of various eggs and larvae. The chemical persistence of hexadecanol in the environment could be measured in years, depending on the types and amounts of additives, and the reaction of the additives to environmental processes.

SEEPAGE HISTORY

Fifteen active seeps are monitored along the downstream toe of the Gatun Dam. Weirs have been constructed at each of these seeps for the purpose of measuring the seepage quantities. Due to the large area occupied by the embankments (slightly greater than 1/2 km across the base) and the flat slopes (4 on 1 to 16 on 1), infiltration from rainfall can greatly affect the weir measurements. Therefore, measurements made during the dry season most accurately represent the true seepage from Gatun Lake. Table 32 - 2 shows measurements made during the dry season, during a period with a relatively high lake level. As can be seen, only eight of the seeps were actually flowing when the measurements were made. As shown on the table, the seepage from Gatun Lake through the dam is relatively minor, measuring about 7 LPS (approximately 1/4 CFS, or about 115 GPM).

Table 32 - 2 Gatun Dam – Weir Measurements (Typical Dry Season) *

Date : 15 March 1990	Lake Level = 85.89 ft.
Weir No.	Flow (CFS)
1W	0.03067301
2W	0.00422784
3W	0.00000000
4W	0.01426002
5W	0.00500448
6W	0.01429291
7W	0.00000000
8W	0.00249046
9W	0.00000000
10W	0.00000000
11W	0.00000000
12W	0.00054955
13W	0.00068939
5E	0.00000000
5W	0.18302397
TOTAL	0.25521163 (115 GPM)

* The measurements were made and recorded in English units.

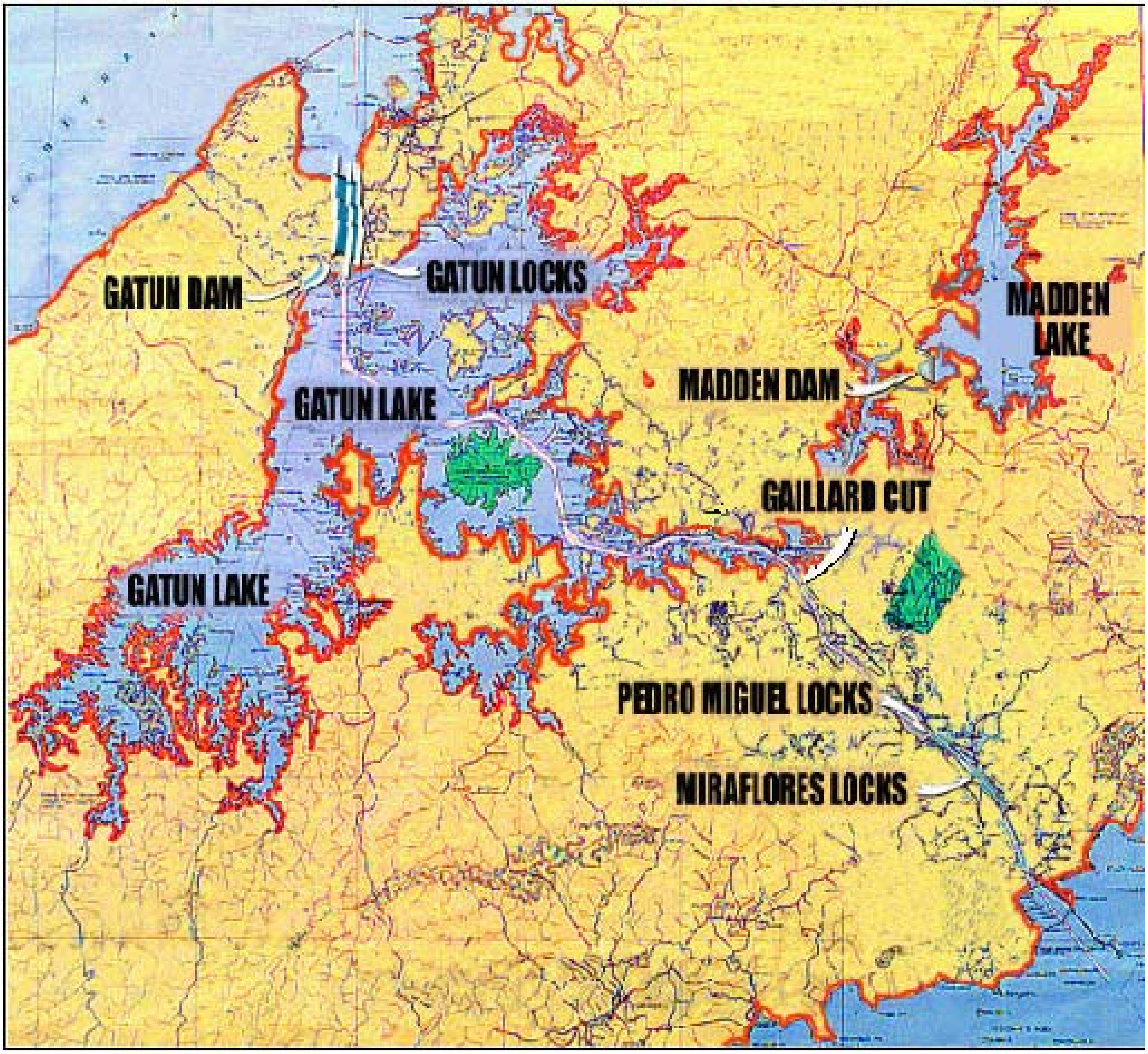
Inspections have also confirmed the fact that a serious problem of seepage does not exist through the saddle dams. The most complete documented inspection of the saddle dams was that conducted in April 1976 by Messrs. Stewart, Long and Robinson of the PCC. This inspection only noted seepage at five saddle dam sites, and it was not determined for certain that all the seepage noted was from Gatun Lake. Their descriptions of the minor amounts of seepage are included in Table 32 - 3. An inspection of 21 of the 27 saddle dams made by the U.S. Army Corps of Engineers, Ohio River Division, in October 1995 only noted seepage at two of the dams (Barro 1 and Caño 4), but quantities were not estimated during this inspection.

Table 32 - 3   1976 PCC Saddle Dam Inspection

SADDLE DAM	SEEPAGE DESCRIPTION
Caño 3	very little seepage
Caño 4	2 to 3 gpm
Arroyo	approximately 30 GPM
Barro 3	little or no evidence of seepage
Canoa 1	continuous seepage (no amount given)

* The measurements were made and recorded in English units.

REDUCE LOSSES FROM GATUN AND MADDEN LAKES



Project Location Map

Plate 32 - 1 Project Location Map

REDUCE LOSSES FROM GATUN LAKE

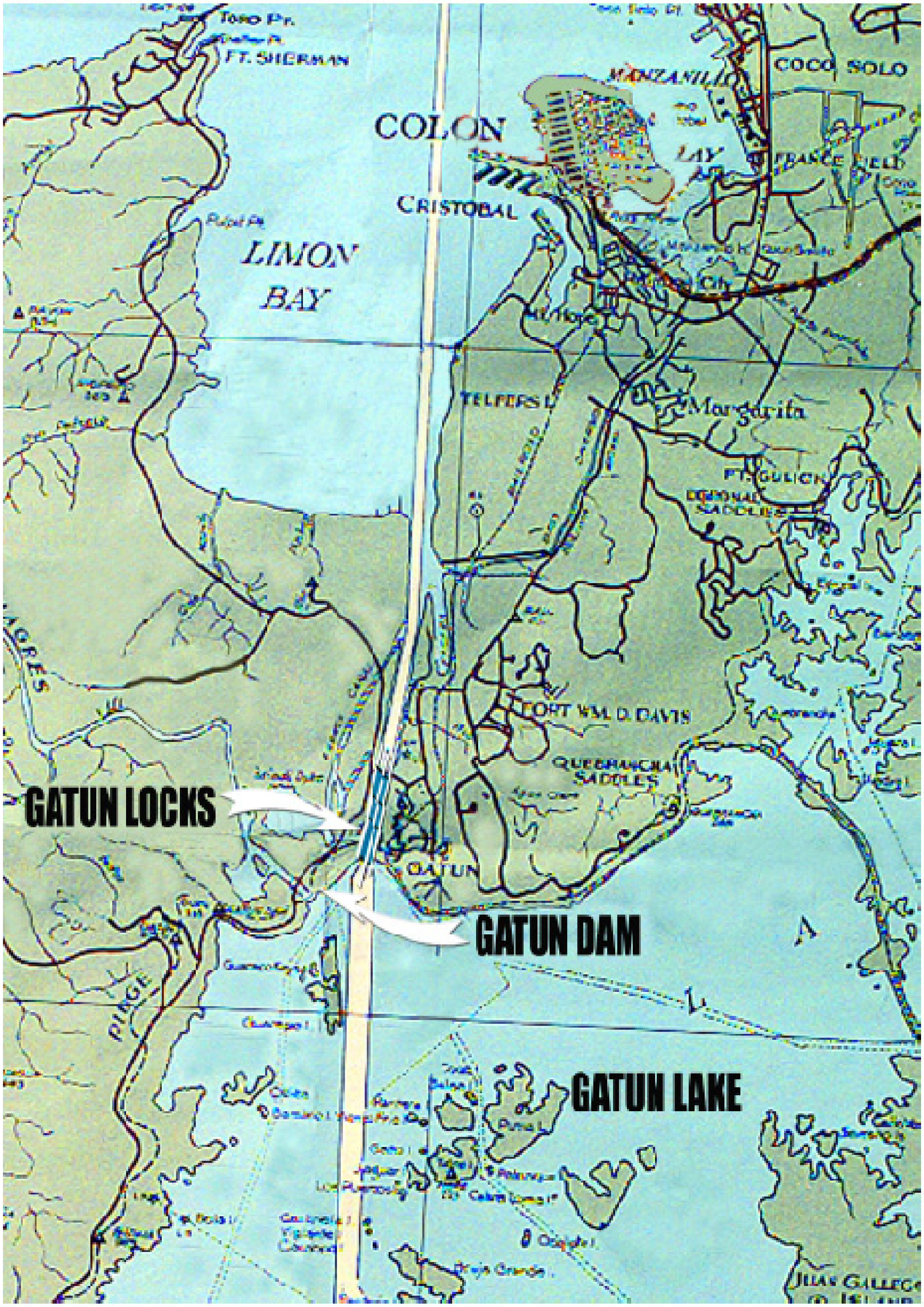


Plate 32 - 2 Existing Features Map

SECTION 33

Pump Saltwater to Gatun Lake

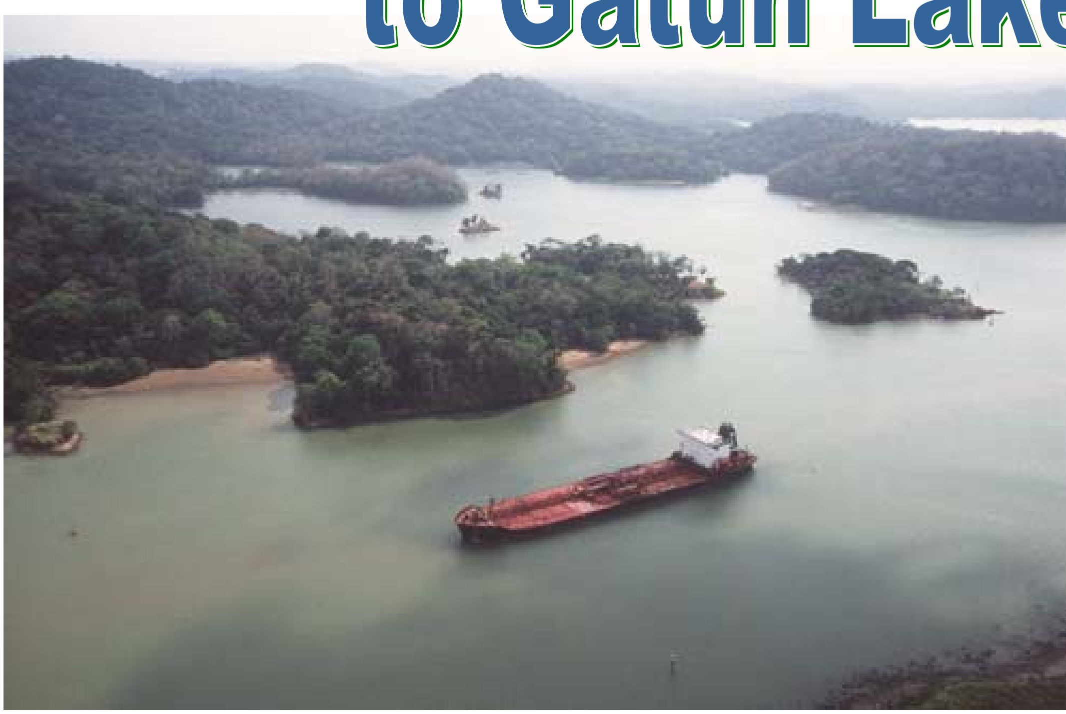


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The Pump Saltwater to Gatun Lake alternative considers pumping of saltwater from the Atlantic Ocean to Gatun Lake to supplement water for operational needs in the Panama Canal. The concept suggests placing a pumping station immediately below Gatun Dam at the end of the old French Canal and pumping water up over the dam into the lake. Plate 33 – 1 shows the location of the proposed Pump Saltwater to Gatun Lake project. The placement of a pumping station at the Pacific end of the Panama Canal was determined not to be feasible. At the Pacific end of the Panama Canal, water would need to be pumped from the Pacific Ocean to Pedro Miguel Locks, a considerable distance over developed infrastructure. See Figure 33 - 1 for a schematic of the proposed plan.

The pumping station would be designed to pump the equivalent of one lockage (55 million gallons) in 24 hours. The total first costs of the proposed Saltwater Pumping project are estimated to be $471,331,000.

Energy requirements for the pumping station would be significant and likely not available through local electrical supplies. The pumping station would be constructed with its own power source. The power source could be either diesel or electric motors. The electric motors would require a gas turbine electric plant. The generation plant could produce energy when pumping was not required and the energy could be used for other purposes or sold.

This project would contribute to the hydrologic reliability of the Panama Canal to serve its customers but would experience high maintenance and operational costs. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent (46.42 lockages) of current level would be 98.8 percent. The pumping station presented in this section provides for only one lockage per day. It is assumed that the plant operations would be repeated a number of times to produce the total requirement. A rough economic analysis indicated that 5 plants would produce a benefit cost ratio greater than one. With a 5-unit system, pumping levels could be controlled up to a maximum of 5 lockages and reliability could be maintained until demand levels exceed 112.9 percent (43.68 lockages) of current levels. The pumps would only be needed during the dry season to avoid imposing draft restrictions but as demands increase the frequency and duration of pumping would also increase.

While this alternative appears to meet the engineering and economic criteria established in Section 4, the injection of saline water into Gatun Lake at the proposed rate will impose significant environmental impacts. In addition, several M&I entities are currently extracting raw water for potable water supply from Gatun Lake. These water supplies would be significantly impacted and would require new freshwater sources. A new treatment plant would be required for one set of raw water intakes. There may be other water intakes such as those for the steam electric powerplant that would also require a new source of fresh water.

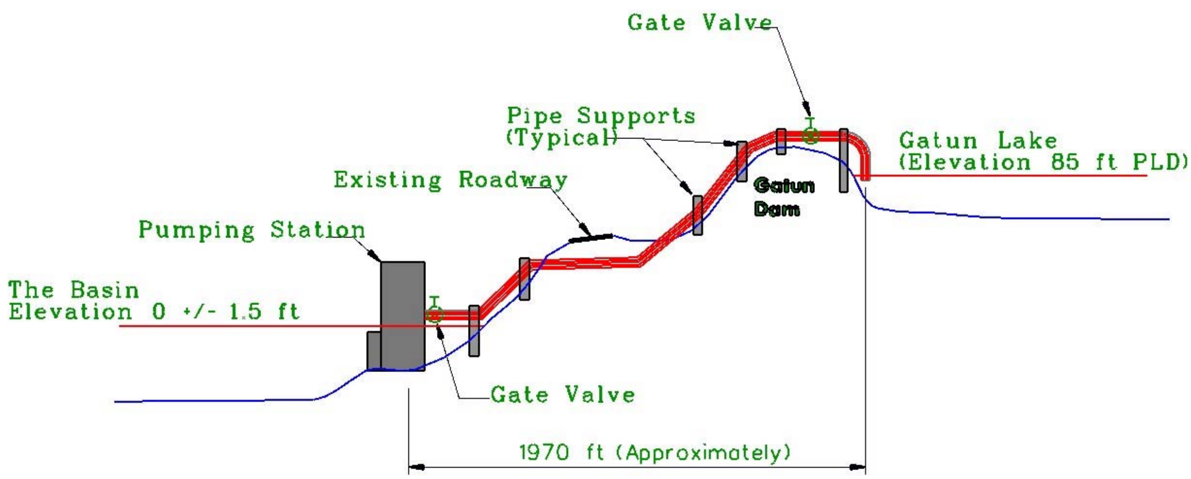


Figure 33 - 1   System Profile

Site Selection

The recommended sites for the saltwater pumping station was chosen with a view toward minimizing equipment requirements, utilizing available space and minimizing impacts on Panama Canal operation.

Careful review of the topography, local infrastructure, and available space at each end of the Panama Canal determined that the Gatun Dam area at the end of the old French Canal would best accommodate the pumping station, pipelines and powerplant. Miraflores Lake between Pedro Miguel Locks and Miraflores Locks contained several roads, railroads, and other facilities that would be interrupted if pipelines were placed through those areas. In addition, the pumping distance would be approximately 2.5 km. Considering these facts and the magnitude of pumping required, it was judged impractical to place a system at the Pacific Ocean end of the Panama Canal.

Hydrologic Considerations

The Panama Canal watershed has two distinct seasons, a dry season and a wet season. The dry season normally begins in mid December and lasts approximately 4 months. The remaining 8 months comprise the rainy season. Heaviest rains fall from September to December. Average annual rainfall varies from 3,300 mm along the Atlantic Coast to 1,600 mm along the Pacific Coast. In the upper mountain ranges above the Madden Dam, average annual rainfall reaches nearly 4,000 mm.

The Gatun and Madden Lakes provide storage for regulation and the use of rainfall runoff during the dry seasons. They provide both navigation lockage water and raw water for M&I consumption. Gatun Lake also serves as the connector route for vessels transiting the Panama Canal. During drought conditions, water is not only needed for water supply but also to insure sufficient navigation depth for ships. Eighty-five years of hydrologic data and operational records are available for this system.

Lake Operation

Gatun Lake was planned in the early 1900s to be filled during the rainy season to elevation 85 ft (25.91 m) MSL for normal operations, with storage above this level to be reserved for flood control operations. The design of the lock walls and gates were based on the assumption that the lake level would seldom be permitted to rise to more than elevation 87 ft (26.52 m) MSL, 2 ft (0.61 m) above normal operating levels.

The 1991 Panama Canal Flood Control Plan increased the maximum normal operating level of Gatun Lake to 87.5 ft (26.67 m) MSL. Currently, Gatun Lake flood storage lies between the maximum normal operating level and 92.0 ft (28.04 m) MSL. This apparently did not take into consideration the fact that the bottom of the spillway gates in the fully raised position is 91.5 ft (27.89 m) MSL. Raising the maximum operating lake level from elevation 85 ft (25.91 m) MSL to elevation 87.5 ft (26.67 m) MSL reduced the available flood storage capacity by approximately one-third but provided additional storage for water supply during the dry season.

Analysis of this alternative considered that the current operating plan would continue to be used.

During dry seasons, storage is taken from Gatun and Madden Lakes to provide water for locking vessels and for M&I water supply. Normal navigation depth is available until the water level of Gatun Lake drops below elevation 81.5 ft (24.84 m) MSL. With lake levels below 81.5 ft (24.84 m) MSL, draft restrictions must be imposed on shipping. For this study, it is at this point that the pumping activities would be employed. The actual initiation of pumping activities would occur before that point and would be determined in a more detailed feasibility study. With current demand levels of water supply needs, the pumping of saltwater would be infrequent. Based on HEC-5 model simulation runs, this would have occurred only three or four times over the last 50 years. The Panama Canal is expected to average 34.5 lockages per day in the year 2000 and is expected to reach the maximum limit of 40 lockages (43 transits) in the year 2012. As demands for water supply increase, the frequency for using the pumps would increase.

Project Features

GENERAL

This proposed project would consist of a pumping station and a powerplant located near the base of Gatun Dam. The pumping station would withdraw seawater from the small lake at the end of the old French Canal. The old French Canal connects to the entrance channel from Bahia Bay at the Atlantic end of the Panama Canal. A 42 in (115 cm) pipeline would carry the water up the face of Gatun Dam and inject the saltwater into Gatun Lake. The pumping station would have the ability to pump 55 million gallons (208,180 M^3) in 24 hours, which equates to one lockage. The following paragraphs provide a description of the proposed structures and improvements for the Pump Saltwater project.

Performance of the design was only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. The purpose of this level of effort is to determine if the project is feasible. Optimization of the project features should be accomplished in the next level of effort. The PCC received separate documentation that contained assumptions and design calculations for the reconnaissance level investigations of these structures. Plate 33 – 2 is a basic site layout of the proposed system.

Since this project involves the injection of saltwater into Gatun Lake, the existing water supply facilities would be significantly impacted or disabled. In addition to the features presented here, a new source of fresh water will be needed for those facilities. Some costs for a replacement reservoir and a replacement reservoir with a water treatment plant are estimated in the project costs. Optimization of these features should be accomplished in the next level of effort.

PUMPING PLANT

Pumping Capacity

Based on information provided by the PCC, the average volume of water needed to pass a transit from ocean to ocean is 55 million gallons (208,180 M^3). The average elevation of Gatun Lake is 85 ft (25.9 m) MSL. The total lift would be approximately 85 ft (25.9 m). Assuming that the pump would operate continuously for 24 hours, a pumping capacity of 2.41 CMS (85.71 CFS) would be required. Approximately 1,968 ft (600 m) of 25.28 in (115 cm) pipe would be needed to carry the water to Gatun Lake. Considering energy losses through the pipe, the pump would have a total dynamic head of 99.1 ft (30.2 m). Since the water would be brackish, the piping and pump would be designed to operate in a corrosive environment.

Powerplant

The pump would require a 980 metric HP powerplant. This plant could be either diesel or electric. Electric motors would be easier to maintain but would require a 1.0 MW power source. Sufficient power could be purchased from the local electrical service for one pumping station but it was assumed that local sources would not be able to provide for multiple stations. Since the basic assumption to this alternative was to employ multiple stations, the project would provide its own energy source. A 1 MW gas turbine generating plant would be provided in the area near the pumping station. If desired, energy produced by the plant during the times pumping would not be required, could be used for other purposes or sold.

CLEARING AND / OR GRUBBING

Only areas necessary for construction of the pumping station, pipelines and powerplant would require clearing and grubbing. The transmission lines, connecting the powerplant to the national grid, would require clearing.

ACCESS ROUTE

Access to the proposed projects sites is already available.

Sources of Construction Material

Special items such as pumps, motors, pipe, and valves would be fabricated outside the Republic of Panama and imported for final assembly.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported.

Real Estate Requirements

All property for the Pump Saltwater to Gatun Lake alternative is located within PCC property. No additional property would be required.

Relocations

By pumping 30 ppm saltwater into Gatun Lake when water shortages are apparent, Gatun Lake would eventually become significantly saline. Relocation of the M&I water supply intakes that are currently withdrawing water from Gatun Lake would be required since these systems are not designed to treat saline waters. This would include the Panama Canal treatment plant intake at Gamboa, the intake for the City of Colon and several other small intakes. An alternate source of freshwater would need to be supplied for these entities. Also, many facilities along the Gatun Lake that would not be tolerant to saltwater would need to be modified or relocated, including metal structures and equipment.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed project would also be made to assure environmental acceptability of the project features and develop the necessary mitigation plans. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising, and award phase, and on through construction of the project. In this instance, it was assumed that the environmental scrutiny of the proposed action would be very thorough, since the alternative under consideration stands to completely change the Gatun Lake ecosystem over time. For this reason, the final design would be accomplished for the recommended project only after all environmental issues have been addressed and resolved to the satisfaction of the jurisdiction having authority. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would normally begin with land acquisition and construction of the access facilities. For this alternative, it is assumed that all of the lands required for this project are already under PCC control and the only access required would be that incidental to the construction effort and within the construction area.

Socio-economic programs would begin shortly before construction would start. Socio-economic programs to assist those individuals impacted by the construction of the proposed project would continue throughout the construction phase, however, for this project they are expected to be insignificant.

Construction would begin with isolation of the pumping plant site using a sheetpile cofferdam. Following preparation of the foundation, the concrete structure would be placed and the pumping equipment would be installed. Concurrent with the pumping plant construction, the required pipe supports would be placed as required across the dam and the cluster pile support for the pipe outlet would be placed. The pipe would then be placed and connected to the pumping plant. The pumping station cofferdam would then be removed. Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the nature of the work, it is estimated that development of this project could be completed in approximately 6 years, from initial planning to lake filling. Figure 33 - 2 depicts the development sequence of the various project features.

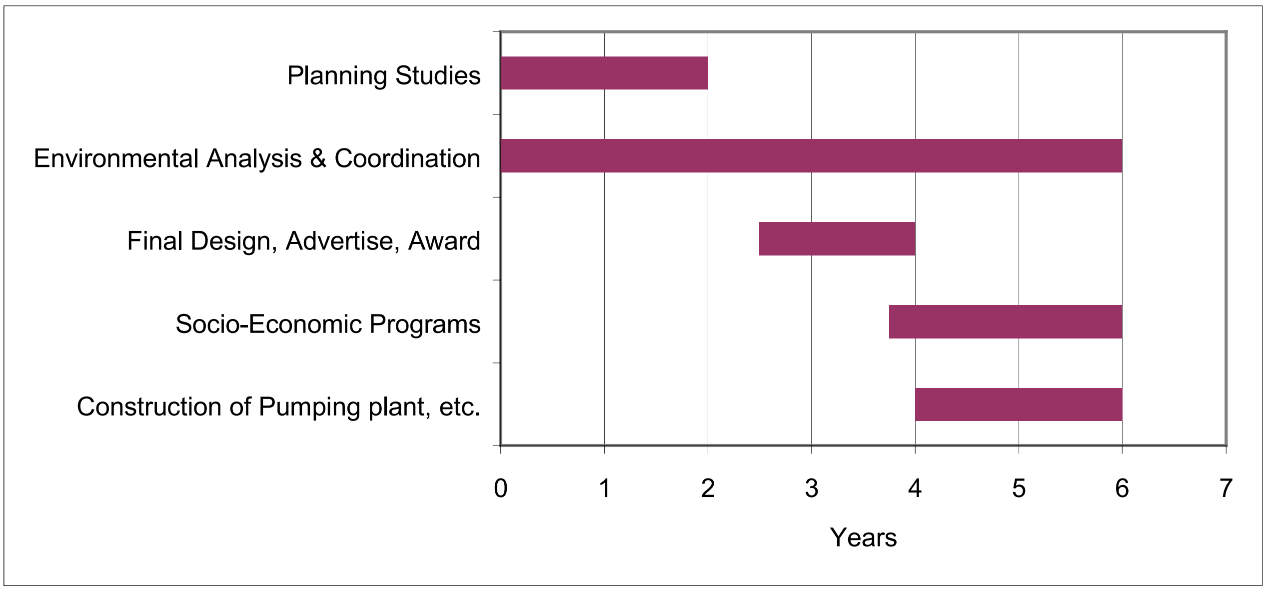


Figure 33 - 2 Development Sequence

The development sequence depicted above is for the pumping plant only. This proposal would also require the replacement of the raw water source for several intakes and an additional water treatment plant. The development sequence for these facilities resembles that for the proposed Rio Camito project (Section 14) which is approximately a 7 year period from initial planning to lake filling.

Hydrologic Reliability

The existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. One pumping station would only provide a slight increase in reliability (1 lockage or an increase of 2.6 percent); however, the desired increase would be a function of the number of plants installed. Rough economic analyses indicate that 5 plants will produce a benefit cost ratio greater than one. With a 5-unit system, pumping levels could be controlled up to a maximum of 5 lockages and reliability could be maintained until demand levels exceed 112.9 percent (43.68 lockages) of current levels. As total demand levels (navigation plus M&I water supplies) increase, the number of pumping plants could be increased to maintain the necessary reliability.

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts and general guidance from technical sources. The unit prices applied to these quantities were based on: historical information from previous estimates prepared for similar construction in the Republic of Panama, previous estimates for similar construction in the Southeastern United States, information gathered from the U.S. Army Corps of Engineers, Mobile District, Construction Division personnel in the Republic of Panama, and the publication, Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1979.

Engineering and design is estimated to be 12 percent and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent was included for contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $471,331,000. Table 33 - 1 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 33 - 1 Summary of Project First Costs

Principal Feature	Costs ($)
Below Ground Work for 42 in Pipe	94,750
Pumping Station	3,120,000
Gas Turbine Generating Plant	400,000
Replacement Reservoir	185,302,866
Replacement Reservoir with Water Treatment Plant	125,302,866
Subtotal	314,220,482
E&D, S&A, Field Overhead	62,844,096
Contingencies	94,266,145
Total Project First Costs	471,330,723 **approximately** 471,331,000

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Saltwater Pumping Plant continuously. A staff would also be needed to operate and maintain the 2 replacement reservoirs and the replacement water treatment plant. The full-time staff would ultimately consist of a total force of 68 who would include a 3 station managers, 6 multi-skilled supervisors, 19 leaders (Electronics / Instrumentation, Electrical and Mechanical), 33 craftsmen, and 7 laborers. The annual costs of the staff are estimated to be $2,677,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants, and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $650,000 per year for the main project facilities.

Major Replacements

The average service life of a pumping station (gates, electrical equipment, turbines, and other features) would be less than the total useful life of the proposed project, which would be 100 years. To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it was assumed that specific items would cost the same as at present. No allowance was made for salvageable fixed parts. Table 33 - 2 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements would be $1,615,000 and the average annual replacement costs would be $194,000.

Table 33 - 2   Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	3,300,000	11,419
Bridges	50	1	1,800,000	6,228
Water Supply System				
Pumps w/Diesel Backup	25	2	33,630,000	1,047,297
Steel Water Lines	50	1	129,000,000	446,363
Intake				
Head Gates	50	1	750,000	2,595
Minimum Flow Gates	50	1	345,000	1,194
Stoplogs	50	1	111,000	384
Trashracks	50	1	85,500	296
Access Stairs	50	1	90,000	311
Saltwater Pumping Plant				
Automated Gate Valves	25	2	135,000	4,204
Controls for Valves & Pumps	25	2	300,000	9,343
Pump Station	33	1	3,000,000	71,273
Gas Turbine	33	1	600,000	14,255
Total			89,281,500	1,615,162
Average Annual Replacement Costs				194,000

Annual Costs

The total project first costs are estimated to be $471,331,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the total project first costs was computed from mid-year throughout the 7-year period from initiation of the Planning Studies until completion. The interest during construction at 12 percent would be $152,092,000 and it was added to the total project first costs for total project investment costs of $623,423,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $75,070,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to the present worth as of completion of lake filling. Table 33 - 3 contains a summary of the annual costs.

Table 33 - 3 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	471,331,000
Interest During Construction	152,092,000
Total Project Investment Costs	623,423,000
Annual Average Investment Costs	75,070,000
Operation and Maintenance Costs	
Staff Costs	2,677,000
Ordinary Maintenance Costs	650,000
Major Replacement Costs	194,000
Total Average Annual Costs	78,591,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Section 4. The following paragraphs present the results of the economic investigations for the proposed Pump Saltwater to Gatun Lake project. The 50-year planning period for this proposal is 2005 to 2055.

The proposed Pump Saltwater to Gatun Lake project would not significantly alter the reliability of providing water to accommodate the total daily number of lockages demanded. Therefore, benefits associated with the change in reliability were not estimated for this proposal.

With the proposed Saltwater Pumping to Gatun Lake project, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands increase, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. The proposed project is designed to provide a single lockage. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages provided by each option. The average annual benefits for water supply would be $19,946,000. Table 33 - 4 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed project in operation, the annual benefits for meeting shortages, and the average annual benefits.

Table 33 - 4 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits ($)
2005	3.06	2.06	18,332,000
2015	8.14	7.14	20,622,000
2025	9.83	8.83	20,622,000
2035	12.04	11.04	20,622,000
2045	14.81	13.81	20,622,000
2055	18.30	17.30	20,622,000
Average Annual Benefits			19,946,000

SUMMARY OF ANNUAL BENEFITS

As shown in Table 33 - 5, the total average annual benefits for the proposed Pump Saltwater to Gatun Lake project would be $19,946,000.

Table 33 - 5 Summary of Annual Benefits

Benefit Category	Average Annual Benefits
Navigation – Water Supply	19,946,000
Navigation – Reliability	Not estimated
M&I - Reliability	Not estimated
Hydropower	None
Total Annual Benefits	19,946,000

Once average annual benefits and costs are estimated, the ratio of benefits to costs and the net benefits (net of costs) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. Table 33 - 6 provides the benefit to cost ratio and the net benefits for the propose project.

Table 33 - 6 Economic Evaluation

Item	Value ($)
Average Annual Benefits	19,946,000
Average Annual Costs	79,591,000
Benefit to Cost Ratio	0.3
Net Benefits	(58,645,000)

Internal Rate of Return

An internal rate of return analysis for the proposed project was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For the Pump Saltwater to Gatun Lake project, the internal rate of return would be 1.3 percent.

Incremental Evaluation of Pumping Saltwater

A rough order of magnitude analysis was performed to determine if there is a level of pumping that would be feasible. The results of this analysis show that this alternative would be feasible if five (5) sets of pumps and pipelines that would provide five (5) additional lockages were implemented. The costs of additional sets of pumps and pipelines were incrementally added to the first costs, the operation and maintenance costs for the pumping plants were increased, and the resulting average annual costs were calculated. The total project first costs increased from $471,331,000 to $493,019,000. The average annual costs increased from $$78,591,000 to & 82,094,000. The costs for replacing the freshwater sources and the water treatment plant were not increased since these would be one-time costs. The level of benefits was increased by a factor of 5 to match the number of lockages provided by the increased number of pumps and pipelines. The average annual benefits increased from $19,946,000 to $99,730,000, producing a benefit to cost ratio of 1.2.

Socio-Economic Impacts

Because of the nature of this project, its socio-economic impacts could be significant. The project area does not contain any municipalities. The project could produce supplemental power that could be sold or used for other purposes when pumping was not required in the wet season.

Several M&I entities that use Gatun Lake for a potable water supply could require a new freshwater source. In addition, a new treatment plant would be required for one set of raw water intakes. Many facilities along Gatun Lake that are not tolerant to saltwater would need to be modified or relocated, including metal structures and equipment.

Environmental Setting

The following summarizes the potential impacts of the Pump Saltwater to Gatun Lake project. The structure that would be impacted by the proposed project are Gatun Dam. These impacts are ranked in terms of measure and importance in Tables 33 - 8 (Environmental Effects) and 33 - 9 (Socio-economic Effects). The measure category relates to the degree of impact of the raising of Gatun Lake to the impact categories listed in each table. The measure numbers range from 1 to 10, with 1 to 4 representing a continuum of negative impacts, 5 indicating neutral, and 6 to 10 representing an increasing continuum of positive impacts. The importance numbers range from 1 to 10, with 1 representing low importance and 10 being significant.

LAND USE

The Pump Saltwater to Gatun Lake project would pump saltwater from a pumping station with a powerplant near the base of Gatun Dam. The saltwater would be withdrawn from a small lake at the end of the old French Canal. The saltwater would be pumped through a 115 cm pipeline at a rate of 55 million gallons a day (one lockage volume) into Gatun Lake above Gatun Dam. The landscape surrounding the Gatun Dam is maintained by PCC. Most of this area is deforested and has been disturbed since the initial construction of the Panama Canal. This project could impact Gatun Dam; however, the land use and local towns in the area would not be impacted by the proposed project.

INFRASTRUCTURE

After careful review of the topography, local infrastructure, and utilizing available space at the end of each end of the Panama Canal, it was determined that the Gatun Dam at the end of the old French Canal would accommodate the pumping station, powerplant and pipelines. The PCC own and manage the space required for the project. Both paved and dirt roads are well maintained in the area of Gatun Dam. The operation and maintenance of the Panama Canal is the only industry in the area. There are no towns or inhabitants within the project area.

TERRESTRIAL HABITAT

Tall grass fields and sparse patches of secondary growth forest make up the terrestrial habitat surrounding Gatun Dam. The terrestrial habitat within the project area has remained disturbed by maintenance activities since the construction of the Panama Canal. The fields of tall grass offer habitat for a variety of wildlife species, even though exotic plant species dominate the vegetation. Secondary growth forests offer another type of habitat. Terrestrial habitat is used by both migratory and native, resident species as feeding, breeding, and resting grounds. The complex and diverse tropical ecosystems connect a variety of wildlife communities. This area may provide critical wildlife habitat to many native species.

ANIMALS ON ENDANGERED LIST

ANAM by its Resolution 001-80 on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Exotic species introduced to Panama are pushing native species towards the endangered and threatened status. The construction of the Panama Canal, along with continuous slash and burn land use practices, has caused species to concentrate into fragmented forest areas where competition for resources is high and weaker species are quickly and significantly reduced. Although it has not been determined with certainty, some or all of the marine animals and other species listed as threatened or endangered habitat might be found in the project area.

AQUATIC HABITAT

Gatun Lake, one of the largest man-made lakes in the world, contains many different types of aquatic habitat ranging from forests inundated during Panama Canal construction, to various depths and degrees of water quality, influenced by the proximity of shipping lanes and topographical features below the surface of the lake. Gatun Lake provides habitat for a variety of wildlife species, both resident and migratory, as well as for both native and introduced fish and other aquatic species.

WETLANDS

Areas containing hydric soils, hydrophytic plant communities, and hydrologic conditions are termed wetlands. Typical wetlands in the project area consist of shallow water habit that experiences frequent flooding. Shallow water areas along the banks of Gatun Lake receive sunlight to a depth of approximately 3.28 ft (1 m), depending on water clarity. Sunlight stimulates plant growth in the forms of submergent, emergent, or aquatic mats of floating vegetation at some distance from the shore and into the deeper aquatic habitats. Wetlands occur in topographic areas where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the project area are stressed by wave action created by ships and by runoff from slashed and burned areas.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities, lasting 2 weeks to a month. At the end of the dry season in March or early April, areas of forests and secondary growth are burned and cleared to prepare the land for agricultural use. During these activities the air is filled with smoke and burnt debris transported by winds. Air quality monitoring systems have not been implemented within the project area. The natural environment could provide indicators that could be useful in making an air quality assessment.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The Pump Saltwater to Gatun Lake project is within PCC property boundaries form old French Canal to Gatun Dam. No known parks or other government-protected lands are located within the project area. It should be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, and international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts on the terrestrial habitat in the Pump Saltwater to Gatun Lake project area would be substantial. Clearing and grubbing is required to prepare the land for construction, resulting in a permanent loss of terrestrial habitat. However, the area required for construction is small. In addition, the most significant disturbance would be the elimination of a freshwater drinking water source for all the neighboring habitats in the proximity of Gatun Lake.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered species cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Some endangered and / or threatened species may use Gatun Lake or the habitat near the lake, for part or all of their life cycle.

WATER QUANTITY

The impacts of the project on water quantity should be beneficial, because the pumping of saltwater should result in additional water for lock operations. The increase in water volume should allow less restrictive navigation through the Panama Canal during the dry season.

WATER QUALITY

The impacts of the project on water quality are substantial. Saltwater that is continuously pumped into Gatun Lake could degrade the overall quality of Gatun Lake from freshwater to saline. Pollution from the operation and maintenance of the locks, incidental discharges that result from shipping traffic, a vessel, and other factors may also impact water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat would be substantial. Fish and other freshwater aquatic organisms would be killed by the change from freshwater to saline. Aquatic fauna within the lake would probably also not survive the change from freshwater to saline.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities would be substantial. The future aquatic plant community would be changed to those that can survive in a saline environment.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting Gatun Lake and the affected areas would be substantial. Fish and other freshwater aquatic organisms would be killed by the change from fresh to saline water. Aquatic fauna within the lake also would probably not survive the change from fresh to saline water. Transforming Gatun Lake from a freshwater lake to a saline environment would remove the natural freshwater barrier that prevents the migration of organisms from one ocean to the other.

WETLANDS

The impact of the project to wetlands is substantial. Wetland areas around Gatun Lake would be changed over time from the existing freshwater environment to a saline environment.

AIR QUALITY

During project implementation, emissions from equipment could impact air quality in the project area. After project implementation, the air quality would be permanently impacted by the air emission from the powerplant.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties cannot be defined. Prior to project implementation, surveys would be conducted to locate cultural resource and historic properties and the important sites would be preserved or salvaged as appropriate. Due to the small areas to be disturbed and the ability to relocate the pumping station, powerplant and pipeline, no impacts are anticipated.

Additional Environmental Information Required

This section identifies the subject areas for which insufficient data are available to fully evaluate the scope and magnitude of their potential effects. The gaps are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an SIA. The SIA would consist of three tasks; scoping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities.
  - Employment.
  - Land Use.
  - Property Values.
  - Public and Community Facilities and Services (including utilities and schools).
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major terrestrial and aquatic habitat types are identified and quantified.
- Conduct field studies to locate rare and unique habitat features such as wetlands, primary forests, roosting sites, foraging areas, old growth, migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts regarding terrestrial and aquatic habitats before and after project implementation.
- Provide species inventory lists for each site, identifying their status, and if they are threatened and / or endangered species.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for animals on the endangered and / or threatened species list.
- Determine field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts to determine the presence of these species.

WATER QUALITY

- Locate alternate sources of freshwater for existing users of freshwater from Gatun Lake.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Information regarding cultural resources is incomplete. Additional evaluation studies need to be completed to identify cultural resources and historic properties.

Evaluation Matrices

In accordance with evaluation procedures described in Section 4, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Section 35. Tables 33 - 7 through 33 - 9 present the evaluation of the proposed Pump Saltwater to Gatun Lake project as related to developmental effects, environmental effects, and socio-economic effects.

Table 33 - 7 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	1	10	10
	Supplements Existing System	0	10	0
	Satisfies Future Canal Needs/Expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	7	6	42
	Feasibility of Concept	7	6	42
Operational Issues	Compatibility	2	6	12
	Maintenance Requirements	3	2	6
	Operational Resources Required	3	2	6
Economic feasibility	Net Benefits	0	9	0
	Total			118

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 33 - 8 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	1	8	8
Animals on Extinction List	1	10	10
Water Quantity Impacts – Lake	1	10	10
Water Quantity Impacts - Downstream	1	7	7
Water Quality	1	10	10
Downstream Aquatic Fauna Habitat	1	8	8
Future Lake Aquatic Plant Community	1	8	8
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	2	5	10
Potential for Fishing on Lake	1	6	6
Wetlands	1	4	4
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			146

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 33 - 9 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	4	7	28
Relocation of People	5	10	50
Relocation of Agricultural/Ranching Activities	5	6	30
Post-Construction Business	5	5	25
Post-Construction on Existing Employment	5	5	25
Property Values During Construction	5	4	20
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	5	4	20
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	5	5	25
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	5	4	20
Communities Receiving Displaced People	5	8	40
Community Cohesion	5	8	40
Tourism	5	5	25
Total			438

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

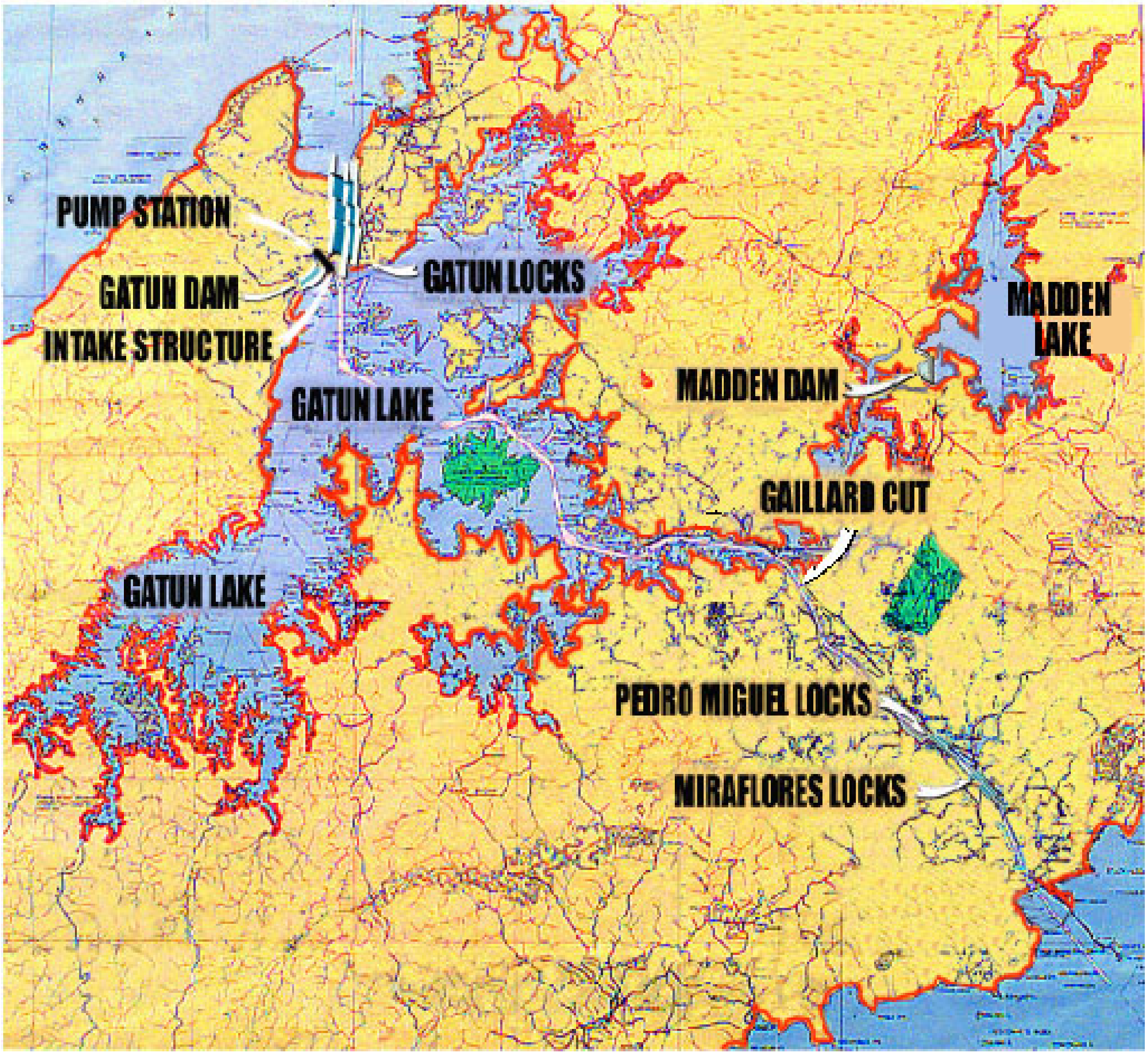
Pertinent Data

Table 33 - 10 presents pertinent data for operating Gatun Lake as proposed by the Pump Saltwater to Gatun Lake project.

Table 33 - 10 Pertinent Data for Operating Project

GENERAL	
Project Site	At the Base of Gatun Dam
LAKE	
Elevation of Normal Operating Lake Level	85 m MSL
Elevation of Maximum Flood Lake Level	88.5 m MSL
Elevation of Minimum Operating Lake Level	81.5 m MSL
Area at Normal Operating Lake Level	4,280 ha
Area at Maximum Flood Lake Level	4,440 ha
Area at Minimum Operating Lake Level	3,630 ha
PUMPING STATION	
Pump Specifications	
Pumping Capacity	2.41 CMS
Total Dynamic Head	30.2 m
Brake Horsepower	980 HP
Pipeline Specifications	
Diameter of Pipe	115 cm
Length of Pipe	600 m
Type of Pipe	Steel – Enamel Coated
GENERATING PLANT	
Type of Plant	Gas Turbine
Capacity	1 MW

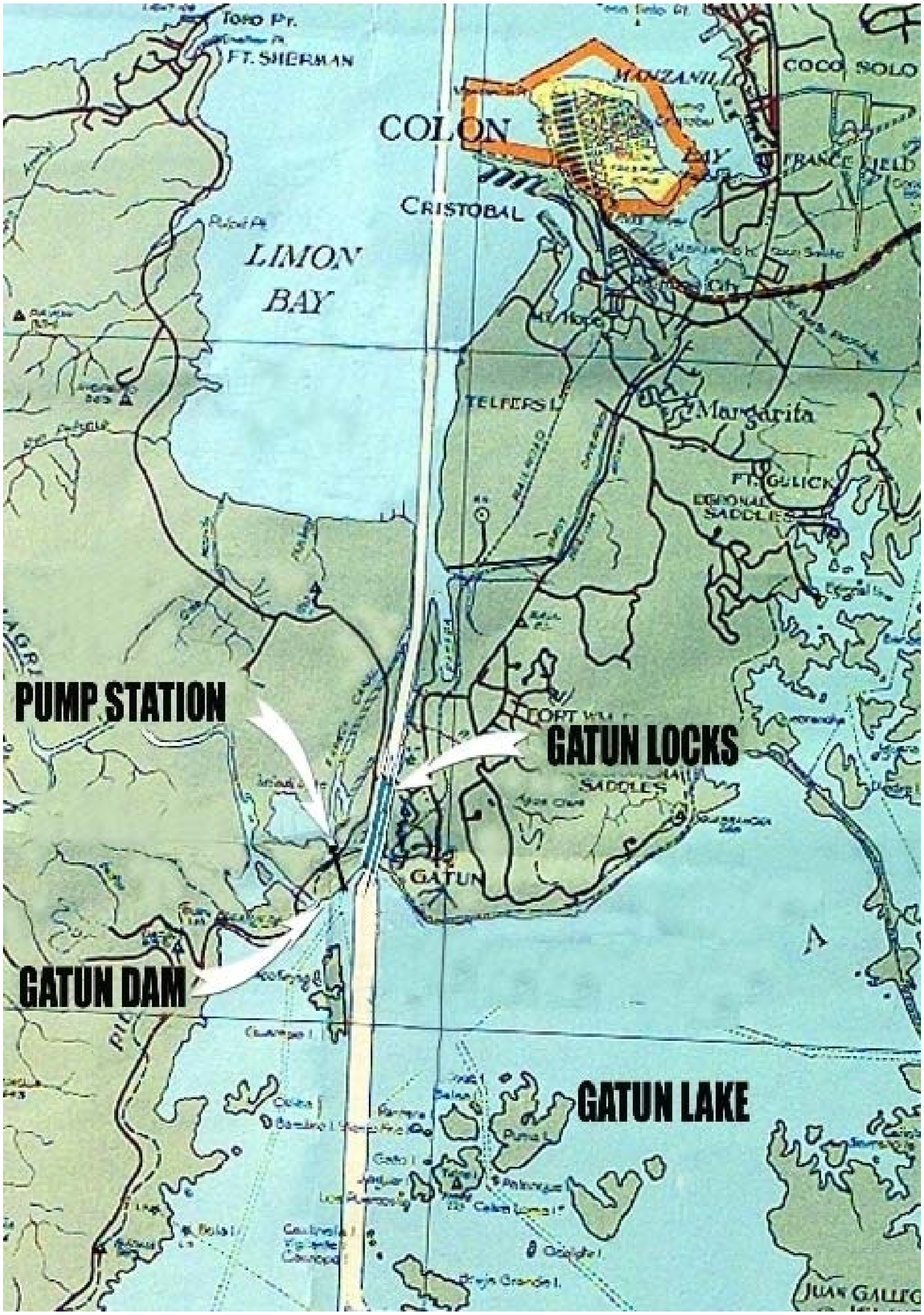
PUMP SALTWATER INTO GATUN LAKE



Project Location Map

Plate 33 - 1   Project Location Map

PUMP SALTWATER INTO GATUN LAKE



Proposed Feature Map

Plate 33 - 2 Proposed Feature Map

SECTION 34

Recycling Ponds

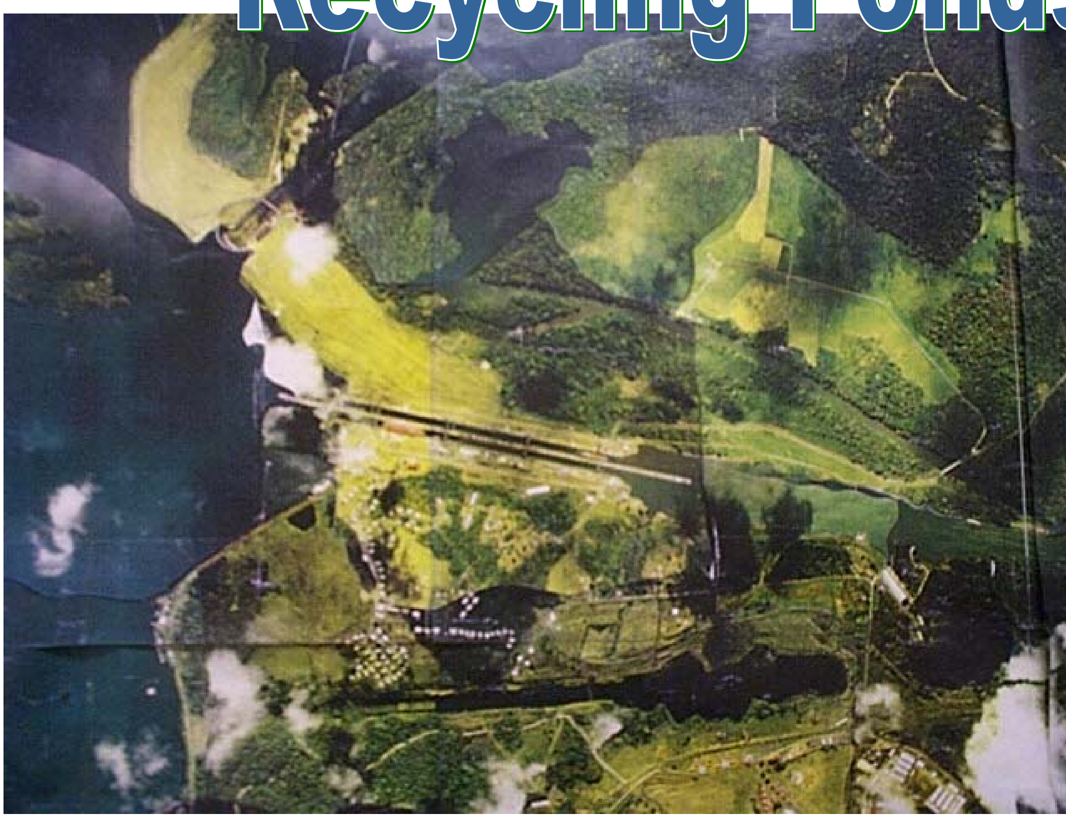


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The Recycling Ponds alternative presented herein considers modification of the Gatun Locks to allow capture of lockage water in holding basins and reuse of the water by pumping water to the upper chambers of the locks. The concept evaluated in this section involves placing recycling ponds on either side of the Gatun Locks lower chambers with pumping stations to return water to the upper chambers on demand. Placement of recycling ponds at the Pacific end of the Panama Canal was determined not to be feasible. An analysis of the Pacific end revealed that water would need to be pumped several kilometers to Pedro Miguel. Pipelines would cross several roads, communities, and PCC facilities. See Plate 34 - 1 for a schematic of the proposed plan.

This alternative proposes the placement of ponds near the downstream end of the lower lock chambers of Gatun Locks. These ponds, one on each side, would be sized to contain at least one chamber of lockage water approximately 22.5 million gallons (104,090 M^3). Pumping stations would be provided for each pond with the ability to pump approximately one half of a chamber of water to the upper chamber during normal filling of the chamber. The locks would be modified to allow capture of water from the lower chamber and to transfer the water, via pumping, into the filling culverts of the upper chambers in the outer lock walls. Water would be captured from the lower chamber for every other lockage and returned to the upper chamber during the next lockage. This operation methodology was employed to minimize intrusion of saltwater into Gatun Lake. Each time the lower chamber is opened and vessels exit the chamber to the Atlantic Ocean, the chamber water will mix with seawater, making the lower chamber water saline. This alternative would pump the lower chamber water to the holding pond and eventually to the upper chamber. This would make the upper chamber saline. When the upper miter gates to the upper chamber are opened to Gatun Lake the saline water would mix with the lake. Over time, this could accumulate a significant quantity of saline water in Gatun Lake. The structural configuration of Gatun Locks will only accommodate connection to the filling and emptying systems in the outside walls. The total first costs of the proposed Recycling Pond project are estimated to be $165,000,000.

Energy requirements for the pumping stations would be significant and likely not available through local electrical supplies. The pumping stations would be constructed with their own power sources. The power source could be diesel motor or electric motors. The electric motors would require a gas turbine electric plant. Energy from an electrical system could be used for other purposes or sold when pumping is not required.

This project would contribute to the hydrologic reliability of the Panama Canal to serve its customers but would experience high maintenance and operational costs. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent (46.42 lockages) of current level would be 98.8 percent. Since the concept can only be applied at the Gatun Locks, with current traffic levels, a total of 3.66 lockages per day would be saved if both lanes were operating when traffic reaches the maximum limit. The net daily savings would be 4.24 lockages for a maximum traffic level of 40 lockages. The pumps would only be used during the dry season to extend existing water supplies to avoid draft restrictions.

Site Selection

The recommended sites for the recycling ponds were chosen with a view toward optimizing the capture and return process, minimizing equipment requirements, utilizing available space and minimizing impacts on canal operation.

Careful review of the topography, local infrastructure, and available space at each end of the Panama Canal determined that the Gatun Locks would accommodate the capture ponds, pumping stations, pipelines and powerplants. Miraflores Lake between Pedro Miguel Locks and Miraflores Locks contained several roads, railroads, and other facilities that would be interrupted if pipelines, capture ponds and powerplants were placed in those areas. In addition, the pumping distance would be approximately 1.6 mi (2.5 km). Considering these facts and the magnitude of pumping required, it was judged impractical to place a system at the Pacific Ocean end of the Panama Canal.

Hydrologic Considerations

The Panama Canal watershed has two distinct seasons, a dry season and a wet season. The dry season normally begins in mid December and lasts approximately 4 months. The remaining 8 months comprise the rainy season. Heaviest rains fall from the beginning of September to December. Average annual rainfall varies from 129.9 in (3,300 mm) along the Atlantic Coast to 63 in (1,600 mm) along the Pacific Coast. In the upper mountain ranges above the Madden Dam, average annual rainfall reaches almost 157.5 in (4,000 mm).

The Gatun and Madden Lakes provide storage for regulation and use of rainfall runoff during the dry seasons. They provide both navigation lockage water and raw water for M&I consumption. Gatun Lake also serves as the connector route for vessels transiting the Panama Canal. Therefore, during drought conditions, water is not only needed for water supply but also to insure sufficient navigation depth for ships. Eighty-five years of hydrologic data and operational records are available for this system.

Lake Operation

Gatun Lake was planned in early 1900 to be filled during the rainy season to elevation 85 ft (25.91 m) MSL for normal operations, with storage above this level to be reserved for flood control operations. The design of the lock walls and gates was based on the assumption that the lake level would seldom be permitted to rise to more than elevation 87 ft (26.52 m) MSL, 2 ft (0.61 m) above normal operating levels.

The 1991 Panama Canal Flood Control Plan increased the maximum normal operating level of Gatun Lake to 87.5 ft (26.67 m) MSL. Currently, Gatun Lake flood storage lies between the maximum normal operating level and 92.0 ft (28.04 m) MSL. This apparently did not take into consideration the fact that the bottom of the spillway gates in the fully raised position is 91.5 ft (27.89 m) MSL. Raising the maximum operating lake level from elevation 85 ft (25.91 m) MSL to elevation 87.5 ft (26.67 m) MSL reduced the available flood storage capacity by approximately one-third but provided additional storage for water supply during the dry season.

Analysis of this alternative considered the current operating plan would continue to be used. The operational strategy for the recycling pond system is described later in this document.

Project Features

GENERAL

This proposed project would consist of two capture ponds or lakes, pumping stations, and powerplants located near the end of the lower chambers of the Gatun Locks. These ponds, one on each side, would be sized to contain at least one chamber of lockage water approximately 22.5 million gallons (104,090 M^3). Pumping stations would be provided for each pond with the ability to pump approximately one half of a chamber of water to the upper chamber during normal filling of the chamber (18 minutes). The locks would be modified to allow the capture of water from the lower chamber and to transfer the water, via pumping, into the filling culverts of the upper chambers in the outer lock walls. One half of a chamber of water would be captured form the lower chamber every other lockage and returned to the upper chamber during the next lockages. This operation methodology was employed to minimize intrusion of saltwater into Gatun Lake. The following paragraphs provide a description of the proposed structures and improvements for the Recycling Pond project.

Performance of the design was only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. The purpose of this level of effort is to determine if the project is feasible. Optimization of the project features should be accomplished in the next level of effort. The PCC received separate documentation that contained assumptions and design calculations for the reconnaissance level investigations of these structures.

CAPTURE PONDS

The capture ponds would be located near the Atlantic end of the lower lock chambers. See Figure 34 - 1 for a basic site layout. The ponds would be 16.4 ft (5 m) deep with a concrete slab bottom with a surface area of approximately 189,983 sq ft (17,650 $M^{2)}$. Side walls could be formed by concrete. If the ponds were square they would be 436.35 ft by 436.35 ft (133 m by 133 m) but they can be constructed in a rectangular format if desired. Anchors will be required to restrain the bottom of the pond against uplift forces.

Water would be diverted to the capture ponds by connecting a 15.1 ft by 15.1 ft (4.6 m by 4.6 m) concrete conduit to the 50.96 ft (15.5 m) diameter lock wall culvert in outer walls of the lower chambers. The conduit would be equipped with a gate to control flow to the capture pond. The connection can be made into the lock wall upstream of the last emptying valve.

PUMPING PLANTS

Pumping Capacity

Based on information provided by the PCC, previous studies, and general traffic information, an average of 18 minutes is needed to fill a lock chamber to the necessary level. Gatun Locks use three chambers to step a vessel from the Gatun Lake to the Atlantic Ocean. The average elevation of Gatun Lake is 85 ft (25.9 m) MSL. However, the Lake operates down to elevation

81.5 ft (24.84 m) MSL when inflows are insufficient. When the lake level drops to the minimum elevation of 81.5 ft (24.84 m) MSL, pumping would be required to assist lockages. One chamber would fill vertically approximately one third of the difference between Gatun Lake at elevation 81.5 ft (24.84 m) MSL and the Atlantic Ocean. Thus, one chamber would require approximately 23.3 million gallons (88,260 M^3). Since only half of a chamber can be captured each time a vessel is locked through Gatun Lake, only 11.7 million gallons (44,130 M^3) would be diverted to the capture pond when the last lock chamber is lowered. During the next lockage, this water would be pumped to the upper chamber. This would require a total pumping capacity of 1,443 CFS (40.86 CMS). To achieve this rate, five pumps with a capacity of 300 CFS (8.5 CMS) would be needed. The pumps should have a total dynamic head of 164 ft (50 m). Each pump would be connected to the outer lock wall filling culvert with a 5 ft (1.524 m) diameter steel pipes. Since the water would be brackish, the piping and pumps would be provided with appropriate protection.

Large pumping plants cannot be cycled on and off quickly. Therefore, the pumping plants would need to be equipped with a by-pass system to keep water circulating during the times that the upper chambers are not being filled.

Powerplant

Each pump would require a 6,600 HP powerplant. This plant could be either diesel or electric. Electric motors would be easier to maintain but would require a 5.16 MW power source. Therefore, each recycling pond system would require 28.35 MW of power. Since two systems are proposed, one on each side of the Gatun Locks, 56.7 MW would be needed to operate the recycling system. It is not likely, especially during the dry season, that the Republic of Panama would have this much power in reserve. Therefore, a 60 MW gas turbine-generating plant would also be required. Energy produced by the plant during the times pumping would not be required could be used for other purposes or sold.

RECYCLING OPERATIONAL SCHEME

The recycling system would only be operated to extend existing water supplies and to avoid draft restrictions during the times that the Gatun Lake drops to near its minimum level. This time would normally occur during the dry season and would be relatively infrequent. The number of recycling applications is controlled by the number of vessels passing through the Panama Canal. The Panama Canal is expected to average 34.5 lockages per day in the year 2000 and is expected to reach the maximum limit of 40 lockages (43 transits) in the year 2012. Therefore, with a saving of 11.7 million gallons every other lockage, a total of 204.825 million gallons would be saved each day during the project levels for the year 2000. For the year 2012 and beyond, 234 millions gallons would be saved each day.

CLEARING AND / OR GRUBBING

Only areas necessary for construction of the capture ponds, pipelines and powerplant would require clearing and grubbing. The transmission lines, connecting the powerplant to the national grid, would also require clearing.

ACCESS ROUTE

Access to the proposed projects sites is already available.

Sources of Construction Material

Special items such as pumps, motors, pipe, and valves would be fabricated outside the Republic of Panama and imported into the country for final assembly.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported.

Real Estate Requirements

All property for the Recycling Pond System is located within PCC property. No additional property would be required.

Relocations

Relocations are not required.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising, and award phase and on through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would normally begin with land acquisition and construction of the access facilities. It is assumed that all of the lands required for this project are already under PCC control and the only access required would be that incidental to the construction effort and within the construction area.

Socio-economic programs would begin shortly before construction of the dam. For this alternative, socio-economic impacts would be minimal. Some minor impacts to shipping interests would be realized during the construction period because of traffic delays.

Construction of the project would begin with the clearing and grubbing of the capture pond sites. Navigation traffic in the locks would be reduced during some construction periods since the outer wall culverts would be disabled. Therefore, only one side would be disabled at a time. Construction of the generation plant would be accomplished concurrently with the construction of the capture ponds and pumping plants.

Considering that much of the special hardware would need to be acquired outside the country, development of this project could be completed in approximately 7 years, from initial planning to activation of the project. Figure 34 - 1 depicts the development sequence of the various project features.

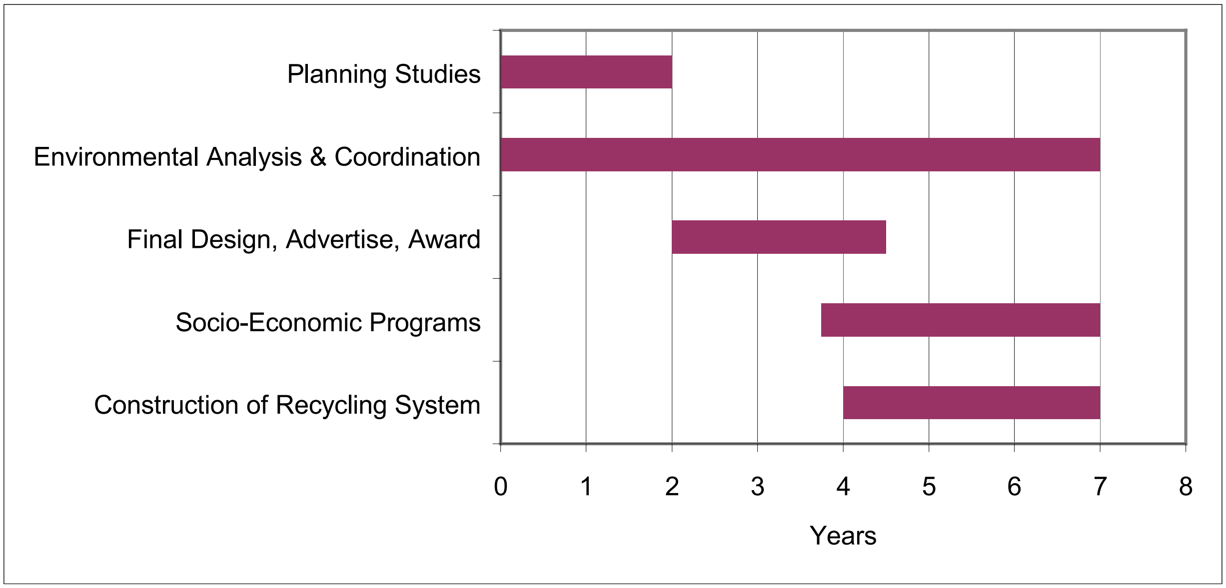


Figure 34 - 1 Development Sequence

Hydrologic Reliability

The existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. Since the number of vessels passing through the Panama Canal controls the number of recycling applications, the maximum contribution this project could provide toward reliability would be a function of traffic levels. The Panama Canal is expected to average 34.5 lockages per day in the year 2000 and is estimated to reach the maximum limit of 40 lockages (43 transits) in the year 2012. The proposed project would recycle one-half of a lock chamber (approximately 11.125 million gallons) every other lockage; therefore, with current levels of traffic the recycling system would support 3.66 additional lockages and maintain current reliability levels. When traffic reaches maximum, the recycling system would support 4.24 additional lockages. Once total demand levels (lockages plus M&I water supplies) exceed the equivalent of these values, reliability will diminish.

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts shown on Plates 34 - 1 and 34 - 2. The unit prices applied to these quantities were based on: historical information from previous estimates prepared for similar construction in the Republic of Panama, previous estimates for similar construction in the Southeastern United States and information gathered from U.S. Army Corps of Engineers, Mobile District, Construction Division personnel in the Republic of Panama.

Engineering and design is estimated to be 12 percent and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent was included for contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $165,000,000. Table 34 - 1 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 34 - 1 Summary of Project First Costs

Principal Feature	Costs ($)
Access Roads	1,130,000
Clearing and Grubbing	1,143,750
Recycle Ponds	14,084,295
Below Ground Work for 60” Pipes	2,330,850
Pumping Station	69,180,000
Gas Turbines 60 MW	21,000,000
Subtotal	108,868,895
E&D, S&A, Field Overhead	21,773,779
Contingencies	32,660,669
Total Project First Costs	163,303,343 **Approximately** 165,000,000

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Recycling Ponds project 24-hours per day. The full-time, three shift staff would ultimately consist of a total force of 31 who would include a station manager, 3 multi-skilled supervisors, 9 leaders (Electronics / Instrumentation, Electrical and Mechanical), 15 craftsmen, and 3 laborers. The annual costs of the staff are estimated to be $1,222,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $400,000 per year for the main project facilities.

Operation Cost for Gas Turbine

The needs of the Panama Canal would not require continuous operation of the 60 MW gas turbine-generating plant. The increase in demand for navigation lockage water over time and the frequency of water supply shortages would determine the percent of each dry season that the recycling ponds would be needed. During those times, the gas turbine would be operated continuously. Table 34 - 2 presents the approximate frequency and resulting number of days that the recycling ponds and the gas turbine would be required during the dry season, and the annual operating costs. The annual operating costs of a gas turbine are not uniform due to different inspection requirements, generally based upon cumulative hours of operations. The costs associated with each different type of inspection vary between a few hundred thousand dollars and a few million dollars. The present worth of these varying annual costs were summed and a capital recovery factor applied to estimate the average annual operating costs of the gas turbine for the operating needs of the Panama Canal. It was assumed that the turbine would be operated for peak power requirements (6 hours per day, 5 days per week) during the remainder of the year. Average annual costs for this operation are estimated for that period and added to the average annual operating costs for the Panama Canal needs.

Table 34 - 2 Annual Costs of Ordinary Operation of Gas Turbine

Current Demand Ratio	Year	Days of Continuous Operation	Annual Cost of Operation
1.0	2000	2	1,150,000
	2008	15	3,150,000
	2010	18	3,425,000
1.2	2014	24	3,900,000
	2015	26	4,050,000
	2020	33	4,500,000
	2025	41	4,950,000
	2030	49	5,350,000
	2035	57	5,700,000
	2040	64	6,000,000
	2045	72	6,350,000
1.4	2047	75	6,500,000
	2050	77	6,575,000
	2055	81	6,750,000
	2057	83	6,800,000
	2060	85	6,900,000
	2065	89	7,100,000
1.6	2066	90	7,160,000
Average Annual Cost –Canal Operations			4,042,000
Average Annual Cost – Peak Power			5,605,000
Total Average Annual Costs			9,647,000

Major Replacements

The average service life of gates, valves, electrical equipment, turbines, and other features would be less than the total useful life of the proposed project, which would be 100 years. To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it was assumed that specific items would cost the same as at present. No allowance was made for salvageable fixed parts. Table 34 - 3 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements would be $6,690,200 and the average annual replacement costs would be $806,000.

Table 34 - 3 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Pump Station				
1.5 Million gpm Pump	25	2	180,000,000	5,605,500
Diesel Back-up	25	2	5,550,000	172,800
Automated Gate Valves	25	2	2,250,000	70,100
Controls for Pumps and Valves	25	2	3,000,000	93,400
Gas Turbine	33	1	31,500,000	748,400
Total			222,300,000	6,690,200
Average Annual Replacement Costs				806,000

Annual Costs

The total project first costs are estimated to be $165,000,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the total project first costs was computed from mid-year throughout the 7-year period from initiation of the Planning Studies until the project is certified for operation. The interest during construction at 12 percent would be $31,892,000 and it was added to the total project first costs for total project investment costs of $196,892,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $23,505,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to the present worth as of completion of lake filling. Table 34 - 4 contains a summary of the annual costs.

Table 34 - 4 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	165,000,000
Interest During Construction	31,892,000
Total Project Investment Costs	196,892,000
Annual Average Investment Costs	23,505,000
Operation and Maintenance Costs	
Staff Costs	1,222,000
Ordinary Maintenance Costs	400,000
Ordinary Operation Costs	9,647,000
Major Replacement Costs	806,000
Total Average Annual Costs	35,580,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Section 4. The following paragraphs present the results of the economic investigations for the proposed Recycle Ponds project. The 50-year planning period for this proposal is 2008 to 2058.

The proposed Recycle Ponds project would not increase the reliability of providing water to accommodate the total daily number of lockages demanded. Therefore, benefits associated with the increase in hydrologic reliability were not estimated. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation.

With the proposed Recycle Ponds project, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands increase, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Recycle Ponds project, these shortages would be less than they would be under the existing system. The benefits for this amount of additional water would be attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages provided by the proposal. The average annual benefits for water supply would be $84,274,000.
Table 34 - 5 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Recycle Ponds project in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 34 - 5 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages With Recycling Ponds	Annual Benefits for Recycling Ponds ($)
2008	5.08	1.03	77,234,000
2010	6.43	2.30	80,719,000
2015	8.14	3.90	87,439,000
2020	8.93	4.69	87,439,000
2030	10.87	6.63	87,439,000
2040	13.34	9.10	87,439,000
2050	16.45	12.21	87,439,000
2057	19.12	14.88	87,439,000
Average Annual Benefits			84,274,000
With the Recycle Ponds alternative, the system will provide a total of 42.92 equivalent lockages at the 99.6 percent level of reliability or 4.24 more lockages than the existing system.			

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Recycle Ponds project, the system would not be altered materially. Therefore, no benefits for additional hydropower generation are estimated.

The gas turbine would not be needed continuously for canal operations. When it is not needed, it could be operated for other needs. Two of the major assumptions used in the analyses for this study is that there will always be a need for electrical power generation, and that the Panama Canal Authority will be allowed to sell excess power at their cost of production. With these assumptions, it would be feasible, by definition, to provide the generating capacity needed to operate the pumps for the proposed Recycle Ponds project. The benefits would equal the costs during the periods when the canal does not need the power generation and the benefits would greatly exceed costs during those periods when the pumps are being used for canal operations. If this proposal is pursued further, additional effort should be expended in any future planning studies to determine the economic value of electrical power generation.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 34 - 6, total average annual benefits for the proposed Recycle Ponds project would be $84,274,000.

Table 34 - 6 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	84,274,000
Navigation – Reliability	Not Estimated
M&I - Reliability	Not Estimated
Hydropower	Not Estimated
Total	84,274,000

Once average annual benefits and costs are estimated, the ratio of benefits to costs and the net benefits (net of costs) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. Table 34 - 7 provides the benefit to cost ratios for the proposed Recycle Ponds project and the net benefits.

Table 34 - 7 Economic Evaluation

Item	Value ($)
Average Annual Benefits	84,274,000
Average Annual Costs	35,580,000
Benefit to Cost Ratio	2.4
Net Benefits	48,694,000

Internal Rate of Return

An internal rate of return analysis was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. The internal rate of return would be 31.6 percent.

Socio-Economic Impacts

Because of the nature of this project, its socio-economic impacts will be minor. Some delays in ship traffic can be anticipated during construction of the project. The project area does not contain any municipalities.

Environmental Setting

The Recycling Ponds alternative considers modification of the Gatun Locks to allow capture of lockage water in holding basins and the reuse of the water by pumping water to the upper chambers of the locks. The recycling ponds will be placed on either side of the Gatun Lock lower chambers with pumping stations to return water to the upper chambers on demand. The project will consist of two capture ponds or lakes, pumping stations, and powerplants located near the end of the lower chambers of Gatun Lake.

LAND USE

The Recycling Ponds project will modify Gatun Locks to allow capture of lockage water in holding basins and its reuse by pumping water to the upper chambers of the locks. The ponds near the downstream end of the lower lock chamber will be sized to contain at least one chamber of lockage water approximately 22.5 million gallons (104,090 M^3) per pond. The landscape surrounding Gatun Locks is maintained by the PCC. Most of these areas are deforested and have been disturbed since the initial construction of the Panama Canal. This project will impact Gatun Locks; however, the land use and local towns in the Gatun Lock area will not be impacted by the proposed project.

INFRASTRUCTURE

After careful review of the topography, local infrastructure, and available space at each end of the Panama Canal, it was determined that Gatun Locks will accommodate the recycling ponds, pumping stations, pipelines and powerplants. The PCC own and manage the space required for the project. Both paved and dirt roads around Gatun Locks are well maintained. The operation and maintenance of the Panama Canal is the only major industry in the area. There are no towns within the project area.

TERRESTRIAL HABITAT

Tall grass fields and sparse patches of secondary growth forest make up the terrestrial habitat surrounding Gatun Locks. The terrestrial habitat within the project area has remained disturbed, by maintenance activities since the construction of the Panama Canal. The fields of tall grass offer habitat for a variety of wildlife species, even though exotic plant species dominate the vegetation. Secondary growth forests offer another type of habitat. Terrestrial habitat is used by both migratory and native, resident species as feeding, breeding, and resting grounds. The complex and diverse tropical ecosystems connect a variety of wildlife communities. This area may provide critical wildlife habitat to many native species.

ANIMALS ON ENDANGERED LIST

ANAM by its Resolution 002-80 on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although it has not been determined with certainty, some of the animals and other species of concern listed might be found in the project area.

AQUATIC HABITAT

Gatun Lake, one of the largest man-made lakes in the world, contains many different types of aquatic habitat ranging from forests inundated during Panama Canal construction, to various depths and degrees of water quality, influenced by the proximity of shipping lanes and topographical features below the lake surface. Gatun Lake provides habitat for a variety of wildlife species both resident and migratory as well as for both native and introduced fish and other aquatic species.

WETLANDS

Areas containing hydric soils, hydrophytic plant communities, and hydrologic conditions are termed wetlands. Typical wetlands in the project area consist of shallow water habitat that experiences frequent flooding. Shallow water areas along the banks of Gatun Lake that receive sunlight to a depth of approximately 1 m, depending on water clarity. Sunlight stimulates plant growth in the forms of submergent, emergent, or aquatic mats of floating vegetation at some distance from the shore and into the deeper aquatic habitats. Wetlands occur in topographic areas where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the project area are stressed by wave action created by ships and by runoff from slashed and burned areas.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season in March or early April, areas of forests and secondary growth are burned and cleared to prepare the land for agricultural use. During these activities the air is filled with smoke and ash transported by winds. Air quality monitoring systems have not been implemented within the project area. The natural environment could provide indicators that could be useful in making an air quality assessment.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The Recycling Ponds project is within PCC property boundaries on either side of Gatun Locks. No known parks or other government-protected lands are located within the Recycling Ponds project area. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts on the terrestrial habitat in the Gatun Lake project area will be substantial. Clearing and grubbing is required to prepare the land for construction, resulting in a permanent loss of terrestrial habitat.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered species cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Also, the significance of the natural environmental features in this area may increase if species on the endangered list are found in the region. Some endangered and / or threatened species may use Gatun Lake for part or all of their life cycle.

WATER QUANTITY

The impacts of the project on water quantity should be beneficial, because the creation of capture ponds will hold water in the area.

WATER QUALITY

The impacts of the project on water quality are unknown. Water that is continuously recirculated within Gatun Locks may degrade in quality. Pollution from the operation and maintenance of the locks, incidental discharges that result from shipping traffic, a vessel, and other factors may impact water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be significant. Fish and other aquatic organisms could be pumped into the capture ponds and killed. The capture ponds may not incorporate escape routes for trapped aquatic life. Aquatic fauna trapped within the locks will probably not survive the continuous re-circulation of water. If aquatic organisms are killed as water is captured, stored, and re-circulated, the impacts on the aquatic ecosystem could be significant.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities could be substantial. The recycling ponds will hold water, and some aquatic life should colonize these ponds. The environmental health of the capture ponds is unknown; however water from these ponds will eventually be released into larger aquatic systems, where it could have significant impacts.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting Gatun Lake and the affected areas would be substantial. Fish and other freshwater aquatic organisms would be killed by the change from fresh to saline water. Aquatic fauna within the lake also would probably not survive the change from fresh to saline water. Transforming Gatun Lake from a freshwater lake to a saline environment would remove the natural freshwater barrier that prevents the migration of organisms from one ocean to the other.

WETLANDS

The impact of the project to wetlands is not known. Wetland areas around Gatun Locks are stressed from ship traffic. The construction of intake and outflow pipes may impact some wetland areas.

AIR QUALITY

During project construction, emissions from equipment will impact air quality in the project area. After project completion, the air quality will return to its former condition.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties cannot be defined or mitigated. Prior to project implementation, surveys will be conducted to locate cultural resource and historic properties and the important sites will be preserved or salvaged as appropriate.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Recycle Ponds alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an SIA. The SIA will consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities.
  - Employment.
  - Land Use.
  - Property Values.
  - Public and Community Facilities and Services (including utilities and schools).
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Evaluate the impacts on aquatic organisms during intake, storage and outflow of lock water.
- Prepare site-specific habitat maps to ensure that all major terrestrial and aquatic habitat types are identified and quantified.
- Conduct field studies to locate rare and unique habitat features such as wetlands, primary forests, roosting sites, foraging areas, old growth, migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Locks project area.
- Coordinate with local experts regarding terrestrial and aquatic habitats before and after project implementation.
- Provide species inventory lists for each site area identifying their status as native or exotic and if they are threatened and or endangered species.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for animals on the endangered and / or threatened species list.
- Determine field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.

- Coordinate with local experts to determine the presence of these species.

WATER QUALITY

- As limited water quality data are available for Gatun Locks, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Information regarding cultural resources and historic properties is incomplete. Additional evaluation studies need to be completed to identify cultural resources and historic properties.

Evaluation Matrices

In accordance with evaluation procedures described in Section 4, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Section 35. Tables 34 - 8 through 34 - 10 present the evaluation of the proposed Recycling Ponds project as related to developmental effects, environmental effects, and socio-economic effects.

Table 34 - 8 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I demands	3	10	30
	Supplements Existing System	0	10	0
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	6	6	36
	Feasibility of Concept	6	6	36
Operational Issues	Compatibility	7	6	42
	Maintenance Requirements	5	2	10
	Operational resources required	5	2	10
Economic feasibility	Net Benefits	1	9	9
	Total			173

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 34 - 9 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	2	8	16
Animals on Extinction List	2	10	20
Water Quantity Impacts – Lake	2	10	20
Water Quantity Impacts - Downstream	2	7	14
Water Quality	2	10	20
Downstream Aquatic Fauna Habitat	2	8	16
Future Lake Aquatic Plant Community	2	8	16
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	3	5	15
Potential for Fishing on Lake	2	6	12
Wetlands	2	4	8
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			222

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 34 - 10 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	4	7	28
Relocation of People	5	10	50
Relocation of Agricultural/Ranching Activities	5	6	30
Post-Construction Business	5	5	25
Post-Construction on Existing Employment	5	5	25
Property Values During Construction	5	4	20
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	5	4	20
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	5	5	25
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	5	4	20
Communities Receiving Displaced People	5	8	40
Community Cohesion	5	8	40
Tourism	5	5	25
Total			438

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

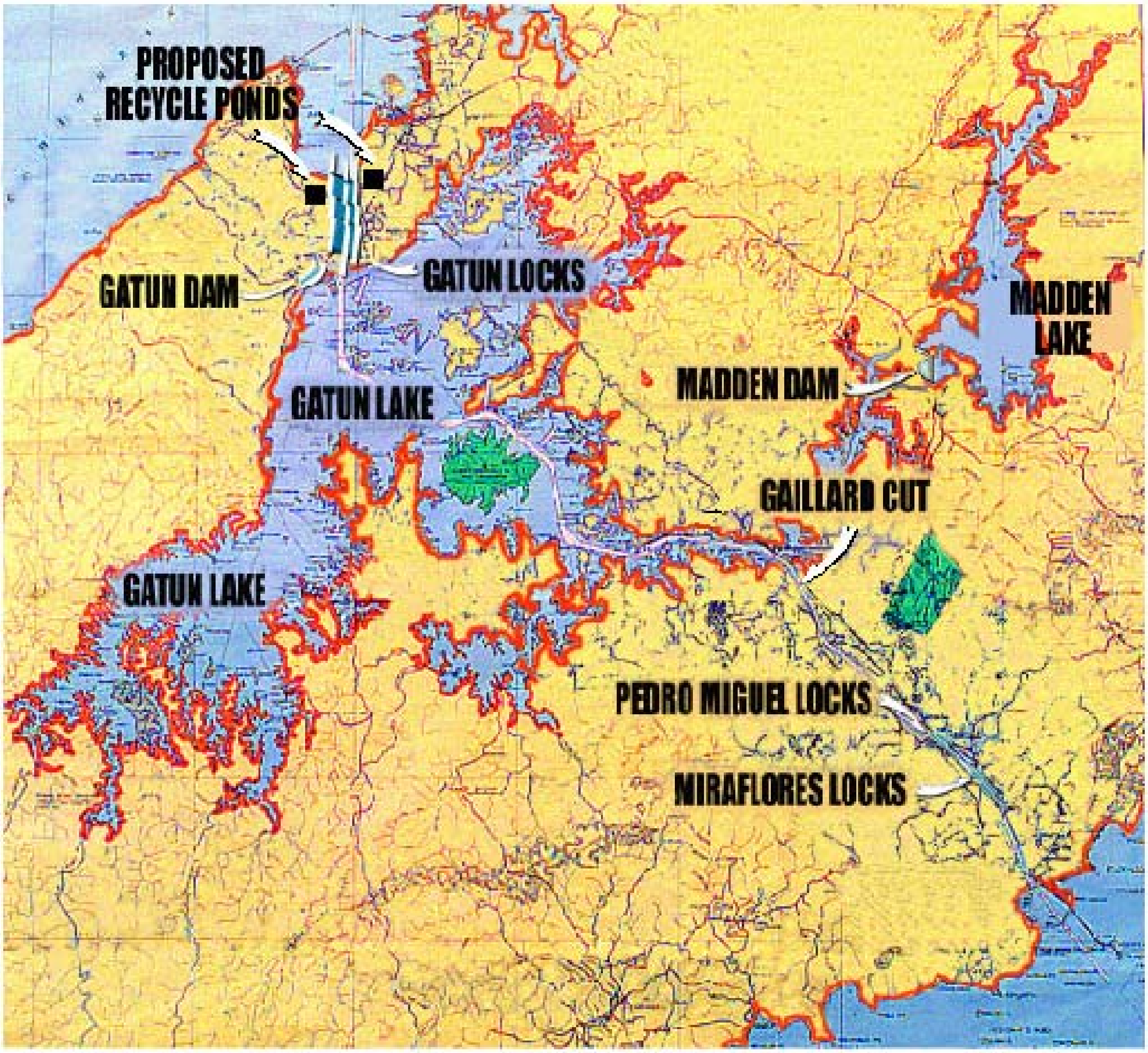
Pertinent Data

Table 34 - 11 presents pertinent data for the proposed Recycling Ponds project.

Table 34 - 11 Pertinent Data

GENERAL	
Project Site	Gatun Locks
Number of Systems	2
CAPTURE PONDS	
Invert elevation of ponds	-10 m MSL (-32.81 ft)
Surface area of ponds	177 ha (437.4 ac)
Elevation of minimum operating level	-4 m MSL (-13.12 ft)
Cross-sectional area of culvert Connecting to Lower Lock chamber(224 sf)	20.9 M^2
PUMPING STATIONS	
Pumps	
Number per system	5 units
Pumping Capacity of each pump	8.5 CMS (300.2 CFS)
Total Dynamic Head	50 m (164 ft)
Brake Horsepower	6,600 HP
Delivery system to upper chamber	
Pipe Diameter	1.524 m (5 ft)
Number of pipes per system	5
Length of pipe per pump	1,640 m (5,380.6 ft)
Total length of pipe per system	8,200 m
GENERATING PLANT	
Type of Plant	Gas Turbine
Capacity	60 MW

RECYCLING PONDS FOR GATUN LOCKAGE WATER



Project Location Map

Plate 34 - 1   Project Location Map

RECYCLING PONDS FOR GATUN LOCKAGE WATER

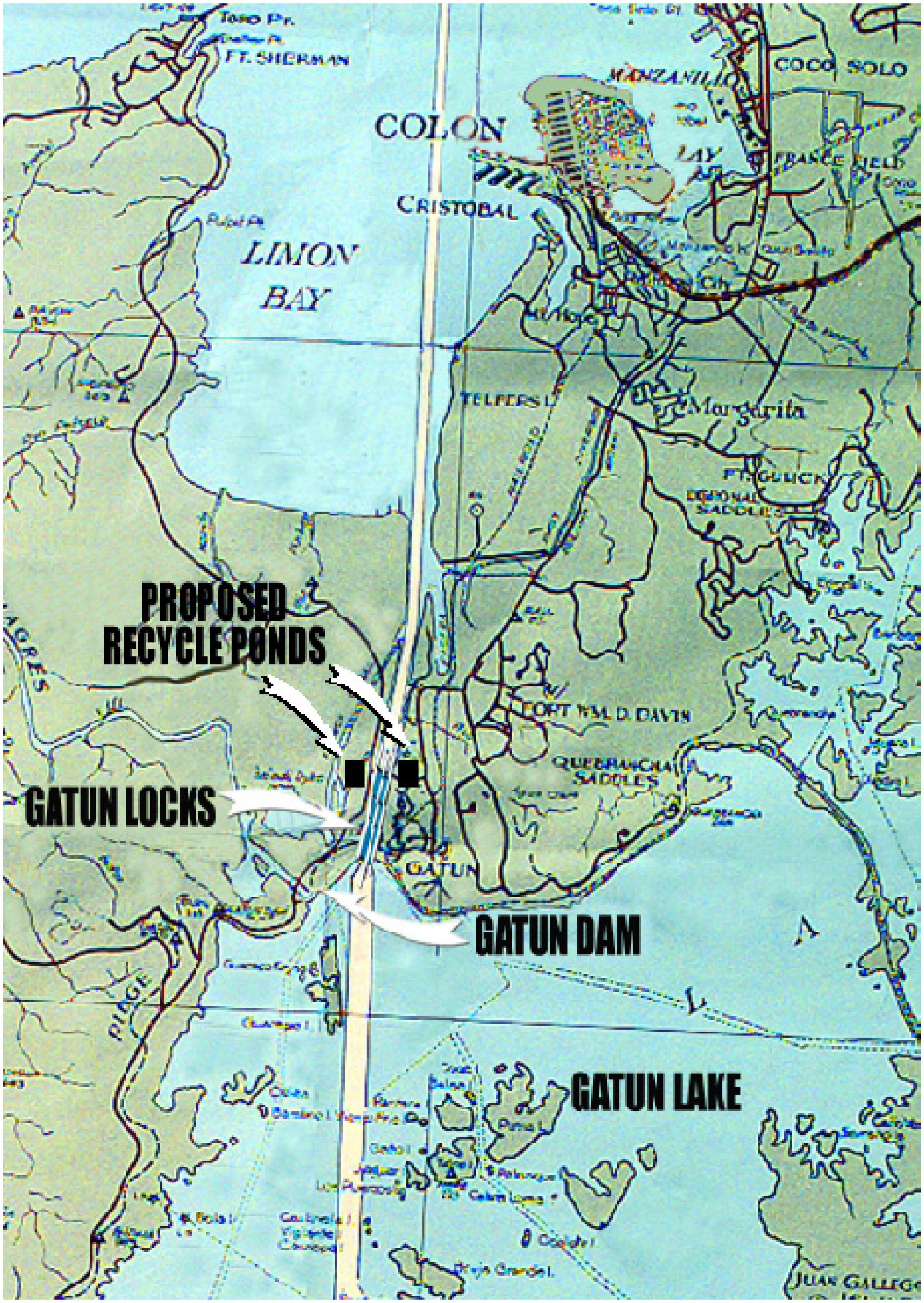


Plate 34 - 2 Proposed Feature Map

SECTION 35

Comparitive Evaluation of Alternatives

TABLE OF CONTENTS

LIST OF TABLES

Synopsis

The purpose of this study effort was to define the project concepts, determine if a feasible project could be developed for each alternative, develop project costs, and provide an economic analysis. The objective was to present each alternative at the same level of analysis so that the alternatives could be compared and ranked. This section presents the final step of ranking the alternatives previously indicated to be feasible by satisfying the criteria set forth in Section 4. Description of project features, detailed analyses, and results for each alternative were presented in Sections 5 through 34.

Evaluations

In the selection of an alternative for implementation, the ability of that alternative to meet wholly or partially the objectives of the planning process must be considered. As part of the reconnaissance study, evaluation matrices have been provided with each alternative that passed the initial screening criteria. These matrices incorporated the five evaluation criteria points presented in Section 4. The matrices are found in each section of the alternative analysis and are entitled: Developmental Effects, Environmental Effects, and Socio-Economic Effects. Each matrix provides a means to apply a significance or weight to each analysis criterion, and a measure of how each project satisfies the criterion. The measure column is a numerical value ranging from 0 to 10 representing the degree, or level, to which an alternative was deemed to have satisfied the criteria. A value of 10 indicates the greatest degree of success in satisfying a criterion, and a value of zero indicates the least degree of success in satisfying a criterion. The importance column provides a weighting factor from 1 to 10 to balance the relative significance of a criterion to the other criterion within its respective matrix. Importance values were established for each matrix and remained the same for all projects. The final column, the composite, is the product of the measure and importance. This product provides a balanced assessment of each criterion ranging from 0 to 100.

Table 35-1 presents the maximum possible score for the respective matrices. The total composite scores from each of these matrices were tabulated and normalized by dividing the total by the maximum possible score. Then a composite score was developed by combining the normalized values. The Socio-Economic effects represented twenty five percent of the composite score; Environmental effects represented twenty five percent and Developmental effects represented 50 percent. The Developmental Effects matrix included water yield, design, technical viability, operational requirements, and economic effects. Each of these were assigned importance levels within the Developmental Effects matrix that resulted in 26.5 percent of the final composite score represented by water yield, 9.1 percent by technical viability, 7.6 percent by operational requirements, and 6.8 percent by economic feasibility. The final step in ranking the alternatives was to list the alternatives sorted by composite score. The alternative with the highest score received the highest ranking.

Table 35 - 1 Maximum Possible Scores

Evaluation Criteria	Function	Importance	Maximum Possible Composite
Developmental Effects			
Water Contribution (Water Yield)	Meets M&I demands	10	100
	Supplements Existing System	10	100
	Satisfies Future Panama Canal needs/expansion	10	100
	Additional Hydropower Potential	5	50
Technical Viability	Design Constraints	6	60
	Feasibility of Concept	6	60
Operational Issues	Compatibility	6	60
	Maintenance Requirements	2	20
	Operational resources required	2	20
Economic feasibility	Net Benefits	9	90
	Maximum Possible		**660**

Item	Importance	Maximum Possible Composite
Envrionmental Effects		
Terrestrial Habitat	8	80
Animals on Extinction List	10	100
Water Quantity Impacts – Lake	10	100
Water Quantity Impacts – Downstream	7	70
Water Quality	10	100
Downstream Aquatic Fauna Habitat	8	80
Future Lake Aquatic Plant Community	8	80
Aquatic Faunal Inhabiting Rio Indio and Upstream Tributaries	5	50
Potential for Fishing on Lake	6	60
Wetlands	4	40
Air Quality	3	30
Cultural Resources and Historic Properties	10	100
Maximum Possible		**890**
Socio-Economic Effects		
Land Use	7	70
Relocation of People	10	100
Relocation of Agricultural/Ranching Activities	6	60
Post-Construction Business	5	50
Post-Construction on Existing Employment	5	50
Property Values During Construction	4	40
Property Values Post-Construction	5	50
Public/Community Services During Construction	4	40
Public/Community Services Post-Construction	8	80
Traffic Volumes over Existing Roadway System During Construction	5	50
Traffic Volumes over New Roadway System Post- Construction	5	50
Noise-Sensitive Resources or Activities	4	40
Communities Receiving Displaced People	8	160
Community Cohesion	8	80
Tourism	5	50
Maximum Possible		**970**

Table 35 - 2 lists the projects that were analyzed and indicates the projects that failed to meet the initial screening parameters. Table 35 - 3 presents the list of projects that were carried forward to the evaluation matrices with the aggregate scores. The projects are sorted by final composite score, with the highest score ranked first.

Table 35 - 2 List of Projects Analyzed

Section Number	Status	Project
5		Rio Indio - Option 1
6		Rio Cocle del Norte – Lake at Elevation 65 - Option 1 (Operated in conjunction with Indio Lake)
7		Rio Cocle del Norte – Lake at Elevation 80 (Operated in conjunction with Indio Lake)
8		Rio Cocle del Norte – Lake at Elevation 100 (Operated in conjunction with Caño Sucio and Indio Lakes)
9		Rio Toabre and Rio Caño Sucio (Operated in conjunction with Indio Lake)
10		Rio Lagarto - Option 2
11		Rio Salud - Option 2 (Working in conjunction with Lagarto Lake)
12	Not feasible	Rio Piedras
13	Insufficient data	Rio Cuango
14		Rio Caimito - Option 1 (M&I Water Supply Project With Water Treatment Plant)
15		Rio Pacora - Option 2 (M&I Water Supply Project With Water Treatment Plant)
16		Lower Rio Trinidad – Option 1
17	Not feasible	Upper Rio Trinidad
18		Rio Chagres - Option 1
19	Not feasible	Rio Pequeni
20		Rio Ciri Grande Option 2
21	Not feasible	Rio Caño Quebrado
22		Rio Caño Sucio – Option 1 (Operated in conjunction with Indio Lake)
23		Raise Gatun Lake
24		Deepen Gatun Lake
25		Raise Madden Lake - Option 1
26	Not feasible	Raise Miraflores Lake
27	Not feasible	Pump Storage to Madden Lake
28	Not feasible	Pump Groundwater to the Panama Canal Watershed
29		Pump Storage From Cocle Del Norte Lake to Toabre Lake (Operated in conjunction with Caño Sucio and Indio Lakes)
30	Not feasible	Tide Gates (At the Pacific Entrance to the Panama Canal)
31	Not feasible	Lower Gatun Lake and Eliminate Upper Locks
32	Not feasible	Reduce Seepage and Evaporation Losses From Gatun and Madden Lakes
33		Pump Saltwater into Gatun Lake
34		Recycling Ponds for Lockage Water

Table 35 - 3 Ranking of Feasible Alternatives

Rank	Section Number	Project	Sum of Composite Developmental Matrix	Sum of Envrionmental Matrix	Sum Socio-Economic Effects Matrix	Developmental divided by Maximum Possible	Environmental divided by Maximum Possible	Socio-Economic divided by Maximum Possible	Final Composite
1	8	Rio Cocle del Norte - Lake at Elevation 100 (Operated in conjunction with Caño Sucio and Indio Lakes)	557	337	302	0.844	0.379	0.339	0.601
2	7	Rio Cocle del Norte - Lake at Elevation 80 (Operated in conjunction with Indio Lake)	539	337	302	0.817	0.379	0.339	0.588
3	9	Rio Toabre and Rio Caño Sucio (Operated in conjunction with Indio Lake)	502	369	315	0.761	0.415	0.354	0.572
4	6	Rio Cocle del Norte - Lake at Elevation 65 - Option 2 (Operated in conjunction with Indio Lake)	496	345	302	0.752	0.388	0.339	0.557
5	22	Rio Caño Sucio - Option 1 (Operated in conjunction with Indio Lake)	398	460	409	0.603	0.517	0.460	0.546
6	29	Pump Storage From Cocle Del Norte Lake to Rio Toabre Lake (Operated in conjunction with Caño Sucio and Indio Lakes)	421	345	302	0.638	0.388	0.339	0.501
7	18	Rio Chagres - Option 1	314	381	456	0.476	0.428	0.512	0.473
8	5	Rio Indio - Option 1	342	399	325	0.518	0.448	0.365	0.462
9	24	Deepen Gatun Lake	266	488	367	0.403	0.548	0.412	0.442
10	20	Rio Ciri Grande - Option 1	259	477	380	0.392	0.536	0.427	0.437
11	25	Raise Madden Lake - Option 1	185	495	455	0.280	0.556	0.511	0.407
12	10	Rio Lagarto	229	452	341	0.347	0.508	0.383	0.396
13	16	Lower Rio Trinidad - Option 1	169	501	452	0.256	0.563	0.508	0.396
14	15	Rio Pacora	220	465	333	0.333	0.522	0.374	0.391
15	14	Rio Caimito	220	465	333	0.333	0.522	0.374	0.391
16	11	Rio Salud	211	452	341	0.320	0.508	0.383	0.383
17	23	Raise Gatun Lake	153	491	455	0.232	0.552	0.511	0.382
18	34	Recycling Ponds for Lockage Water	173	222	438	0.262	0.249	0.492	0.316
19	33	Pump Saltwater into Gatun Lake	118	146	438	0.179	0.164	0.492	0.253

Note 1: Projects for Rio Cocle Lake at elevation 80 m MSL, Rio Cocle Lake at 100 m MSL, and the Pump Storage from Rio Cocle Lake to Toabre Lake provide 100 percent reliability through the life of the project. Thus additional water would be available for future expansion of the Panama Canal.

Note 2: Final composite score =
0.5* Developmental / Maximum Possible + 0.25* Environmental / Maximum Possible + 0.25*Socio-Economic / Maximum Possible

For the Developmental Effects matrix, a scale was established that provided a measure the ability of each alternative to meet the water yield objectives of (1) satisfying long-term M&I water supply needs without adversely affecting the operation of the Panama Canal; (2) providing sufficient navigation waters to meet existing Panama Canal transit demands without restricting vessel operation and maintaining historic reliability levels of 99.6 percent; (3) providing sufficient navigation waters to meet future Panama Canal transit demands without restricting vessel operation while maintaining historic reliability levels of 99.6 percent; and, (4) maintaining or increasing the current level of hydroelectric power production as demands for other water uses increase.

The measure for satisfying long-term M&I water supply needs without adversely affecting the operation of the Panama Canal considered the existing and forecast demands for M&I water supply up to the year 2070. The net increase in M&I water supply demand was calculated by subtracting the forecasted demand for the year 2000 from the forecast for each decade. The results were rounded to a whole number and graduated to a scale of 2, 3, 5, 8 and 11, which corresponded to measures of 2, 4, 6, 8 and 10 respectively. If a proposed project would provide 5 lockages of water, it would receive 6 points for this criterion.

A gradation scale for the ability of a project to provide sufficient navigation waters that meet transit demands for the existing Panama Canal system, without restricting vessel operation and maintaining historic reliability levels of 99.6 percent, considered the net increase in forecast lockage demands for existing Panama Canal operations. The net increase in lockages through the year 2070 is approximately 6 lockages, since the existing Panama Canal system is constrained to a sustainable average of 43 transits per day. The measure for each increment (0, 2, 4, 7 and 10) was linearly portioned to the 6 lockages (0, 1, 3, 4, and 6) respectively. M&I requirements were satisfied first. Therefore, any proposed project that provided 15 lockages of water, received 7 measure points for this criterion. (15 lockages of project yield – 11 lockages for M&I requirements = 4 net lockages for navigational increases. The 4 net lockages would correspond to 7 measure points.)

The gradation scale for providing navigation waters to meet future unconstrained Panama Canal transit demands, without restricting vessel operation and maintaining historic reliability levels of 99.6 percent, considered a potential future demand of 32 additional lockages. Since M&I forecasts estimated a net increase up to 11 lockages and the existing Panama Canal system could support increases up to 6 lockages, a total of 17 lockages would be accounted for in the 2 previous criterions. The remaining 15 lockages could only be accommodated through modification of the Panama Canal system. Therefore, the 15 remaining lockages were linearly distributed over the measure range. Thus, the increments are 3, 6, 9, 12 and 15 lockages correspond to measure points of 2, 4, 6, 8 and 10 respectively. If a proposed project provided 20 additional lockages, it would receive two measure points for this criterion. (20 lockages of project yield – 11 lockages for M&I requirements – 6 lockages for existing system = 3 net lockages for Panama Canal expansion.)

The most effective method to consider the measure of additional hydropower effects is to consider the net benefits provided by hydropower when the project is integrated into the system. Several factors influence the contribution that additional hydropower facilities provide. These factors are the capacity of the plant, electrical energy production, transfer of water across basins and the impact of the system on operation of other plants. Net hydropower benefits reflect the composite impact of these factors. The scale for maintaining or increasing the current level of hydroelectric power production as demands for other water uses increase was established by considering the amount of net benefits estimated for power production of the entire system. The scale runs from greater than $5,000,000 to greater than $25,000,000 in average annual benefits by increments of $5,000,000. The measure points assigned to each increment were 1, 3, 5, 7 and 10. If a proposed project had a net increase of average annual hydropower benefits of $17,000,000, it would receive 5 measure points for this criterion.

The technical viability of a project was measured based on two functional areas: design constraints and the feasibility of the concept. Design constraints reflect the difficultly of the engineering and construction technology required to design, construct and operate a proposed project. The feasibility of a concept measures the magnitude of economic and physical resources required to accomplish the design, construction and operation of a proposed project against the ability of the country to implement the project. A scale of 1 to 10 was used to determine the measure of this criterion. These functions cannot be readily represented by a simple numerical value but had to be based on professional judgment. The ranking committee, comprised of representatives from the U.S. Army Corps of Engineers, Mobile District design team and the PCC - Canal Capacity Projects Office, developed these values through consensus, based on their experience and knowledge of the projects and the resources of Panama Canal and the Republic of Panama.

A measure of the operational constraints for a proposed project was based on the compatibility of the project with the existing system, maintenance requirements (including skills and magnitude or frequency), and operational resources. These functions also require the judgment of the professionals with the knowledge and experience of the type of projects considered and the resources of the PCC. The ranking committee developed values from a scale of 1 to 10.

Also in the Development Effects matrix, a part of the rankings are based upon the economic effects of each alternative project. One of the criterion useful in these rankings is the benefit to cost ratio. This ratio determines whether a project is feasible, that is, it determines whether the benefits attributable to the alternative outweigh the costs of implementing the project. All of the alternatives that were analyzed for economic effects are included in Table 35 - 4. These projects are sorted by their benefit to cost ratio from greatest to least in Table 35 - 4.

Table 35 - 4 Projects Sorted by Benefit-Cost Ratio

Section Number	Project	Average Annual Benefits	Average Annual Costs	Benefit to Cost Ratio	Net Benefits
25	Raise Madden Lake - Option 2	24,901,000	101,000	246.5	24,800,000
25	Raise Madden Lake - Option 1	18,947,000	88,000	215.3	18,859,000
22	Rio Caño Sucio - Option 1 (Operated in conjunction with Indio Lake)	417,544,000	88,590,000	4.7	328,954,000
22	Rio Caño Sucio - Option 2 (Operated in conjunction with Indio Lake)	416,498,000	88,590,000	4.7	327,908,000
20	Rio Ciri Grande - Option 1	68,691,000	15,412,000	4.5	53,279,000
5	Rio Indio - Option 2	189,406,000	46,291,000	4.1	143,115,000
24	Deepen Gatun Lake	121,819,000	36,819,000	3.3	85,000,000
10	Rio Lagarto - Option 2	22,349,000	7,107,000	3.1	15,242,000
5	Rio Indio - Option 1	144,889,000	46,291,000	3.1	98,598,000
18	Rio Chagres - Option 2	177,127,000	59,183,000	3.0	117,944,000
23	Raise Gatun Lake	36,492,000	13,812,000	2.6	22,680,000
9	Rio Toabre and Rio Caño Sucio (Operated in conjunction with Indio Lake)	482,098,000	189,802,000	2.5	292,296,000
11	Rio Salud - Option 2 (Working in conjunction with Lagarto Lake)	70,669,000	27,929,000	2.5	42,740,000
6	Rio Cocle del Norte - Lake at Elevation 65 - Option 1 (Operated in conjunction with Indio Lake)	582,869,000	238,383,000	2.4	344,486,000
6	Rio Cocle del Norte - Lake at Elevation 65 - Option 2 (Operated in conjunction with Indio Lake)	581,505,000	238,383,000	2.4	343,122,000
11	Rio Salud - Option 1 (Working in conjunction with Lagarto Lake)	66,544,000	27,929,000	2.4	38,615,000
34	Recycling Ponds for Lockage Water	84,274,000	35,580,000	2.4	48,694,000
8	Rio Cocle del Norte - Lake at Elevation 100 (Operated in conjunction with Caño Sucio and Indio Lakes)	748,621,000	391,025,000	1.9	357,596,000
7	Rio Cocle del Norte - Lake at Elevation 80 (Operated in conjunction with Indio Lake)	644,748,000	344,093,000	1.9	300,655,000
29	Pump Storage From Cocle Del Norte Lake to Rio Toabre Lake (Operated in conjunction with Caño Sucio and Indio Lakes)	448,683,000	255,714,000	1.8	192,969,000
16	Lower Rio Trinidad - Option 1	89,589,000	63,151,000	1.4	26,438,000
18	Rio Chagres - Option 1	82,149,000	59,183,000	1.4	22,966,000
20	Rio Ciri Grande - Option 2	19,890,000	15,412,000	1.3	4,478,000
33	Pump Saltwater into Gatun Lake - 5 Lockages	99,730,000	82,094,000	1.2	17,636,000
14	Rio Caimito - Option 1 (M&I Water Supply Project Without Water Treatment Plant)	21,288,000	22,187,000	0.96	(899,000)
16	Lower Rio Trinidad - Option 2	60,045,000	63,151,000	0.95	(3,106,000)
15	Rio Pacora - Option 2 (M&I Water Supply Project Without Water Treatment Plant)	20,083,000	21,210,000	0.95	(1,127,000)
14	Rio Caimito - Option 1 (M&I Water Supply Project With Water Treatment Plant)	21,288,000	44,742,000	0.5	(23,454,000)
15	Rio Pacora - Option 2 (M&I Water Supply Project With Water Treatment Plant)	20,083,000	46,798,000	0.4	(26,715,000)
14	Rio Caimito - Option 2 (M&I Water Supply Project With Water Treatment Plant)	18,878,000	44,742,000	0.4	(25,864,000)
15	Rio Pacora - Option 1 (M&I Water Supply Project With Water Treatment Plant)	18,878,000	46,798,000	0.4	(27,920,000)
33	Pump Saltwater into Gatun Lake - 1 Lockage	19,946,000	78,591,000	0.3	(58,645,000)

Using the benefit to cost ratio as a selection criteria will not provide the decision maker with sufficient information. It merely indicates whether the benefits of alternative exceed its costs. For example, there are operating schemes for both the Rio Lagarto and Rio Indio projects that provide a benefit to cost ration of 3.1. Yet, the Rio Lagarto project only provides 1.1 lockages while the Rio Indio project provides 6.43 lockages. Clearly, the Rio Indio project with its Option 1 operating scheme is superior to the Rio Lagarto project.

A more appropriate selection criterion is maximum net benefits (net of costs). Table 35 – 5 lists all of the alternatives that were analyzed for economic effects by their net benefits from greatest to least. The measure of maximum net benefits is used to determine the appropriate scale of development of any projects or system of projects. It also ensures that the full economic potential of the project will be realized. Selection of a scale of project development using maximum net benefits means that the cost of adding the last increment in scale of development is equal to the added benefits resulting from the last increment. Extension of the scale of development beyond this point would require expenditures in excess of the added benefits. To add to the scale of the development would not be economically justified. Each increment in the scale of development of a project or system of projects should be the smallest increment on which there is a practical choice as to inclusion in or omission from the project. To be justified for inclusion in a plan, each project in a group, each purpose of a project and each separable segment of a project should add as much or more benefits than it adds in costs.

Net benefits for the alternatives considered ranged from no cost to over $300 million. Therefore, the gradation scale for the measure of economic feasibility of 2, 4, 6, 8 and 10 corresponded to increments of $75 million. For example, a project that with net benefits of $225 million would receive a measure of 6 for this criterion.

Table 35 - 5 Projects Sorted by Net Benefits

Section Number	Project	Average Annual Benefits	Average Annual Costs	Benefit to Cost Ratio	Net Benefits	Hydropower Benefits ($ Millions)	Year in which Total Demand Exceeds Total Supply	Total Lockages	Net Lockages from 2000
8	Rio Cocle del Norte - Lake at Elevation 100 (Operated in conjunction with Caño Sucio and Indio Lakes)	748,621,000	391,025,000	1.9	357,596,000	17	2070+	63.97	25.29
6	Rio Cocle del Norte - Lake at Elevation 65 - Option 1 (Operated in conjunction with Indio Lake)	582,869,000	238,383,000	2.4	344,486,000	28	2069	63.76	25.08
6	Rio Cocle del Norte - Lake at Elevation 65 - Option 2 (Operated in conjunction with Indio Lake)	581,505,000	238,383,000	2.4	343,122,000	27	2065	61.55	22.87
22	Rio Caño Sucio - Option 1 (Operated in conjunction with Indio Lake)	417,544,000	88,590,000	4.7	328,954,000	0	2041	52.53	13.85
22	Rio Caño Sucio - Option 2 (Operated in conjunction with Indio Lake)	416,498,000	88,590,000	4.7	327,908,000	0	2041	52.37	13.69
7	Rio Cocle del Norte - Lake at Elevation 80 (Operated in conjunction with Indio Lake)	644,748,000	344,093,000	1.9	300,655,000	21	2070+	63.97	25.29
9	Rio Toabre and Rio Caño Sucio (Operated in conjunction with Indio Lake)	482,098,000	189,802,000	2.5	292,296,000	13	2066	62.05	23.37
29	Pump Storage From Cocle Del Norte Lake to Rio Toabre Lake (Operated in conjunction with Caño Sucio and Indio Lakes)	448,683,000	255,724,000	1.8	192,959,000	-1	2070+	63.97	25.29
5	Rio Indio - Option 2	189,406,000	46,291,000	4.1	143,115,000	6	2030	49.55	10.87
18	Rio Chagres - Option 2	177,127,000	59,183,000	3.0	117,944,000	9	2012	46.59	7.91
5	Rio Indio - Option 1	144,889,000	46,291,000	3.1	98,598,000	5	2010	45.11	6.43
24	Deepen Gatun Lake	121,819,000	36,819,000	3.3	85,000,000	-1	2009	44.30	5.62
20	Rio Ciri Grande - Option 1	68,691,000	15,412,000	4.5	53,279,000	-1	2005	41.78	3.10
34	Recycling Ponds for Lockage Water	84,274,000	35,580,000	2.4	48,694,000	0	2007	42.92	4.24
11	Rio Salud - Option 2 (Working in conjunction with Lagarto Lake)	70,669,000	27,929,000	2.5	42,740,000	0	2003	40.58	1.90
11	Rio Salud - Option 1 (Working in conjunction with Lagarto Lake)	66,544,000	27,929,000	2.4	38,615,000	0	2003	40.38	1.70
16	Lower Rio Trinidad - Option 1	89,589,000	63,151,000	1.4	26,438,000	0	2006	42.74	4.06
25	Raise Madden Lake - Option 2	24,901,000	101,000	246.5	24,800,000	-1	2002	39.92	1.24
18	Rio Chagres - Option 1	82,149,000	59,183,000	1.4	22,966,000	12	2005	41.89	3.21
23	Raise Gatun Lake	36,492,000	13,812,000	2.6	22,680,000	-1	2002	40.33	1.65
25	Raise Madden Lake - Option 1	18,947,000	88,000	215.3	18,859,000	-1	2002	39.65	0.97
33	Pump Saltwater into Gatun Lake - 5 Lockages	99,730,000	82,094,000	1.2	17,636,000	0	2008	43.68	5.00
10	Rio Lagarto - Option 2	22,349,000	7,107,000	3.1	15,242,000	0	2002	39.78	1.10
20	Rio Ciri Grande - Option 2	19,890,000	15,412,000	1.3	4,478,000	-1	2001	39.50	0.82
14	Rio Caimito - Option 1 (M&I Water Supply Project Without Water Treatment Plant)	21,288,000	22,187,000	0.96	(899,000)	0	2002	39.74	1.06
15	Rio Pacora - Option 2 (M&I Water Supply Project Without Water Treatment Plant)	20,083,000	21,210,000	0.95	(1,127,000)	0	2002	39.68	1.00
16	Lower Rio Trinidad - Option 2	60,045,000	63,151,000	0.95	(3,106,000)	0	2004	41.36	2.68
14	Rio Caimito - Option 1 (M&I Water Supply Project With Water Treatment Plant)	21,288,000	44,742,000	0.5	(23,454,000)	0	2002	39.74	1.06
14	Rio Caimito - Option 2 (M&I Water Supply Project With Water Treatment Plant)	18,878,000	44,742,000	0.4	(25,864,000)	0	2001	39.62	0.94
15	Rio Pacora - Option 2 (M&I Water Supply Project With Water Treatment Plant)	20,083,000	46,798,000	0.4	(26,715,000)	0	2002	39.68	1.00
15	Rio Pacora - Option 1 (M&I Water Supply Project With Water Treatment Plant)	18,878,000	46,798,000	0.4	(27,920,000)	0	2001	39.62	0.94
33	Pump Saltwater into Gatun Lake - 1 Lockage	19,946,000	78,591,000	0.3	(58,645,000)	0	2002	39.68	1.00

Measure and importance values for the Socio-Economic and Environmental Effects were developed by an inter-disciplinary team of professionals from Black & Veatch, the PCC, and the U.S. Army Corps of Engineers, Mobile District.

Projects with benefit to cost ratios less than one would clearly not be recommended for further consideration. Also, the recycling ponds at Gatun Locks and Pump Saltwater into Gatun Lake are ranked very low and are not recommended because of the potentially significant environmental impacts. The Lower Trinidad and Raise Gatun Lake elevation projects are also not recommended because of the significant uncertainties of design requirements for the project features. These uncertainties are explained in the respective sections.

Based on the analyses and findings of this study, the first 13 projects ranked in Table 35 - 3 above are recommended as feasible alternatives for further consideration to develop a long-term plan to meet future needs for M&I water supply, operation of the Panama Canal, and possible modifications or expansion of the Panama Canal.

APPENDIX A

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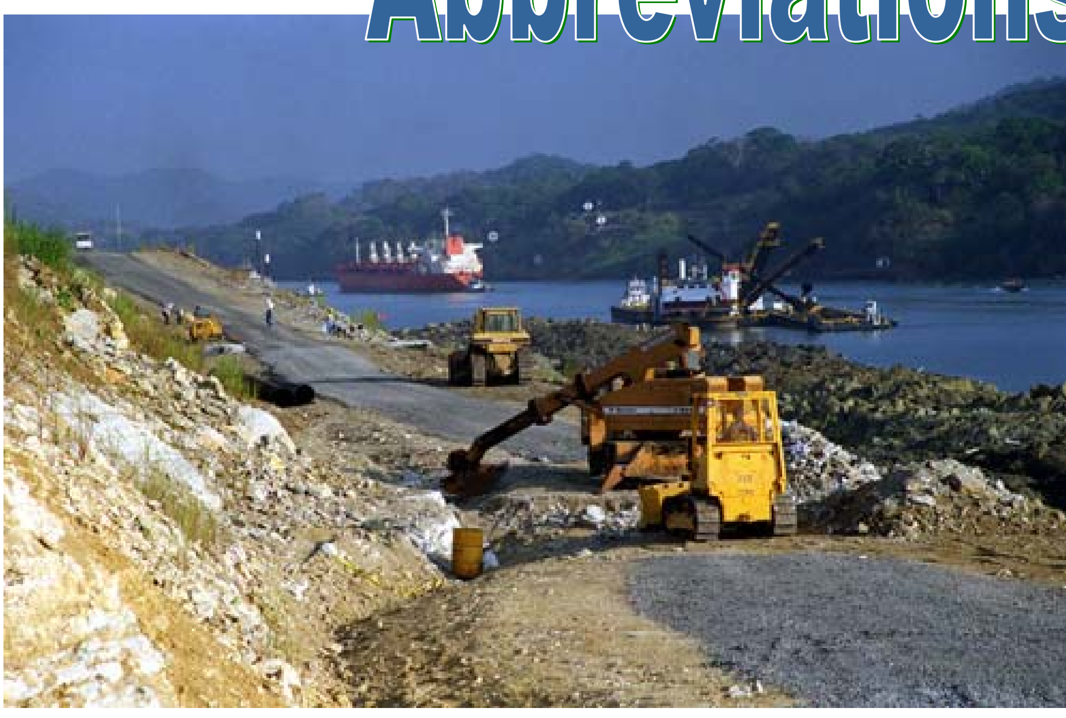
APPENDIX B

Abbreviations



The following abbreviations are used in this report.

AF	Acre-Feet
ANAM	Autoridad Nacional del Ambiente (National Authority of the Environment)
BCF	Billion Cubic Feet
CFS	Cubic Feet per Second
cm	Centimeter
CMD	Cubic Meters per Day
CMS	Cubic Meter per Second
CWT	Canal Waters Time
CY	Cubic Yard
DWT	Dead Weight Tonnage
E&D	Engineering and Design
ETL	Engineering Technical Letter
ft	Foot, Feet
GPM	Gallons per Minute
ha	Hectare
HP	Horsepower
in	Inch
IRHE	Instituto de Recursos Hidraulicos y Electrificacion (Institute of Hydraulics and Electrical Resources)
kg/m^2	Kilograms per Square Meter
kg/m^3	Kilograms per Cubic Meter
kgps	Kilograms per Second
km	Kilometer
km^2	Square Kilometer
km^3	Cubic Kilometer
kmph	Kilometers per Hour
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt Hour
l	Liters
LPD	Liters per Day
LPM	Liters per Minute
LPS	Liters per Second
m	Meter
M&I	Municipal and Industrial
M^3	Cubic Meter
MCM	Million Cubic Meters
mg/l	Milligrams per Liter
MGD	Million Gallons per Day
mi	Mile
mi^2	Square Mile
mm	Millimeter
MPH	Miles per Hour
MPS	Meters per Second
MSL	Mean Sea Level
MSM	Million Square Miles
MT	Metric Ton
MW	Megawatt
MWh	Megawatt Hour
NTU	Nephelometric Turbidity Unit
PCC	Panama Canal Commission
PCF	Pounds per Cubic Foot
PMF	Probable Maximum Flood
ppm	Parts per Million
PSF	Pounds per Square Foot
PSI	Pounds per Square Inch
S&A	Supervision and Administration
SIA	Socio-Economic Impact Assessment