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7.0 IDENTIFICATION OF SPECIFIC ENVIRONMENTAL IMPACTS

This chapter discusses the identification and evaluation of the possible social and environmental impacts associated with the construction works and operation of the Panama Canal Expansion Project, aimed at adding a Third Set of Locks to the existing infrastructure. It is worth mentioning that the identification and evaluation of impacts are both based on the Project description approved by the Panama Canal Authority (ACP), the promoter, the survey of the existing environmental baseline, and environmental sensitivity analysis of the impacts from the proposed works. The Project will be designed, constructed, and operated in compliance with environmental regulations of the Republic of Panama and includes international guidelines, particularly those to meet the sustainable development criteria set out in the Equator Principles.

The chapter is organized into eight (8) major sections following the structure suggested by Executive Decree 209, and includes additional sections to facilitate the review process.

The first section of this chapter provides a comparative analysis of the existing environmental situation relative to the expected transformations.

Section two presents a description of the process involved in the analysis, valuation, and hierarchy of potential impacts on specific components of the corresponding physical, biological, socioeconomic, and historical-cultural environments. Accordingly, the following five sections provide a detailed analysis of the impacts evaluated, including a special section on transboundary impacts.

Lastly, in line with the sequence defined in Executive Decree 209, section eight describes the methodologies used for the identification, analysis, valuation, and hierarchy of potential impacts according to the nature of actions implemented, the potentially affected environmental variables, and baseline characteristics of the area of influence involved. The identification and evaluation of impacts is carried out using matrices, and along the process such matrices are evaluated as to their positive or negative effect, probability of occurrence, duration, magnitude, and cumulative and synergistic effects.

As can be seen from the explanation of the methodology applied, the analysis of cumulative and/or synergistic effects was performed in a joint and integrated manner as part of the process of identification, valuation, and hierarchy of impacts. In addition to that provided under Decree 209, an evaluation of transboundary impacts has been included at the request of the Project promoter (ACP).

It is important to point out that the process of identification and evaluation of impacts in this chapter has considered, and is also compatible with, the results of the identification and evaluation of specific impacts derived from the construction and operation of the Panama Canal Pacific Entrance Widening and Deepening (ACP / PB Internacional, April 2007), Earthmoving and Leveling of Cartagena Hill (ACP / PB Internacional, March 2007), and T6 Site Preparation (ACP / URS Holdings Inc., May 2007) Projects, obtained from the corresponding Environmental Impact Studies, of which the summaries and more relevant aspects are included as Annex 5.

7.1 Analysis of Previous Environmental Situation in Comparison with Expected Environmental Transformations

The identification and evaluation of potential impacts requires a comparative analysis of existing conditions (baseline) and the main transformations expected in the general environment of the Canal, especially those changes expected in the Direct Impact Area (DIA). In this regard, it is appropriate to note that the activities required for the implementation of the Panama Canal Expansion - Third Set of Locks Project, are for the most part very similar to those developed more than a century ago for the initial construction and maintenance of the present Canal.

Seen from that perspective, it is clear that the greatest impacts to the natural environment occurred during the initial construction period of the Panama Canal in the early 20th century. This resulted in the flooding of about 425 km^2 and the forming of Gatun Lake; modification of the watersheds upstream and downstream of Gatun Dam;

creation of rubble storage areas; construction of the causeway to join the islands of Naos, Perico, and Flamenco on the Pacific Side; and relocation of populations within the Gatun Lake area. Several areas became isolated with the raising of the water level of Gatun Lake. Barro Colorado Island was formed as a result of these activities, which were also responsible for the destruction and fragmentation of existing ecosystems that were replaced by the present ones.

The second period of environmental impacts due to modifications made to the Canal included works such as the creation of Madden Dam and Alhajuela Lake, 1931-1939, and attempts at constructing the Third Set of Locks during the forties. These activities led to excavation close to the Canal entrances on the Caribbean and Pacific coasts. Impacts on the environment during these activities are considered minor, inasmuch as excavation occurred in previously altered areas with ecosystems of secondary origin, subsequent to the impacts caused by the construction of the original Canal.

Potential environmental impacts that may occur as a result of the Panama Canal Expansion - Third Set of Locks Project will likewise be low and will occur in previously affected areas. The ecosystems in construction areas of the new locks and their access channels have all been previously affected by activities related to the construction and operation of the Panama Canal. The vegetation is dominated by species that have adapted to disturbances. All forested areas affected by the Project are of secondary growth. Although a few fragments of secondary forests have developed characteristics of a mature forest, there are no residual primary or mature forests in direct impact areas. The environment is typical of previously affected areas.

Both ends of the Specific Study Area (Zone 1 - Atlantic Coast and Zone 6 - Pacific Coast), and the Direct Impact Area (DIA) contain marine coastal environments with residual mangrove. These environments are relatively fragile or susceptible to impacts. Similarly, both zones have coral reefs outside the DIA that are also susceptible to impact due to changes in aquatic conditions. However, Canal widening and dredging activities will take place in the same areas that have been affected in the past. Expected impacts are therefore of low significance.

The environmental impact due to the raising of the Gatun Lake water level is considered minor. Vegetation in the area affected by the 45 cm increase in water level is already adapted to fluctuations in the Lake operating level. There will be a difference in that the borders of the fringe of adapted vegetation growing on the shores of the Lake will spread out further. On the other hand, accessibility or the use of any of the lowlands along the shores of the Lake may be limited during the months of higher precipitation, although not on a permanent basis. The effect of maximum future rises will be controlled, just as the ACP currently does, by releasing water through the Gatun Dam spillway gates.

Some of the dwellings located on the banks of Gatun Lake will have a greater probability of being affected during the operations phase of the Project. The 45 cm increase in the level of Gatun Lake may affect land use in low areas just as the increase in the groundwater table may also change the soil drainage in these areas. Nevertheless, it must be made clear that the ACP Land Use Plan (Agreement 102 of August 25, 2005 of the ACP Board of Directors) does not designate agricultural zones directly adjacent to the Lake, because ACP has exclusive jurisdiction up to an elevation of 30.5 m PLD (100') and the lake level will only rise up to 27.1 m (89'); however, the possibility of the existence of such agricultural zones must be considered for the purposes of this analysis. Some of the intakes for the water distribution systems supplying water to small communities may be affected by the raising of the level of Gatun Lake, and would need to be refitted.

Socioeconomic effects from the construction phase of the Expansion Project will be positive for the most part. The increase in direct job openings will be low in comparison with the number of active workers. It is likely that workers for the Project will come from the more populated areas in the central region of Panama (the provinces of Panama and Colon) close to Project areas, rather than from more distant areas. In view of the current traffic conditions and the maximum number of possible workers, the impact on vehicle traffic will be low and should not require any changes.

Current Canal maintenance activities include dredging. The proposed activities will increase the volume of dredged material, which will be placed in areas designated for this purpose; most of these sites h have been previously used for Canal maintenance and modernization projects. . Impacts on land resulting from this dredging work will be limited to the areas used for the disposal of excavated and dredged material. The environment could be affected by the new proposed disposal sites as the available natural areas decrease. Soil vibrations and noise generated from blasting work with explosives will impact the surrounding environment. The areas selected for these activities are all located far from the major urban centers, except for some areas near La Boca, Paraiso, Pedro Miguel, Diablo, and Amador.

The cumulative and synergistic effect of the expected alterations to be caused by the Project in the physical, biological, socioeconomic, and historical-cultural environments will not result in significantly adverse changes when compared to the trends and development of the existing environmental situation in the country and the Study Area. However, the construction phase of the Project could generate short duration adverse impacts of greater significance than those occurring due to current Canal operations.

7.2 Analysis, Valuation, and Hierarchy of Positive and Negative Impacts Derived from Project Implementation

Tables 7-1 and 7-2 show a summary of the analysis, valuation, and hierarchy of positive and negative impacts derived from Project implementation, organized according to the elements of interest and significance rating of each impact in the corresponding construction (Table 7-1) and operations (Table 7-2) phases. Impacts considered significant are those with a moderate to very high rating (significance rating of +/- 3.4 or higher).

It is important to point out that the significance rating of each impact was determined according to the methodology described in Section 7.8 of this chapter. This methodology is based on the assessment of the impact in which numerical values are assigned to a series of criteria (magnitude, duration, development time, cumulative and synergetic effects, and probability of occurrence), and then jointly analyzed using a mathematical formula to determine the specific significance of the impact evaluated.

The individual analysis of each impact is shown in the following sections.

Table 7-1
Analysis, Valuation, and Hierarchy of Significant Impacts from the Construction Phase of the Panama Canal Expansion – Third Set of Locks Project

Impact	Analysis	Valuation	Significance
	Physical Elements		
Increase in Landslide Risk	• Increase in magnitude and occurrence of landslides in slopes from channel deepening and excavation	-7.50	High
Increase in Soil Erosion	• The exposure of the soil surface due to removal of vegetation • A local increase in steepness of excavation and backfill slopes	-6.30	High
Increase in Noise and Vibration Levels	• Noise emission from construction equipment and machinery • Noise and vibrations from blasting and other Project work	-5.74	Medium or Moderate
Deterioration of Water Quality	• An increase in turbidity levels from added suspended solids • Trace metals in sediments • Potential pollution from other activities	-5.54	Medium or Moderate
Deterioration of Air Quality	• Emissions of particulate materials and polluting gases from construction equipment and machinery • Generation of particulate material due to earthmoving, excavation and blasting	-3.43	Medium or Moderate
Microclimate Change	• The loss of vegetative cover and change in soil use • Increase in local ambient temperature	-3.10	Low
Soil Compaction	• Movement of equipment and machinery • Disposal of excavated and backfill material • Reduction of soil infiltration capacity due to removal of vegetation	-3.04	Low
Increased Sedimentation	• Soil erosion on account of soil surface exposure due to removal of vegetation • Soil erosion due to local increase of sloping in excavation and fill slopes	-2.93	Low
Alteration of Drainage Pattern	• Land disposal of dredged and excavated material • Diversion of Cocoli and Rio Grande (Southern branch) Rivers • Construction of hydraulic works	-2.40	Low
Loss of Potential Carbon Capture	• Change in land use and loss of vegetated areas • Loss of soil biomass • Increased carbon dioxide emissions	-2.38	Low
Decrease of Land use Capability	• The various types of construction activities such as erosion, compaction, contamination and water holding capacity affect soil properties	-2.16	Low
Increase in Odor Perception	• Unpleasant odors due to noxious gas emissions from blasting detonators and movement of heavy equipment • Odors generated by liquid and solid wastes	-1.96	Low
Soil Contamination	• Accidental spills of oil, fuel, grease, chemicals and other pollutants • Disposal of excavated and dredged material at designated sites • Blasting of basaltic-type igneous rock	-1.27	Low
Alteration of Water Flow Regime	• Disposal dredged and excavated material on land • Diversion of Cocoli and Rio Grande (Southern branch)	-1.20	Low

Impact	Analysis	Valuation	Significance
	Rivers • Construction of hydraulic works, operation of field offices and quarrying		
Undermining – Cave-ins	• Potential changes in the local geological and/or hydrogeological features • Stress release in soil and rocky massif • Introduction of stress as a result of fills	-0.15	Very Low
Biological Elements			
Alteration of Aquatic Resources in Miraflores Lake	• Area and volume loss in the Lake • Diversion of Cocoli River • Increase or reduction of suspended sediments	-5.78	Medium or Moderate
Alteration of Marine Coastal Ecosystems	• Increase in suspended sediments • Increased sedimentation • Alteration of coastal bottoms due to deepening of the navigation channel • Vibration due to blasting	-5.60	Medium or Moderate
Loss of Vegetative Cover	• Permanent vegetation loss in the footprint of the new accesses, locks and water saving basins, and other permanent infrastructures • Temporary loss of vegetative cover at new disposal sites and temporary work areas	-4.20	Medium or Moderate
Loss of Land Habitats	• Permanent loss of land habitats in the footprint of new accesses, locks and water saving basins, and other permanent infrastructure • Temporary conversion of land habitats into new disposal sites and temporary work areas	-3.87	Medium or Moderate
Alteration of Aquatic Resources in Gatun Lake	• New disposal sites • Increase in suspended sediments • Alteration of Lake bottom due to deepening of the navigation channel • Vibration due to blasting	-3.50	Medium or Moderate
Loss of Forest Potential	• Permanent loss of forest resources in the footprint of new accesses, locks and water saving basins, and other permanent infrastructures • Temporary loss of forest resources at new disposal sites and temporary work areas	-3.24	Low
Alteration of Aquatic Resources in Rivers and Creeks	• Diversion of Rio Grande (Southern branch) and Cocoli Rivers • Impact due to new disposal sites (T6 and Cocoli)	-3.08	Low
Increased Risk of Running Over Wildlife	• Increase in vehicle traffic over access roads	-2.64	Low
Direct Impact on Fauna	• Fauna with low mobility not being able to move away or escape from machinery and work within the Project footprint	-2.56	Low
Impact on Protected Areas	• No direct impacts on land areas within the Protected Areas • Impact on the lake environment of Barro Colorado Island NM	-2.04	Low
Poaching	• Increase in the temporary local worker population and persons involved in indirect activities	-1.74	Low
Disturbance to Wildlife	• Temporary increase in noise levels and activities by people, vehicles and machinery	-1.50	Low
Socioeconomic Elements			
Increased National	• Temporary increase in revenues from customs, business	+6.80	High

Impact	Analysis	Valuation	Significance
Treasury Revenues	taxes, etc.		
Stimulus to the National Economy	• Temporary increase in the demand for labor and skilled workers for construction activities • Temporary increase in the demand for services, goods and supplies	+4.80	Medium or Moderate
Job Creation	• Temporary increase in the demand for labor and skilled workers for construction activities • Temporary increase in the demand for services	+4.71	Medium or Moderate
Increase in Tourism Flows	• No interruption in current visitor traffic • Generation of additional interest in visiting the Canal and witnessing the magnitude of the Project work	+2.48	Low
Increase in Property Values	• Increase in property values due to greater demand for goods and services, and development of new activities	+1.30	Low
Increase in Risk of Work-Related Accidents	• Increase in workforce • Increased health care in the cities of Panama and Colon	-5.33	Medium or Moderate
Increase in Waste Generation	• Further strain on the existing waste disposal system due to the greater amount of waste generated by the increase in the number of employees • Special disposal required for non-organic and hazardous waste generated by the use of heavy equipment and machinery	-3.98	Medium or Moderate
Overload of Public Services	• Increase in health care in the cities of Panama and Colon • Greater use of public services by contractor personnel and their dependents as well as other public services such as customs transactions, work permits, etc.	-3.24	Low
Impact on Vehicle Traffic Due to an Increased Demand for Transportation	• Total expected number of daily trips by workers and related population: 5,316 (36% by private vehicles and 64% on public transportation)	-3.14	Low
Changes in Land use	• Increase in space demand for new settlements in some areas of the Socioeconomic Study Area (SSA)	-2.86	Low
Population and Migration Flow Increase	• Temporary increase in the population due to the arrival of foreign workers, as well as the floating population seeking jobs	-2.76	Low
Impact on Structures	• Relocation or replacement of structures belonging to communities or third parties	-2.72	Low
Risk of an Increase in Work-Related Illnesses	• Generation of insect and other vector breeding sites • Impact on worker health	-1.42	Low
Landscape Changes	• Alteration of the landscape due to excavation, reshaping of the terrain and construction of Borinquen dikes	-1.18	Low
Impact on Public Infrastructure	• Relocation or replacement of public infrastructure	-1.12	Low
Change in Crime Rates	• Arrival of foreign workers, as well as of the floating population seeking jobs • Lower impact due to increase in direct and indirect employment, and improvement in quality of life	-0.40	Very Low
Historical-Cultural Elements			
Impact on Known Historical and Archaeological Sites	• Direct alteration of sites due to work • Alteration of sites close to the work	-3.80	Medium or Moderate
Impact on Unknown Archaeological Sites	• Risk of destruction of unknown archaeological material during excavation and blasting	-2.90	Low

Table 7-2

Analysis, Valuation, and Hierarchy of Impacts from the Operations Phase of the Panama Canal Expansion – Third Set of Locks Project

Impact	Analysis	Valuation	Significance
Physical Elements			
Loss of Potential Carbon Capture	• Changes in vegetated areas due to the increase in the level of Gatun Lake • Reduction of emissions worldwide on maritime and overland routes	+1.39	Low
Deterioration of Air Quality	• Increase in ship traffic through the Canal • Regular maintenance or disposal site operations	-4.07	Medium or Moderate
Increase in Landslide Risk	• Instability of cut and fill slopes as a result of vibrations, overload and water action.	-2.88	Low
Microclimate Change	• Vegetation changes or adaptation due to the increase in the level of Gatun Lake	-2.77	Low
Deterioration of Water Quality	• Increase in turbidity levels due to an increase in suspended solids • Heavy metals in sediments • Fluctuation in the level of Gatun Lake • Operation of the Third Set of Locks	-2.72	Low
Increase in Noise and Vibration Levels	• Ship lockages • Routine maintenance work	-2.60	Low
Drainage Pattern	• Disposal of dredged and land excavated material	-2.08	Low
Increase in Odor Perception	• Gas emissions from the operation of maintenance equipment and machinery	-1.56	Low
Increase in Soil Erosion	• Road maintenance • Slope stabilization • Maintenance and stabilization of lock approach channels • Operation dredged material disposal sites	-1.45	Low
Increased Sedimentation	• Soil erosion due to change in usage or slopes with steep sloping	-1.30	Low
Soil Contamination	• Operation and maintenance of maintenance machinery and equipment • Disposal of dredged and excavated material	-1.18	Low
Soil Compaction	• Operation of dredged and excavated material disposal sites as part of maintenance activities	-1.14	Low
Alteration of Water Flow Regime	• Disposal of dredged and waste material on land • Fluctuation in the level of Gatun Lake	-0.98	Low
Undermining - Cave-in	• Long term effects as a result of construction work (excavation, backfills)	-0.12	Very Low
Biological Elements			
Alteration of Marine Coastal Ecosystems	• A slight increase in maintenance activities for navigation channels and risks associated with ship traffic to the extent that a larger number of vessels, as well as larger sized vessels, transit the Canal	-4.16	Medium or Moderate

Impact	Analysis	Valuation	Significance
Increased Risk of Running Over Wildlife	• While vehicle traffic will decrease, it will still be higher than current levels due to the increase in general activities associated with the expanded Canal	-2.90	Low
Alteration of Aquatic Resources in Rivers and Creeks	• The diversion and channeling of Rio Grande (Southern branch) and Cocoli Rivers as a permanent condition during the operations phase will not allow the recovery of pre-construction conditions • Releases into the lower Chagres River through Gatun Dam may be affected by the rising of the operating level of Gatun Lake	-2.54	Low
Alteration of Aquatic Resources in Miraflores Lake	• The main risk during the operations phase is considered to be the increase in the degree of eutrophication of Miraflores Lake • A significant change in the salinity of Miraflores Lake during the operations phase is ruled out	-2.35	Low
Loss of Land Habitats	• Changes in the maximum and minimum operating levels of Gatun Lake will produce alterations of land habitats	-2.24	Low
Loss of Vegetative Cover	• The temporary work areas of the construction phase will be revegetated • The eventual expansion or maintenance of disposal sites could affect the vegetative cover and prevent its regeneration • Changes in the maximum and minimum operating levels of Gatun Lake will produce changes in vegetative cover depending on location and duration	-2.06	Low
Disturbance to Wildlife	• The levels of noise, vibration and material transportation activity by heavy equipment will decrease to levels similar to current conditions • Canal traffic and activities associated with the locks will generate disturbance levels slightly higher than current ones	-1.30	Low
Direct Impact on Fauna	• To the extent that disposal sites continue to be used during Canal maintenance, an eventual elimination will occur of some specimens of species with low mobility	-1.16	Low
Impact on Protected Areas	• An increase in the permanent population due to the expanded Canal could lead to a slight increase in poaching above current levels	-1.12	Low
Alteration of Aquatic Resources in Gatun Lake	• A fluctuation in the level of Gatun Lake up to 2.44 m • A general effect of more fluctuation is the decrease of submersed plants rooted in the sediment and bentonic organisms • A significant change in the salinity of Gatun Lake during the operations phase is ruled out	-0.48	Very Low
Poaching	• An increase in the permanent population due to the expanded Canal could lead to a slight increase in poaching above current levels	-0.48	Very Low
Socioeconomic Elements			

Impact	Analysis	Valuation	Significance
Increase in National Treasury Revenues	• Up to US$4,190 million in net tonnage fees, utility fees, and surpluses by 2025 • During the first eleven years of operation, a total contribution to the State of over US$8,500 more than the Non Expansion alternative	+7.42	High
Stimulus to the National Economy	• The additional economic activity at an aggregate level would provide an additional 26% to the GDP annual growth rate • The contribution of the Canal to Panama's total exports for the year 2025, would be 19.5% above the No Expansion alternative • For that same year, there would be an additional 31.8% in tax revenues with the expansion	+6.40	High
Job Generation	• The demand for additional personnel will decrease close to current levels, except for that required to operate and maintain the new locks • There would be a greater impact resulting from the growth of complementary services and activities due to the increase in Canal transits	+6.40	High
Landscape Changes	• The alteration of the landscape due to transits of larger sized vessels	+5.50	Medium or Moderate
Increase in Tourism Flows	• Once the works are completed and safety restrictions lifted, an even greater interest in visiting the Canal is expected	+3.64	Medium or Moderate
Increase in Property Values	• An increase in property values due to changes in conditions and development of new activities	+1.40	Low
Increase of Population and Migration Flows	• A stimulus to population growth and migration flows as a result of regional economic growth	-3.63	Medium or Moderate
Changes in Land use	• The Project impact on the dynamics of land use will depend mostly on the performance of complementary and/or additional activities to the operation of the Canal, such as the Canal Conglomerate, the housing boom and the overall performance of the economy	-3.51	Medium or Moderate
Overload of Public Services	• The increased population will require broader and better coverage of public services • It is assumed that the additional power requirements to operate the Third Set of Locks will be provided by the ACP itself; therefore, no additional pressure will be placed on this resource	-3.45	Medium or Moderate
Impact on Vehicle Traffic due to an Increased Demand for Transportation	• The greater demand for transportation during the operation will be met by an increased financial capacity to improve road infrastructure	-2.21	Low
Increase in Waste Generation	• A higher level of waste will be generated due to a slight increase in the number of workers in the area and a greater number of tourists, as well as the use of more equipment in	-0.93	Low

Impact	Analysis	Valuation	Significance
	lockage and maintenance activities		
Risk of an Increase in Work-Related Illnesses	• The large-scale need for additional workers will have ended and therefore, the risk of an increase in work-related illnesses due to the Project will be practically nonexistent	-1.12	Low
Increase in Risk of Work-Related Accidents	• Due to the strict safety standards in force at the ACP, the additional number of new jobs generated by the operations of the expanded canal will not increase the risk of accidents	-1.45	Low
Change in Crime Rates	• A potential increase in crime rates should not be attributed directly to the Project but rather to the development of related activities	-0.09	Very Low
Transboundary Impacts			
Reduction of Maritime Transportation Costs by using Post-Panamax Ships	• A reduction in distances and an increase in cargo capacity could generate cost reductions	+2.23	Low
Improvements in the Reliability of Shipping Companies that use the Canal Route	• A reduction of shipping time and the increase in cargo capacity will enable delivery of better services	+1.77	Low
Effect of Increase In Tolls on Some Countries	• An increase in tolls could have a negative effect on the economies of some countries	-1.66	Low
Increase in Accident Risk over International Routes	• An increase in the frequency of use of some maritime routes could result in an increase in accidents	-0.24	Very Low

7.2.1 Impacts on the Physical Environment

Through the analysis performed, a total of fifteen (15) types of potential impacts were identified during the construction and operations phases of the Project that could have negative effects on the physical environment (air, water and soil). It is worth mentioning that during the construction phase, most of the impacts are considered temporary and reversible, while during Project operations , the impacts, though mostly of a permanent nature, are of low intensity because of the proposed designs and in order to comply with applicable standards among other factors.

7.3.1 Microclimate Change

Construction Phase

Changes in weather variables occur mainly due to changes in land use, with the consequent loss of vegetative cover and biomass in the areas that will be permanently occupied by the Project footprint. The loss in vegetation due to changes in land use will result from the following Project activities during the construction phase:

- Clearing, stripping, and grubbing
- Construction of permanent and temporary access roads
- Excavation and filling
- Blasting
- Disposal of excavated and dredged material on land
- Construction of permanent structures (Borinquen dikes, locks and water saving basins)

The loss of vegetative cover will give rise to distinct, localized (microclimate) weather changes, with specific manifestations at sites cleared of vegetation, and will be reflected by an increase in ambient temperature and an ensuing drop in humidity. The temperature rise phenomenon will also occur as a result of changes in surface refraction conditions with a diversified usage of the original surface for paved surfaces or for Project facilities, water surfaces (such as navigation channels, locks and water saving basins), rock or exposed soil surfaces of dikes, cut slopes, etc. These effects will be of a local nature and mainly manifested on the Project footprint.

The section on the loss of vegetative cover provides a detailed breakdown of the areas by category of cover that will be directly affected by the Project footprint, in each of the zones of the Direct Impact Area (DIA).

Based on the above, the impact can be considered an indirect one resulting from the loss of vegetation, and a negative and definite one. It will develop very rapidly, as the occasional or localized effects will be felt immediately with the loss of vegetation. These effects will be of a low magnitude, localized, and permanent (despite any natural regeneration of vegetation on slopes or unoccupied surfaces, or mitigation measures).

On the other hand, microclimate change is considered a cumulative impact with a moderate effect when combined with other impacts generated by projects carried out in the past, such as microclimate change itself or the deterioration of air quality. This impact is not considered to have a synergistic effect.

Considering the foregoing, the impact of microclimate change during the construction phase has a low level of significance (**-3.10**).

Operations phase

During the operations phase and throughout the useful life of the Project, the impact on the microclimate caused during the construction phase of the Third Set of Locks will continue due to the change in land use along the footprint of the Project , although artificial or natural regeneration of vegetation is expected to occur on slope surfaces and surfaces of areas not occupied permanently by the works or installations, regardless of the implementation of mitigation measures.

Considering the legal and institutional context and, above all, the fact that the areas where the Project works will be carried out are located within areas under the exclusive administration of the ACP, it is not expected that the implementation of the Project will lead to the generation of new activities along the axis of the Project footprint that are not associated with the operation and maintenance of the waterway. However, it is anticipated that the performance of the works and their operation will bring about an increase in tourism and guided tours to the various construction sites, and throughout the Canal. However, it is not expected that it will create any additional impact on the microclimate in the region.

The most important aspect to be considered during the operation is the raising of the operating level of Gatun Lake to 0.45 meters above the current maximum operating level. This increase implies a rise in level during the rainy months, which could result in the alteration of vegetation in some lowlands in the months with the highest rainfall.

According to the assessment conducted by URS Holdings using available cartographic information, satellite images and application of the SIG, it is estimated that along the approximately 2,000 km of Lake perimeter and islands, the vegetation on the banks could somehow be altered. A monitoring study conducted over a period of several years (5) may determine the level of these alterations and the type of species that are declining, or which species might replace the existing ones.

The current operating level of Gatun Lake fluctuates between 24.8 m (81.5') and 26.7 m (87.5') PLD[1], whereas with the Project it will fluctuate between 24.8 m (81.5´) and 27.1 m (89´) PLD. Historical Gatun Lake levels s during the period January 1992 – December 2001 (Environmental Viability Report. ACP, 2006) show that under current operating conditions and according to weather seasonality (Canal Watershed rainfall and runoff), the maximum operating level is normally reached between the months of December and January, with Lake levels remaining high for a few weeks (between 0 and 8) and then dropping gradually again as a result of water usage.

In view of the above, this impact is considered to be indirect, the result of vegetation changes or adaptations due to the fluctuation in the level of the Lake banks, a negative and definite one, and with slow development as its local effects will be felt over years with the gradual change in vegetation.

On the other hand, microclimate change is considered a cumulative impact with a moderate effect when combined with other impacts generated by projects carried out in the past, such as microclimate change itself or the deterioration of air quality. This impact is not considered to have a synergistic effect.

Accordingly, the impact of microclimate change during the operations phase has a low level of significance (**-2.77**).

7.3.2 Loss of Potential Carbon Capture

Construction Phase

On the whole, a change in the use of land now occupied by secondary forest, brush, shrubs, grassland, and pasture, to paved surfaces or surfaces occupied by Project

[1] PLD = Precise Level Datum, approximately the same as the mean sea level on both coasts.

installations, including water surfaces (navigation channels, locks, and water saving basins), rock or exposed soil surfaces in cut slopes, will reduce to a certain extent the potential for carbon capture in that land. This loss of potential carbon capture will result from the loss of vegetative cover as well as soil biomass.

The foregoing translates into greater carbon dioxide emissions, which on a worldwide basis are related to the climate change phenomenon. Table 7-3 shows potential carbon capture loss estimates associated with changes in land use[2].

Table 7-3

Loss of Potential Carbon Capture

Category	Surface (in hectares)	Carbon (M.T.C/ha)	Total Carbon (M. T.C)
Mature secondary forest and mangrove	33.87	83.24[*a]	2,819
Intermediate secondary forest	456.69	83.24[*b]	38,015
Brush and Stubble	238.03	10.00[*c]	2,380
Grassland and Pasture	1,137.62	10.00[*d]	11,376
Total Vegetative Cover	**1,866.21**		**54,590**

[*a]The value for "open vegetation".
[*b]Ditto.
[*c]The value for "grasslands and subsistence crops".
[*d]Ditto.

Source: URS Holdings, Inc.

The 54,590 M.T. of carbon that would no longer be captured due to loss of vegetative cover in the Project area barely account for 0.009% of the estimated value of stored carbon in Panama's baseline for the year 2012, which will total 601,316,647 M.T.C according to the "Panama – Facing the Climate Change" report , regardless of the implementation of Clean Development Mechanism (CDM) projects.

Given the above, this impact is considered to be indirect, the result of loss of vegetative cover, a negative and definite one, with a slow development and global effects that will be felt over a long time, of very low magnitude considering that it barely accounts for

2 Carbon capture data by type of usage category were obtained from the Panama – Facing the Climate Change Report, Central American Series on Forest and Climate Change. FAO, October 2003. Where no data were provided for a specific usage type, data established for similar categories were used as reference values.

0.009% of the potential for carbon capture of the country's forests, and a permanent one.

On the other hand, the loss of potential carbon capture is considered a cumulative impact with a moderate effect at a regional level, as it contributes to the process of global warming and climate change which is an ever growing occurrence around the planet. This impact is not considered to have a synergistic effect. Considering the foregoing, the impact from the loss of potential carbon capture during the construction phase has a low level significance (**-2.38**).

Operations phase

As previously mentioned, the resulting raising of the operating level of Gatun Lake and fluctuation in the temporary level of areas along the Lake banks during the operations phase may bring about a gradual change in vegetation. This change could also imply a loss of potential carbon capture, the magnitude of which would be associated with vegetation that is affected by these temporary events.

In early 2007, PB Consultants Inc. conducted a study on behalf of the ACP on the impact on Greenhouse Gas Emissions (GHG) due to the implementation of the Panama Canal Expansion Project, and routes and preferential lanes that would be used for cargo transportation within the context of international trade.

According to that study, carbon dioxide (CO_2) emissions were the main GHGs produced by maritime and ground transportation sources, and were therefore the emissions analyzed in the study.

The main source of CO_2 anthropogenic emissions is derived from fossil fuels, which account for approximately 70-90% of the total emissions of anthropogenic origin on the planet. Fossil fuel combustion is mainly used for power generation, transportation, heating and industry. Transportation is one of the major contributors to the production of CO_2 emissions. The Panama Canal expansion could affect transportation, modifying trade lanes and volumes along these routes.

Due to its characteristic as a passageway for international and intercontinental transportation, estimates of GHG emissions in international waters had to be based on the estimates of trade and the number of trips/ship, the routes used and the corresponding CO_2 emissions produced on such routes, in order to analyze the effect on CO_2 emissions from the implementation of the Canal expansion program.

For the purposes of considering the changes in transport patterns by ships around the world due to the Panama Canal expansion, PB Consultants used the ACP Integrated Demand Model to predict the future situation with and without the expansion. According to the ACP model, the most affected segments of ship transportation would be container, automobile, and grain transportation. Other items transported by ship will not change their routes in any significant way as a result of the Canal expansion.

On account of the canal expansion, a relative reduction is expected to occur in the frequency of transits through the Suez Canal and U.S. West Coast ports and an increase in transits through the Panama Canal to U.S. East Coast ports. Otherwise, if the Canal Expansion Project were not implemented, the Canal would reach its maximum capacity around 2012-2014 with the opposite effect occurring from that point on, meaning that there will be an increase in the frequency of transits through the Suez Canal and U.S. West Coast ports. It is expected that the Canal expansion will also affect U.S. overland transport of cargo from the Far East using the U.S. intermodal system between the West and East Coasts.

The analysis completed by PB Consultants estimated CO_2 emissions for the three segments most affected by maritime transportation along international routes (containers, grains and automobiles), as well as for all transport segments through the Panama Canal and the ground transportation of containers between the West and East Coasts of the United States, including all road and rail modalities. To that end, scenarios with and without the Canal expansion were compared, on the assumption that total transportation would remain the same in both alternatives.

The results of the analysis indicate that CO_2 emissions of ship transportation on international waters will increase with the Canal expansion between 2015 and 2020, but will decrease as of 2025, compared to the scenario without the canal expansion. The increase in CO_2 emissions with the Canal expansion between 2015 and 2020 can be attributed to the fact that a greater number of ships, including larger container ships, will be sailing from the Far East through the Canal directly to the U.S. East Coast, instead of over the shorter maritime route they currently use through the West Coast. After 2025, once the expanded Canal capacity is fully reached due to the subsequent increase in transportation demand, CO_2 emissions will be offset by the corresponding increased use of transportation using the longer route through the Suez Canal.

The effect of CO_2 emissions on overland transport between the West and East Coasts of the United States was evaluated in two transportation modes: road and rail. Due to uncertainty over the future distribution of transportation between both modalities, two scenarios were considered that included the full spectrum of possibilities, the predominant transportation by road, and the predominant transportation by rail. CO_2 emissions for road transportation were estimated using the USEPA Mobile Emissions Model 6.2, while emissions generated by railway engines were estimated using the combustion efficiency factor and CO_2 emissions of the BNSF (Burlington Northern and Santa Fe Railway) railway system located in the United States. The results of both scenarios showed less CO_2 emissions in all the analysis years of the Panama Canal expansion scenario.

On the whole, adding the effect of ship transportation along international routes (containers, grains, and automobiles), transportation through the Panama Canal, and the ground transportation of containers between the West and East Coasts of the United States, it was found that by 2015, the total CO_2 emissions will increase (with the full operation of the expanded Canal) by approximately 9.2 million tons of CO_2, compared to the scenario without an expansion. This increase is expected to be much lower around 2020 (by about 100 to 500 thousand tons), while by 2025 total CO_2 emissions are expected to drop by about 5-6 million tons of CO_2.

Accordingly, based on the assumptions of the ACP Integrated Demand Model, current power outputs of ship engines, and current factors of CO_2 emissions, it is expected that the benefits of the expanded Canal would be realized after 2020, when saturation in the capacity of the Canal without an expansion would compel many large ships to take the longer route through the Suez Canal, and then use the overland route in that country to move the cargo to the U.S. West Coast.

Based on the aforementioned conditions, the impact on gas emissions causing a greenhouse effect during the operations phase of the Project is considered, overall, to be indirect, positive, of a probable occurrence, although with very slow development and relatively low magnitude, and of a permanent duration.

On the other hand, the relative reduction of CO_2 emissions is considered a cumulative impact generally with a moderate effect as it helps prevent acceleration of the global warming and climate change process which is an ever growing occurrence worldwide. This impact is not considered to have a synergistic effect.

Considering the above, the impact of the relative reduction of CO_2 emissions or loss of potential carbon capture during the operations phase has a low level of significance (+**1.39**).

7.3.3 Deterioration of Air Quality

Air is a determining factor for life; any impact on its quality could generate other secondary effects on the health of the population, flora, fauna and structures, etc.

Impacts on air quality will depend on emission sources and their specific characteristics, as well as the meteorological conditions for the area and location of receptors.

Construction Phase

Impacts on air quality caused about during the construction phase are considered temporary and related to typical construction activities, as well as the management and transportation of materials and wastes.

As part of the Project construction activities, gas emissions will be generated in areas of high work activity and intensity. Air quality may be potentially impaired by gaseous and particulate emissions from equipment, machinery and vehicles using hydrocarbons as a fuel source. The traffic of vehicles transporting construction material and equipment to and from the Project work sites, including the removal of waste material from work sites; as well as the operation of equipment, machinery and vehicles involved in Project construction activities, will generate gas emissions that will increase the introduction of particles into the atmosphere (particulates, dust, dirt, etc.), and other pollutant gases. In addition, earthmoving to prepare the ground and access roads, ground clearing, excavation, and blasting, etc. will contribute to the increase of particulate material emissions in the atmosphere.

Equipment that typically contributes emissions includes trucks, light-duty vehicles, construction machinery, power generators, etc., that use hydrocarbons as a fuel source.

The atmospheric pollutants that will be generated mainly include CO, NOx, SO_2 and particulate material.

Table 7-4 below shows activities that would generate impacts and the main types of pollutants emitted:

Table 7-4

Activities that Generate Impact on Air

Activities	**Associated Pollutants**
Setting up of work areas, construction of temporary and permanent access roads; vegetation clearing, grubbing, and stripping; construction of infrastructures; blasting; installation of temporary works; construction work, disposal sites, transportation of materials and rubble, and removal and relocation of structures and infrastructures	- Particulate material

Activities	Associated Pollutants
Use of equipment, machinery and vehicles with combustion engines	- Particulate material - Carbon monoxide (CO), nitrogen oxides (NOx) and sulphur dioxide (SO_2)

Source: URS Holdings, Inc.

Construction activities related to the removal of vegetation and earthmoving, as well as the management of storage sites for dry materials, can be emission sources of diffuse particulate material, the effects of which would be significant during the dry season due to weather conditions that can facilitate their dispersion.

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Emissions associated with the use of equipment and machinery powered by combustion engines will depend directly on the type of vehicle used, the number of vehicles, and their periods of operation, and their maintenance conditions.

This impact would increase as a result of emissions arising from the continuous transit of ships through the Canal, and of the diffuse emissions of particulate material as a consequence of the Canal modernization work. Furthermore, the study made by PB Consult (2006) estimates that the highest rate of air pollutants would result from the daily transit of ships through the waterway.

Estimates made (PB Consult, 2006) to determine emissions due to construction work based on the amount of equipment that would be used during the month with the most activity, for work carried out on the Atlantic and Pacific Sides as well as the access channel on the Pacific, show these to be minimal when compared to current emissions due to the operation of the Canal. These emissions are shown in Table 7-5.

Table 7-5

Emissions Due to Construction Work

Construction Site	CO (t/day)	NOx (t/day)	PM_{10} (t/day)	SO_2 (t/day)
Atlantic Locks	0.69	2.12	0.20	0.24
Pacific Locks	1.05	3.29	0.40	0.38
Pacific Access Channel	0.67	1.93	0.13	0.21
Total Construction	**2.42**	**7.34**	**0.73**	**0.83**

Construction Site	CO (t/day)	NOx (t/day)	PM_{10} (t/day)	SO_2 (t/day)
Current Emissions Due to the Operation of the Canal and Other Activities	**56.10**	**172.01**	**5.51**	**100.80**

Source: Task Order #30. PB Consult, 2006.

As can be seen in the above Table, the contribution to current emissions due to construction work is minimal: less than 5% of current conditions in the case of CO and NOx, less than 1% of current conditions for SO_2, and less than 15% of current conditions for Particulate Material. The latter parameter is of great interest in terms of construction-related activities.

The above mentioned activities and their associated emissions will generate a negative and direct impacts on air quality, of definite occurrence and slow development because the maximum disturbance will occur when large amounts of work converge simultaneously. This impact would be considered as being of a medium magnitude, taking into account that Project emissions will be minimal when compared to other existing sources. It will be of a long duration as it will happen throughout the construction work, and will have a high cumulative impact given the interaction of Project emissions with the current emissions from ship traffic through the Canal and how close baseline values are to standardized or reference levels. It is not considered to have a synergistic effect with other impacts.

In view of the above, the impacts on air quality during the construction phase is considered to have a medium level of significance (**-3.43**).

Operations phase

During the operations phase, deterioration of air quality will occur mainly as the result of increased ship traffic through the Canal and, to a lesser degree, by the periodic maintenance or disposal site operations.

The expected emissions due to increased transit of ships through the Canal are shown in Table 7-6 below:

Table 7-6

Emissions Due to Increased Ship Transits[3]

Emission Source	CO (t/day)	NOx (t/day)	PM_{10} (t/day)	SO_2 (t/day)
Ship Transit	59.0	171.1	5.0	92.6
Dredging and Drilling	0.3	2.9	0.1	3.8
Tugboats	1.1	10.8	0.3	14.4
Service Boats	1.8	2.7	0.1	NA
Subtotal	**62.1**	**187.5**	**5.4**	**110.8**
Misc. Sources	3.67	12.98	0.80	6.07
Total	**65.80**	**200.44**	**6.20**	**116.83**
Current Emissions from Canal Operation and Other Activities	**56.10**	**172.01**	**5.51**	**100.80**

Source: Task Order #30. PB Consult, 2006.

These results show emission increments of 15% in the various parameters which, considering current baseline conditions, will have a negative, direct, and definite effect, with a very slow development. Since the maximum disturbance from the impact will arise as traffic increases at the new locks, the impact will be of a high magnitude and permanent duration, and will remain while the Canal operating. The period of maximum disturbance is expected to be more than 10 years, with a very high cumulative but non-synergistic effect.

Therefore, after applying the valuation matrix, the deteriorating impact on air quality is considered to have a medium or moderate level of significance (**-4.07**).

7.3.4 Increase in Noise and Vibration Levels

The Canal expansion project will generate an increase in noise levels mainly during the construction phase due to the operation of equipment and machinery, their movement to and from the work sites, and typical construction activities (i.e. excavation and blasting) including construction of temporary or permanent works.

3 Estimates based on expected transits in 2025.

Noise levels during the operations phase of the Project will occur due to the increase in shipping activity in the Canal and to the dredging activities related to Canal maintenance. Increased shipping activities are expected with the increase in the number of ships, of about 25% over the current the number (PB Consult 2006). This will result in an imperceptible increase in noise levels over existing levels at monitoring sites. Dredging operations will be conducted over short periods, and will thus be temporary and not cause any significant disturbance at the monitoring sites (PB Consult, 2006).

The problem of the transmission of vibrations through the ground, and of those generated by civil works is one of the most difficult to study and predict, although the physics involved are relatively simple. In certain cases, geometry and geological characteristics, as well as the techniques used and the blasting of explosive charges play important roles in the transmission of vibrations .

Conditions for the transmission of vibrations and sound wave attenuation will depend both on the type of material as well as on the contact between elements. Soil and subsoil heterogeneity, in addition to the presence of a large diversity of materials, because of their characteristics and their physical shape, are factors affecting this parameter. To a certain degree, the complexity of the natural composition of the soil and subsoil makes it extremely difficult to conduct a study on vibrations, and their prediction must then be based on suitable geotechnical studies.

Construction activities, machinery movement, and the use of explosives, etc., are factors that can generate vibrations.

Construction Phase

During the construction phase, sound levels will increase in the area of the proposed Project. Perceived levels in the closest receptors may vary considerably, depending on the phase of the Project and work progress.

All construction activities, specifically the mobilization and construction of the support infrastructure, use of heavy machinery and trucks, increased human activity in the area, ground preparation activities, excavation, backfills, dredging, blasting, and construction processes will generate an increase in sound levels and produce a negative and direct impact. The Project will use construction techniques and conventional equipment comparable to those used in any construction project, or those used in the past in Canal maintenance activities, including excavators, front-end loaders, trucks, dredges, barges, jackhammers, cranes, and other heavy equipment.

Construction activities at Project sites will result in a temporary increase in ambient noise levels. This increase in noise levels will be experienced mainly in the proximity of emitting sources. Noise magnitude will depend on factors such as the specific construction activity carried out, the noise level emitted by the various construction equipment, the duration of the construction phase, and the distance between noise sources and noise receptors.

To characterize the noise that will be produced, it was considered relevant to split the analysis, in terms of the type of activity to be carried out according to the geographic location of the works, into the following groups: Pacific Locks, Atlantic Locks, and Access and Existing Channels.

This analysis is based on the evaluation of noise levels performed by PB Consult as part of the Task Order 30 Final Report (PB Consult, 2006). The methodology used in that study included the definitions of types and quantity of equipment to be used in each area by category, the assignment of noise levels that would be generated according to the "Noise Emissions Reference Levels and Usage Factors" of the U.S. FHWA Roadway Construction Noise Model (RCNM), or field measurements[4], and forecasts of expected noise levels based on the assumption of construction work as a distinct source from which generated noise decreases by 6 dBA every time the distance doubles[5]. This noise attenuation relationship is determined by means of a logarithmic relationship represented by the following equation:

4 The noise levels of Dredges Rialto M. Christensen and Mindi, as well as Drill Barge Thor, were estimated by PB Consult based on noise measurements taken of this equipment as part of other previous studies performed by the ACP.

5 This relationship does not consider factors such as noise absorption due to soil conditions, existing barriers between the source and the receptor, and atmospheric variables.

$$SPL_2 = SPL_1 - 20\log\left(\frac{d_2}{d_1}\right), \text{ where:}$$

SPL_1	=	known noise level,
SPL_2	=	desired noise level,
d_1	=	known distance, and
d_2	=	desired distance.

The following results were obtained by applying this analysis:

It was considered that Pacific Locks works would involve mobilization and construction of support infrastructure, water management and diversion, excavation, backfill, concrete pouring, operation of electromechanical equipment, and excavation of the access channel on the Pacific Side. It is anticipated that the required equipment will include an aggregate crushing plant and a concrete plant, both located in the designated Contractor area in Cocoli. Regarding the access channel that will connect Gaillard Cut to the new locks, it is estimated that most of that work will require drilling and blasting. Lock works should take 58 months and the access channel works about 56 months.

The equipment to be used in the construction of the Atlantic Locks will be similar to the corresponding equipment for the construction of the Pacific Locks; in this case, the contractor's installations will be located in the former town of Gatun. It is not expected that the approach channel work on the Atlantic Side will require drilling or blasting. Work on the Atlantic Locks should take about 60 months.

In the case of access and existing channels, this work includes dredging and excavation from the northern end on the Atlantic Side, all the way south to the Pacific. This will require excavation, drilling, blasting, and dredging work in the following areas: Atlantic Entrance, Gatun Lake, Gaillard Cut, Pacific Entrance, and Approach Channels of the New Locks.

Table 7-7 provides a breakdown of the construction equipment that will be used in each area and the noise levels associated with their usage.

Table 7-7

Construction Equipment and Noise levels

Pacific Locks				
Equipment Classification[6]	**Equipment Units**	**Acoustic Usage Factor**	**Lmax Specification @ 15.24m (50')**[7]	**Lmax Measurement @ 15.24m (50')**[8]
Excavator	8	40	85	81
Compactor	4	20	85	80
Grader	2	40	85	N/A
Crane	24	16	85	81
Dump Trailer Truck	62	40	84	76
Tractor	12	40	84	N/A
Concrete Plant	9	15	83	N/A
Concrete Truck	2	29	82	81
Pump	6	50	77	81
Front Loader	3	40	80	79
Compressor	19	40	80	78
Power Shovel	14	40	80	78
Dump Truck	14	40	84	74
Pickup Truck	17	40	55	75
Welding Machine	24	40	73	74
Mixing Plant	4	100	78	78
Vibrating Concrete Mixer	9	20	80	80
Truck Mounted Drilling Rig	24	20	84	79
Jackhammer	3	20	85	89
Dredges (Rialto M. Christensen and Mindi)	8	20		95
Drill Barge Thor/Baru	2	20		92

6 According to FHWA RCNM.
7 Noise levels described in the equipment noise specifications according to RCNM.
8 Maximum levels of equipment noise measured according to RCNM.

Atlantic Locks				
Equipment Classification	**Equipment Units**	**Acoustic Usage Factor**	**Lmax Specification @ 15.24m (50')**	**Lmax Measurement @ 15.24m (50')**
Excavator	5	40	85	81
Grader	2	40	85	N/A
Crane	11	16	85	81
Dump Trailer Truck	28	40	84	76
Tractor	2	40	85	N/A
Concrete Plant	8	40	84	N/A
Concrete Truck	2	29	82	81
Pump	6	50	77	81
Front Loader	2	40	80	79
Compressor	5	40	80	78
Power Shovel	14	40	80	78
Dump Truck	3	40	84	74
Pickup Truck	10	40	55	75
Welding Machine	9	40	73	74
Mixing Plant	4	100	78	78
Vibrating Concrete Mixer	11	20	80	80
Dredges (Rialto M. Christensen and Mindi)	8	20		95
Drill Barge Thor/Baru	2	20		92

Access and Existing Channels				
Equipment Classification	**Equipment Units**	**Acoustic Usage Factor**	**Lmax Specification @ 15.24m (50')**	**Lmax Measurement @ 15.24m (50')**
Excavator	5	40	85	81
Grader	2	40	85	N/A
Crane	1	16	85	81
Trailer Truck	29	40	84	76
Tractor	7	40	84	N/A
Pump	6	50	77	81
Front Loader	1	40	80	79
Power Shovel	1	40	80	78
Dump Truck	6	40	84	74
Pickup Truck	7	40	55	75
Truck-Mounted Drilling Rig	15	20	84	79
Dredges (Rialto M. Christensen and Mindi)	8	20		95
Drill Barge Thor/Baru	2	20		92

Source: Task Order #30. PB Consult, 2006.

Based on the information on the preceding Table, the duration of the works, and their distance from the nearest receptors identified in the noise baseline and Road Construction Noise Model (RCNM) of the FHWA, estimates were made of perceived noise levels generated by construction activities at those sites. These estimates are shown on Table 7-8 below:

Table 7-8

Estimates of Noise Levels During Construction

Specific Study Area	Monitoring Site ID	Existing Noise Measurements[9]	Approximate Distance to the Proposed Construction Works (m)			Estimates of Construction Noise Levels		
			Distance to the Pacific Locks	Distance to the Atlantic Locks	Distance to the Access Channel	Leq (dBA) Estimate for the Proposed Locks	Leq (dBA) Estimate for the Access Channel	Leq (dBA) Total Estimate for the Construction
Zone 2 – Gatun Locks	M1	44	---	848	471	64	71	72
	M2	53	---	1191	469	61	71	71
Zone 3 – Gatun Lake	M11	56[10]/66[11]	---	---	102^	---	81	81
	M12	53	---	---	109^	---	81	81
Zone 4 – Gaillard Cut	M13	50	---	---	1614^	---	60	60
	M14	55	---	---	1083^	---	64	64
Zone 5 – Pacific Locks	M5	48	---	---	379	---	73	73
	M6	61	---	---	447	---	72	72
	M7	67[12]/73[13]	---	---	615	---	69	69
	M8	64	---	---	797	---	66	66
Zone 6 – Pacific Side	M3	57	4977	---	520^	52	70	70
	M4	62	2870	---	650	57	68	68
	M9	53	2293	---	2045	59	58	62
	M10	60	1851	---	1780	60	59	63
	M15	67	1590	---	---	62	---	62

Source: Task Order #30. PB Consult, 2006.

9 Refers to the highest measured noise level.
10 Noise level without the train passing through.
11 Noise level with the train passing through.
12 Noise level without the train passing through.
13 Noise level with the train passing through.

Due to the lack of local regulations covering noise produced by construction activities, the assessment of the impact of these noise levels was based on one of the generally accepted criteria in the United States, which is the use of a maximum limit of 75 dBA Leq (hourly) as a reference point, or else a daytime background noise level not exceeding 15 dBA[14].

Considering the above criteria and according to the results shown in Table 7-8, it can be seen that in receptors M11 and M12, corresponding to the receptors in Gamboa – Zone 3 (Gatun Lake), which in turn are the sites closest to the work areas, expected levels will exceed the 75 dBA criterion (see yellow shaded data).

With respect to the results obtained for sites M1, M2 and M5 (see light-blue shaded data), the first two corresponding to Jose Dominador Bazan (Davis) – Zone 2 (Gatun Locks) and the last to Paraiso – Zone 5 (Pacific Locks), estimates indicate that the 15 dBA criterion above the environmental baseline will be exceeded at these sites, according to the baseline levels obtained when taking measurements, and their proximity to the work sites.

To summarize the foregoing, the following sites can be considered critical in regard to noise:

- Zone 2 – Gatun Locks – Receptors in Jose Dominador Bazan.
- Zone 3 – Gatun Lake – Receptors in Gamboa.
- Zone 5 – Pacific Locks – Receptors in Paraiso.

Other sites of concern with respect to noise, are the communities of Pedro Miguel (Zone 5), and Diablo and La Boca (Zone 6), although they do not meet yet the assessment criteria previously defined, but do have high values due to baseline and/or simulated noise levels,.

It must be mentioned that those sites were identified based on the simulation conducted by PB Consult (2006) and a series of assumptions which include the amount and type of equipment that would be used by contractors. In this context, it will be important to include in the

[14] Task Order #30. PB Consult, 2006.

Environmental Management Plan (EMP) a recommendation to assess the occurrence of the noise at other potential critical sites during the construction phase, beginning with construction activities currently under way, including blasting.

In addition to the noise sources evaluated above, ground blasting could constitute another source, as the noise level generated can vary highly depending on the blasting charge and the characteristics of the material or soil, among other considerations. In terms of noise, impact from the levels generated by this activity is different from that of conventional construction equipment, in that it occurs sporadically over short time-spans of 2 or 3 seconds.

Generation of vibration could occur during the construction phase due to the use of ground and subaquatic blasting around the sites where these activities are performed, and should not exceed the peak particle velocity (PPV) criteria of 0.5 in/s established by the ACP. Vibration could also come from the movement of equipment or heavy vehicles to or from construction areas, and from the operating properties of some equipment, mainly that used for the removal of existing structures.

Vibrations from earthmoving could affect the buildings and occupants in the neighborhood of a construction site, or the personnel that operates the equipment and/or machinery that generates the vibrations. In regard to work equipment and power tools, these are designed to minimize vibrations transmitted to the operators and carry specific instructions as to the personal protective gear and/or operating restrictions that must be observed. Due to the distance between the construction sites and communities close to the works, this potential impact is considered to be of a low magnitude.

The intensity of the vibration perceived at a specific distance from a blasting site depends on factors such as: 1) the total charge released per individual delay, 2) the distance between the detonator and the point of interest, 3) the soil characteristics, and 4) the degree of blast confinement.

The Category II Environmental Impact Study of the Panama Canal Pacific Entrance Channel Widening and Deepening Project submitted to ANAM for consideration provides a detailed discussion on the subject of vibrations associated with the use of blasting and the effects on structures and people. According to estimates made by that study based on blasting vibration data in the area of La Boca between 2005 and 2006, the critical PPV level of 0.5 in/s was not exceeded at the receptors closest to the blasting sites, a condition that could continue if charges and delay times remain similar to those indicated in said study.

On the whole, the impact generated from the increase in noise and vibration levels due to construction activities is considered negative and direct. Its probability of occurrence is inevitable and it is considered to have a very quick development and a medium magnitude. With respect to its duration, the increase generated during the construction phase is only expected to last for this phase. Nevertheless, due to the fact that the construction work will take place over a period of 7-8 years, this impact is rated as long lasting. It is not considered to be cumulative or synergistic. Taking into account the foregoing, the impact has a medium level of significance (**-5.74**).

Operations phase

With regard to noise and vibrations during the operations phase, it is considered that both factors will be similar to baseline conditions since the same type of activities would be implemented as have been carried out to this date (ship lockage and routine maintenance work), and the increase in those activities would not generate significant effects on current conditions.

Yearly changes between the actual and expanded canal imply that by 2020, there will be 650 additional transits (+1.7 per day), and by 2025, an expected 1,243 additional transits (+3.4 per day). This increase should not have any significant effect on current noise levels as it is almost imperceptible as to transit frequency. The increase in vessel size and engine power is not considered significant either, as even for Post-Panamax ships with 30% higher engine power, the expected increase of 1–2 dBA in coastal receptors would be practically imperceptible to the human ear[15].

Given the foregoing, the impact is rated as negative and direct with an inevitable probability of occurrence. It will develop very quickly but with a low magnitude, and its duration will be permanent as it will occur while as long as the Canal is operating. However, it is not considered cumulative or synergistic. According to this assessment, it has a low level of (**-2.60**).

7.3.5 Increase in Odor Perception

In the course of the environmental baseline survey it was determined that, within the study area, potential sources of odor emission were not associated with the operation activities currently carried out by the ACP, but rather to third party activities performed in populated areas surrounding the Panama Canal with poor management of industrial processes such as: animal husbandry and processing (hog and poultry farms), fish and shrimp processing, and the handling of solid and liquid wastes. Nevertheless, workers and residents close to the area might be bothered by odors, because different kinds of work will be performed in the construction phase which will involve the use of explosives that will emit gases during blasting and in addition, the constant movement of heavy equipment will produce combustion gases. It is important to study the possible effects from these activities.

It is worth mentioning that these activities will be performed by ACP personnel and contractors who must comply with all mitigation requirements, regulatory compliance, and international procedures required for the implementation of these works. Lastly, it is anticipated that the large demand of work that will be performed and the flow of workers involved will generate liquid and solid waste that could produce emissions of bothersome odors if not managed properly.

[15] ACP, 2007. Clarifications regarding the Category II Pacific Entrance Widening and Deepening Environmental Impact Study.

The results of odor intensity readings taken in the areas covered by this EIS determined that perceived odors are mostly associated with the community and industrial activities developed in the various communities adjoining the operation areas of the Canal rather than upon the Canal's own operations.

Construction Phase

The implementation of the proposed Project will require different kinds of work such as: 1) mobilization and construction of temporary and support facilities (including offices, workshops, aggregate plants and docks), 2) borrow materials and production of aggregates, 3) construction of temporary and permanent access roads, 4) excavation and backfills, 5) blasting, 6) slope and cut stabilization, and 7) preparation and management of disposal sites, etc. These works will require the constant operation of heavy equipment and will generate solid and liquid waste, specifically in the construction phase.

Due to the characteristics of the work to be performed, which will require constant movement of equipment along the Project footprint and the use of a considerable amount of heavy equipment during the construction phase, gas emissions will be produced and introduced into the atmosphere, specifically combustion gases as by-products of incomplete vehicle fuel combustion. The main gases produced by incomplete combustion are nitrogen oxides (NO_x), hydrocarbons (HC), and carbon monoxide (CO). High concentrations of these gases have a characteristic penetrating odor that could affect the health of the workers and the quality of work performed.

Blasting work using explosives may also produce gases with some degree of toxicity that could affect the workers involved in these operations. For this Project, the ACP has assumed the use of an explosive (WRS), made up of 75% emulsion and 25% gel.

Moreover, a large amount of solid and liquid waste will be generated during the construction phase as a result of the multiple activities involved in the implementation of the project. Accumulation of this waste and its mismanagement can produce the releases of gases that can be bothersome to workers close to the area.

The analysis show that this impact is negative, direct, of probable occurrence, with a very fast development or time to produce a disturbance, of low magnitude, with a similar duration to the construction period, and is not considered a cumulative or synergistic impact. After weighing all these attributes and ranking the level of significance, it is accorded a low significance rating (**-1.96**).

Operations phase

During the operations phase, the impact would be generated by maintenance activities on navigation and approach channels involving excavation, cutting, and dredging work, among others, that will require the operation of equipment and heavy machinery. However, these are expected to be on a lower scale and of reduced volume than what is required during the construction. Accordingly, the impact generated is considered negative, direct, of probable occurrence, with a very fast development or time to produce a disturbance, of a very low magnitude and permanent duration, and not expected to be cumulative or synergistic. In view of the foregoing, this impact is rated a low significance level (**-1.56**).

7.3.6 Undermining - Cave-ins

Undermining - cave-in phenomena are associated with potential alterations of the local geological and/or hydrogeological features of the area due to excavation and backfilling activities, which in the first case may influence hydrogeological conditions and cause stress release in the soil and rocky massif, and in the second case may involve the introduction of external stress (as a result of backfilling). Those changes to the local geology in certain areas of the Project, mainly those in which excavations and backfills cross or are close to fault zones, may cause landslides and/or soil settlement. In fact, during the course of excavation and backfill work, an important complementary activity consists precisely of controlling the deformation and formation of excavation and backfill slopes so as to avoid the occurrence of these undermining – cave-in phenomena or settlement by applying appropriate excavation and backfill formation techniques and geotechnical measures such as compaction, drainage control, cut and backfill slope stabilization, etc. Notwithstanding the low probability of this kind of impact, the following evaluation shows the conditions observed and possible implications during the construction and operations phases of the Project, in terms of a probable induction or activation of fault zone movements.

Construction Phase

The implementation of the proposed Pacific Locks Project includes excavation of the channel and construction of Borinquen dikes with components E1, E2, W1 and W2. Geological faults traversing the areas of the new channel and/or dikes have been identified. It was specifically determined that the Pedro Miguel, Miraflores, and Aguadulce faults, along with other minor faults, traverse the Pacific Side area. The faults intersect the layout of the Canal at the points shown on Table 7-9.

Table 7-9
Location of Geological Faults and Characteristics of the Pacific Locks

Approximate location within the Canal	Contact between Formations		Characteristics
	Symbols	Names	
PK 2+000	Tpa – Tpa	Pedro Miguel	Fine to coarse-grained agglomerates
PK 2+600	Tpa – Tl	Pedro Miguel and La Boca	Pedro Miguel: Fine to coarse-grained agglomerates La Boca: Clayey shale, lutite, sandstone, tuff, and limestone
PK 5+100	Tb – Tb	Basalt	Intrusive and extrusive basalt
PK 5+600	Tb – Tb	Basalt	Intrusive and extrusive basalt
PK 6+400	Tl – Tl	La Boca	Clayey shale, lutite, sandstone, tuff and limestone
PK 6+450	Tl – Tl	La Boca	Clayey shale, lutite, sandstone, tuff, and limestone

Source: URS Holdings, Inc.

It is considered unlikely that when excavating the new channel, changes in soil overload or in soil hydrogeology, or the dikes construction will bring about movements in these faults. Nevertheless, these possible effects can be taken into account during the design and construction of the works.

There were no potential geological changes in the channel (access and navigation) or locks areas identified for the Atlantic Side. No cave-in risk is therefore considered to exist. In turn, fault intersections have been identified in the Barro Colorado Island Natural Monument zone in the Gatun Lake area. However, the proposed works will not have a significant effect on the distribution of the overloading in the area. Likewise, they will not have any effect on the hydrogeology of the zone given the existing flooding of the Project area. Finally, there are several minor nameless fault intersections in the Gaillard Cut sector. This is considered a geologically stable zone. It is unlikely that the effect of changes in the overloading produced by the construction works will affect the geology.

Accordingly, the analysis performed on this impact considers it to be negative, direct, with a low probability of occurrence, and a slow development. In addition, it has a low magnitude and short duration as it will not continue once the movement occurs due to changes in overloading or release of stress in excavation areas since there will be no further changes in overloading or release of stress. This impact is not considered to have cumulative or synergistic effects. Upon evaluation of these attributes, the impact is rated at a very low significance level (**-0.15**).

Operations phase

Effects on possible fault activity and occurrence of undermining and/or cave-in phenomena are expected to be more significant during the construction phase. Once soil settlement has occurred due to changes in overloading or hydrogeology, it is unlikely that additional changes will arise from operation activities.

This impact can be characterized as negative and direct, since changes in overloading will occur directly on the fault areas, although its occurrence is considered unlikely. If there are effects, they will probably be slow, of a very low magnitude and a short duration. The result of the evaluation of these attributes is a very low significance level (**-0.12**).

7.3.7 Increase in Landslide Risk

As established in the Environmental Baseline, the occurrence of landslides associated with the construction and operation of the Panama Canal has been of considerable magnitude. The occurrence of landslides in the Project region is attributable mainly to soil, subsoil and geological formation instability, and the rainfall regime. Landslides present a potential risk to navigation and the safety of personnel in sites adjacent to the less stable areas of the Panama Canal. The Environmental Baseline shows the Gaillard Cut and the Pacific regions as those with the highest occurrence of landslides. The following are the specific sites identified in the Environmental Baseline with the highest susceptibility to landslides:

- Gold Hill
- Southern Extension of Cucaracha
- Northeast of Gaillard Cut
- South of La Pita
- Model Slope
- Borinquen: 1997 Landslide
- East Culebra Landslide
- West Culebra Landslide
- Purple Rock Landslide

The potential increase in the occurrence and magnitude of landslides has been properly identified by the Panama Canal Authority since widening work was started in Gaillard Cut in 1999. Given the appropriate documentation of the evident landslide risk to the Canal's operation, the Expansion Project includes the completion of slope stabilization work as an important component both of the construction management plan as well as subsequently,` during maintenance.

The Panama Canal Authority has identified a clear correlation between construction processes (channel widening and deepening) and landslide activity, mainly in Gaillard Cut. According to the ACP Geotechnical Division, the increase in landslides attributable to the widening of the navigation channel has been quantified. To prevent any actual adverse effects on the navigation channel, stabilization work has been carried out generating about 14.3 million cubic meters (See Figure 7-1).

In summary, the increase in the magnitude and frequency of landslides in the Direct Impact Area of the Panama Canal Expansion Project will be higher in sites of demonstrated instability such as Gaillard Cut, the adjacent southern section up to Cucaracha and the section north of Miraflores Locks. The total impact attributable to the increase in landslides during the construction phase of the Panama Canal Expansion Project should be direct, inevitable, of a fast development, high magnitude, and long duration. On the other hand, the occurrence of landslides will have a moderate cumulative effect, as it will contribute to an increase in sedimentation of the navigation channel and of suspended solids in the water, mainly in the Gaillard Cut area. While it is not considered to have a synergistic effect, its significance level is high (**-7.50**).

Operations phase

Following the implementation of early detection protocols and the Environmental Management Plan along with applicable construction measures, the impact in the operations phase of the Project is expected to be negative, direct, of probable occurrence, with a medium development and magnitude, of long duration, and with a non-synergistic, moderate cumulative effect. Thus, the impact has a low significance level (**-2.88**).

7.3.8 Increase in Soil Erosion

The process of hydric erosion is normally determined by parameters associated with precipitation characteristics (erosivity), soil physiochemical properties (erodibility), slopes (gradient and length), and soil protection (type of cover and management practices) (e.g., see Foster, et al., 1997). Accordingly, the analysis of the possible effect of the Project on soil erosion considered the diversity of activities during the construction and operations of the Project and their potential effects on the hydric erosion process in each specific area.

The spatial variability of hydric erosion within an area is mainly determined by variations in ground slope. In other words, areas with steep slopes (greater than 25%) will experience higher levels of hydric erosion. In the construction areas of the new locks and their approach channels, in the Pacific as well as the Atlantic, topography is fairly flat and areas with slopes above 25% within the DIA are on the order of 28% on the Pacific Side and 23% on the Atlantic Side. It has also been considered that major changes (introduced through Project activities) to the variables that determine hydric erosion will have an impact on vegetative cover and management practices, as vegetation must be removed before earthmoving begins. To a lesser degree, slopes in excavation and fill areas will also be modified, in gradient as well as length.

Construction Phase

Of the activities described previously as required during the construction phase of the Project, those considered to have potential effects on soil erosion include the following:

- Cleaning, stripping, and leveling of construction areas;
- Construction of docks;
- Construction of the Borinquen dikes;
- Excavation of the locks footprint and water saving basins;
- Excavation of the lock access channels;
- Installation of aggregate crushing plants and concrete plants;

- Construction of permanent roads and access roads for heavy equipment;
- Installation of sewage treatment plants;
- Backfill work;
- Construction of storage areas and yards for heavy equipment;
- Construction of offices and lockers;
- Stabilization of adjacent land;
- Deepening of the Gaillard Cut navigation channels; and
- Disposal of excavated and dredged material at designated sites.

It is important to point out that the soil will only be exposed to the erosion process for short periods of time while the construction of ancillary structures is under way and excavation progresses. Upon completion of the construction of the ancillary installations, the areas outside the buildings will be converted to green spaces. Likewise, the excavation process for the locks and water saving basins will be undertaken and the excavated material taken directly to disposal sites, thereby minimizing losses due to hydric erosion.

Project works may have a negative impact on soil by causing losses due to hydric erosion during the rainy season. The increase in erosion levels will be greater in sites where work is performed on gradients greater than 25%. At these sites, losses due to hydric erosion are estimated at 70 tons per hectare per year in an area accounting for about 28% (791 ha) of the Direct Impact Area on the Pacific Side and Gaillard Cut (Zones 4, 5 and 6). On the Atlantic Side, mainly in the Atlantic Locks Zone (Zone 2), there are areas with gradients over 15% due to higher precipitation levels, which add up to 196 hectares. Losses due to hydric erosion in this sector are estimated at 77 tons per hectare per year.

Taking account that the current erosion reported for the Environmental Baseline is approximately 15 tons per hectare (section 4.10.4 Environmental Baseline), increased soil losses due to hydric erosion are estimated at 43,505 tons per year on the Pacific Side (including Gaillard Cut) and 12,152 tons per year on the Atlantic Side, provided all areas are intervened simultaneously. Nevertheless, area interventions for contractor areas, diversion of rivers and excavation of channels will begin in year one, while excavation of the locks and water saving basins will not begin until year two. It has also been considered that after the areas have been intervened and stripped, they will only be exposed to an erosion period for a year, as constructions will be completed or soil will be removed from intervened areas during that time. Therefore, and considering that Project activities will be implemented gradually, the overall estimate of erosion has been distributed over the first three years with an average value of 14,502 tons per year on the Pacific Side and 4,051 tons per year on the Atlantic Side.

After the first three-year period, the hydric erosion process should be under control as the construction of the contractor's installations and access roads will have been completed by then and all surface soil removed from the excavation areas. Nevertheless, the magnitude of losses due to erosion in these sites calls for the implementation of the soil conservation measures recommended in the Environmental Management Plan.

In summary, within the Direct Impact Area of the Panama Canal Expansion Project the increase in losses due to hydric erosion will be greater during the rainy season in earthmoving sites with steeper gradients, located mainly in the Pacific Locks area. The total attributable impact resulting from soil erosion due to the Panama Canal Expansion Project during the construction phase will be negative, direct and inevitable, of a very fast development, medium magnitude and permanent duration if corrective measures are not taken, and with a high cumulative and synergistic effect on sedimentation and water quality. Its estimated significance rating is high (**-6.3**).

Operations phase

In turn, during the operations phase of the Third Set of Locks, some activities have also been identified that could affect the intensity of the hydric erosion process, with the following being the most relevant:

- Road maintenance;
- Slope stabilization;
- Maintenance and stabilization of lock approach channels; and
- Management of dredged material disposal sites.

By applying the soil conservation measures contained in the Environmental Management Plan, erosion levels are expected to return to baseline values estimated at around 20-25 tons per hectare per year on the Pacific Side, and 15-20 tons per year on the Atlantic Side. There will always be a slight increase in erosion levels, associated mainly with maintenance activities.

In the operations phase of the Project, upon implementation of the soil conservation measures recommended in the Environmental Management Plan as part of the Project construction, the impact is expected to be negative, direct, of probable occurrence, of medium development and duration, low magnitude, with a moderate cumulative and synergistic effect on sedimentation and water contamination, and a low significance level (**-1.45**).

7.3.9 Increased Sedimentation

The impact analysis of the Panama Canal Expansion Project construction in regard to increased sedimentation began by evaluating the diversity of the civil works associated with the Project, the risk of erosion and its possible effect on the process of the sediments transported through the fluvial network. The sources of sediment are the soil erosion process, discussed above, in which the increase resulting from the Project activities is estimated at 18,370 tons per year during the construction phase, and the disposal of dredged material at sea and lake sites.

The destination of sediment discharged in coastal waters depends mainly on geostrophic currents, currents generated by wind and tides, the operating patterns of the deposits, and properties of the sediment. To predict the path and dispersion of these materials, mathematical simulation models are highly valuable tools as they enable determination of possible impact paths and areas specific discharges can generate under different environmental conditions.

Oceanographic conditions in the zone play an important role in determining the destination of discharges. Factors such as turbulence, density gradients, and velocity differences in the water column have an influence on the initial dispersion and subsequent transportation of materials in the water column, and their deposit on the marine bottom. Simulation models of suspended solids and sedimentation rates for the proposed targeted aquatic sites were developed to simulate the behavior of solid materials and their potential effect on biological communities and other marine and lake resources.

To achieve the objectives of this study, two simulation models were used that fit the physical characteristics of each discharge area. The HydroTrack model was used for the marine disposal sites, and for Gatun Lake disposal sites, the STFATE (Riada Engineering, Inc., 2007) model was used. The simulations and results are discussed in sections 7.3.14 (Deterioration of Water Quality), 7.4.9 (Alteration of Aquatic Resources in Gatun Lake), and 7.4.1 (Alteration of Marine Coastal Ecosystems). A complete description of the models, simulation processes, and results are included in Annex 5. This section will mainly discuss the Project activities that contribute to an increase in sediment levels in the hydrographic network due to the above described soil erosion process.

It must be taken into account that only a fraction of the total eroded soil material ends up as sediment loads in the beds of rivers and creeks, and finally in reservoirs or oceans. This percentage is known as the Yield Factor, which depending on the morphologic characteristics of the watershed and proximity of the eroded sites to the drainage network, can vary from 20% to 50% (Strahler, 1988).

Construction Phase

As explained in section 4.10.4 of the chapter on the physical baseline of this EIS, the estimated erosion rate in the Gatun Lake watershed is 197.46 ton/ha/year. Even by using a high value Yield Factor (50%), the estimated volume of sediments generated during the construction phase accounts for only a small fraction (less than 1%) of the material transported each year through the hydrographic network of Gatun Lake. During the operations phase this value is insignificant.

The effect of the increased generation of sediments will be greater in sites close to the drainage network or in close proximity to the navigation channels. It is estimated that the input of sediment originating in direct influence areas during the rainy season can increase by up to 30%. However, its effect is highly localized and quickly dilutes upon reaching major water bodies.

In summary, the increase in the sediment load in the Direct Impact Area of the Panama Canal Expansion Project is expected to be higher during the rainy season in the earth movement sites with steeper gradients which are located mainly in the Pacific Locks area and Gaillard Cut. The total impact attributable to the increase in sedimentation due to the Panama Canal Expansion Project in the construction phase will be of a very probable occurrence, of a low magnitude, and medium development and duration, and with a moderate cumulative and synergistic effect on water quality, resulting in a low significance level (**-2.93**).

Operations phase

In the operations phase of the Project, with the soil conservation measures recommended in the Environmental Management Plan having been implemented as part of the project construction, the impact on sedimentation is expected to be negative, direct, of probable occurrence, with a medium development and duration, of a low magnitude and moderate cumulative and synergistic effect on water quality, resulting in a low significance level (**-1.30**).

7.3.10 Soil Compaction

Several activities can cause soil compaction directly or indirectly. Soil compaction will be produced directly when using earthmoving equipment and every time equipment and machinery will be moved along the traffic routes used during the construction of the Panama Canal Expansion Project. Soil is also compacted when excavated or dredged material is deposited on the surface. In the first case, soil compaction impacts are localized in the area of the operation and transportation of machinery and equipment, which is the situation discussed in this section. The resulting impacts are of a permanent nature, since compacting of the porous space makes it be very difficult for the soil to return to its unaltered condition. This does not occur in constructed areas, and at material disposal areas, the process is slow.

Vegetation removal can also induce soil compaction: as its content of organic material is reduced, its apparent density increases and infiltration velocity diminishes. The effect on infiltration is analyzed together with the drainage pattern.

In general, any soil compaction caused in the Direct Impact Area of the Project will be determined by the following factors:

- Type of existing soil, mainly its texture and porosity;
- Soil humidity content at the time of earthmoving; and
- Type and frequency of extraction and earthmoving equipment use.

Construction Phase

The activities described in the Panama Canal Expansion Project for the Pacific Side, which produce an increase in soil compaction, include the following:

- Construction docks ;
- Construction of the Borinquen dikes;

- Excavation work for the locks footprint and water saving basins, including concrete works;
- Installation of aggregate crushing plants and concrete plants;
- Construction of permanent roads and access roads for heavy equipment;
- Installation of sewage treatment plants;
- Backfill work;
- Construction of storage areas and yards for heavy equipment;
- Construction of offices and lockers;
- Stabilization of adjacent land;
- Widening of navigation channels,
- Excavation of access channels; and
- Disposal of excavated and dredged material.

The Project footprint area on land comprises a total of 1,957.65 hectares, in which soil compaction phenomenon will occur to a greater or lesser extent. Most of this surface corresponds to excavated or dredged material disposal sites. Most of the designated sites for the disposal of excavated or dredged material have been used historically as disposal sites by the Panama Canal Authority. The material that will be added during the construction phase of the Project will cause further compaction. The aforementioned works will have a negative impact on the soil by producing an additional permanent compaction of the surface soil. Impact levels will be greater under the high humidity conditions typical of the rainy season.

The designated disposal sites on the Pacific Side are Velasquez, Cocoli, Victoria, Farfan, Rousseau, and T6. After site T6 has been cleaned up, materials will be deposited in an area identified as contaminated with explosives left by U.S. Army shooting ranges, which might be seen as a remediation of this condition that would significantly limit its potential usage. Disposal sites on the Atlantic Side are located to the East as well as to the west of the navigation channels at the sites designated as Tanque Negro ("Black Tank") and Mindi, which will be used for the disposal of dirt, and dredged and excavated material from the surface of land that will then be reshaped and leveled with earthmoving equipment. Likewise, dredged and excavated material from the deepening of the navigation channel along Gaillard Cut will be deposited on the sites identified as T2, T3, T4, T5 and T6 mentioned above.

In summary, the increase in soil compaction in the Direct Impact Area of the Panama Canal Expansion Project will be greater in construction, excavation and material disposal sites. The total impact attributable to the increase in soil compaction due to the Panama Canal Expansion Project in the construction phase will be negative, direct, highly probable, of long duration and fast development, and of a low magnitude. It is not considered to have cumulative or synergistic effects. The total resulting significance rating will be low (**-3.04**)

Operations phase

The only activity in the operations phase of the Project with some potential for soil compaction is associated with the operation of dredged and excavated material disposal sites resulting from maintenance activities. If the mitigation and remediation recommendations of the Environmental Management Plan are followed, soil compaction should be minimal, negative, of probable occurrence, of a slow development, very low magnitude and permanent duration. It is not considered to have cumulative or synergistic effects, and consequently has a low significance level (**-1.14**).

7.3.11 Soil Pollution

The risk of soil contamination occurring in the Direct Impact Area of the Project will be mostly determined by the following factors:

- Accidental spills of oil, grease, lubricants, and other chemicals associated with the operation and transportation of machinery and equipment in construction areas;
- Ground blasting for construction at sites containing basaltic-type igneous rocks and quarrying;
- Discharge of soil, sediment, and excavated and dredged material at disposal sites.

Construction Phase

Soil contamination occurs when there are accidental spills of oil, fuel, grease and other chemicals associated with the operation and maintenance of excavation and earthmoving machinery and equipment, and every time the latter are moved along traffic routes during the construction of the Project.

Another potential source of soil contamination is the disposal of dredged material on the surface of disposal sites. This material comes from very different geological sources. The study made by PB Consult for the Panama Canal Authority on the characterization of existing sediments, reported concentrations of pesticides, PCBs, PHAs, and Tributyl tin below the recommended limits. Therefore, their impact will depend on a suitable management and not on their composition. The presence of barium found in sediments is typical of the geological characteristics on the bottom of the Canal. In summary, no special measures are required for managing the sediments that will be dredged.

Lastly, any required blasting for quarrying and excavation purposes at sites with basaltic-type igneous rocks can become an additional source of soil contamination. Even controlled blasting can provide small quantities of chemical pollutants (nitroglycerin mixes) in the materials that will be deposited at designated disposal sites. This effect is highly localized and of low magnitude; nevertheless, it is an effect that must be determined in order to identify future sources of potential pollution.

In summary, the increase in soil pollution in the Direct Impact Area of the Panama Canal Expansion Project is expected to be greater in the construction, excavation, and disposal of excavated or dredged material along the Project. The total impact attributable to the increase in soil pollution due to the Panama Canal Expansion Project construction phase will be negative and direct, of probable occurrence, of a medium development, low magnitude, and permanent duration if corrective measures are not taken. It is not expected to have cumulative or synergistic effects and its significance level should be low (**-1.27**).

Operations phase

During the operations phase of the Panama Canal Expansion Project, activities that could potentially cause soil pollution are related to the operation and maintenance of the machinery and equipment required for the maintenance of the installations and mostly for dredging activities. However, if the mitigation and remediation recommendations of the Environmental Management Plan are followed, soil pollution is expected to be very little and of a very low magnitude.

With regard to its significance, the impact is expected to be negative, of probable occurrence at maintenance work sites and disposal sites of excavated and dredged material from the maintenance of the navigation channels, of a slow development, very low magnitude, without cumulative or synergistic effects, and at a low significance level (**-1.18**).

7.3.12 Decrease in Land Use Capability

The land use for most of the Direct Impact Areas contemplated in the Project has been designated as for the operation of the Panama Canal. In the construction areas of the new locks, land use at both ends (Pacific and Atlantic), is related to the land use plan of the ACP and the Regional Plan for the Development of the Interoceanic Region.

Construction Phase

Changes in land use capability in the Panama Canal Expansion Project are associated with the interrelation between different construction activities that affect soil properties such as erosion, compaction, contamination, and water holding capacity.

The following are included among construction activities that affect land use capability at sites that have not been previously disturbed by the operation and maintenance activities of the Panama Canal:

- Cleaning, stripping, and leveling of construction areas;
- Excavation work for the locks footprint and water saving basins;
- Installation of aggregate crushing plants and concrete plants;
- Construction of permanent roads and access roads for heavy equipment;
- Installation of sewage treatment plants;
- Backfill work;
- Construction of storage areas and yards for heavy equipment;
- Construction of offices and lockers;
- Construction of permanent works; and
- Disposal of excavated or dredged material.

Any reduction in land use capability will only be relevant at sites with forest cover. These areas occupy approximately 470 hectares (Table 7-21).

The total impact attributable to the reduction in land use capability due to the Panama Canal Expansion Project construction phase would be highly probable, of a fast development and medium magnitude. Its duration would be permanent and cumulative or synergistic effects are not expected. The significance rating is low, and estimated at **-2.16**.

Operations Phase

No impacts on land use capability are expected in the operations phase of the Project.

7.3.13 Deterioration of Water Quality

Water resources refer to superficial and underground waters that might be impacted by the activities carried out during the construction and operations phases of the Third Set of Locks. The following are the most relevant activities due to their potential to affect water quality: 1) dredging; 2) excavation; 3) disposal of dredged material in the water (marine and lake); 4) disposal of dredged material on land; 5) disposal of excavated material in the water (marine and lake); 6) disposal of excavated material on land; 7) diversion of the Cocoli and Rio Grande (Southern branch) Rivers, and 8) construction of hydraulic works, as well as the operation of offices, work shops, and field facilities, exploitation of borrow areas, and the operation of concrete and aggregate crushing plants.

Most of these activities, except for the diversion of Cocoli and Rio Grande (Southern branch) Rivers and activity number 8, will also be carried out during the operation of the Third Set of Locks but to a lesser degree. Moreover, these activities have been performed since the start of the Canal operations as part of the maintenance activities and improvements to Canal infrastructures.

Construction Phase

The quality of surface waters will be affected during the construction phase by the eight activities listed in the above matrix. Water quality can be characterized by different physical, chemical, biochemical, and bacteriological parameters. For these types of activities, the total suspended solids (turbidity) was the parameter selected to assess the change in water quality: i) turbidity, which is influenced by suspended solids; and, ii) heavy metals in sediments released into the water at the time of their removal or disposal. The following descriptions show the manner Project activities will affect turbidity and heavy metal content during the construction.

1) Dredging

It has been estimated that 50 million cubic meters will be dredged to complete the new navigation channels for the construction of the new locks. The change in water quality (total suspended solids and other physical and chemical parameters) will depend on the type and productivity of the dredge, and of type of material to be removed. In turn, the type of dredge depends on the type of material to be removed.

The chapter that describes the Project description mentioned that dredging work in basaltic and dacitic areas would require the use of the drill barges Thor and Baru, followed by blasting to allow a hydraulic backhoe dredge and dipper dredge Rialto M. Christensen (RMC) to extract the fragmented rock. In areas with soft to medium hard rock, such as found in La Boca and Panama formations, it will be necessary to use cutter suction dredges, while other sections would require the use of the suction hopper dredge to remove recent and slightly consolidated sediments. The effects on the surrounding water quality (suspended solids) will vary depending on the type of dredges and material to be dredged.

Hydraulic backhoe dredges and the hopper dredge Rialto M. Christensen (RMC) will be used to extract rocky spoils that have fragmented due to drilling or blasting. Locations with very hard or large rocky material are first drilled and then broken up using explosives with heat insulation. These fragmented rocks are loaded on barges that transport them to previously established disposal sites. These activities will result in increased turbidity due to suspended solids, although the bulk will be fragmented rocks.

Cutter suction dredges will be used to extract medium hard rocks, soft rocks, and gravel. Due to the type of material that will be extracted (looser), water turbidity will be greater than that generated by the above mentioned RMC dredge. Finally, hopper dredges will suck clay and sand (muck, sediment), a process that will increase water turbidity even further, compared to what is generated by the aforementioned types of dredges (RMC and cutter suction).

Turbidity is generated at the time of cutting, suctioning, and depositing the material on the hopper (hydraulic) dredge. These actions release sediments into the water column, forming a sediment plume. The plume may consist of two types: dynamic or passive (PB Consult, 2007). In the case of a dynamic plume, muddy water creates its own flow which moves according to the overall physical properties of the sediment, and normally the plume density carries them very rapidly downward to the bottom (lake or marine bed).

A passive plume, unlike a dynamic plume, is formed where sediment discharges are strongly admixed with the surrounding water. In this situation, muddy water loses its identity as a separate water mass and particles will sediment according to their own weight. Therefore, a passive plume requires more time to sediment and has a wider dispersion than a dynamic plume due to dilution and the surrounding water currents. Both plumes also arise under a single dredging process. On one hand, dynamic plumes carry most of the muddy water directly to the bottom and, on the other hand, secondary and passive plumes remain visible for a long period while only containing a small fraction of fine sediment.

A passive plume may have an influence over an area of several square kilometers, depending on the magnitude and direction of the currents as well as the nature of the sediment (PB Consult, 2007). Plume formation and reaccumulation can lead to impacts on the physical quality of water mainly as a result of dispersion of the passive plume. Passive plumes influence a wider surface area in the dredging work performed on the Atlantic Side as well as on the Pacific Side, where currents are much stronger than in Gatun Lake.

In the course of the dredging process, a fraction of sediments circulates around the dredge and returns to the bottom after a while. Table 7-10 shows relevant data on losses resulting from dredging cohesive sediments (mud). Losses are shown in terms of the "S-Factor", which is the amount of kilograms per m^3 of dredged spoils. These data can be joined with the productivity forecast for the Canal dredging including some basic assumptions on the dimensions of the plumes, for the purpose of providing simple estimates of the "order of magnitude" of suspended sediment concentrations (above reference levels) which could persist in the passive plume generated by the dredge (operating 24 hours a day).

Table 7-10

Sediment Loss Typical of Dredging Processes

	Material Spill	Production	Discharge	Passive Plume (mg/l)	
TYPE OF DREDGE	**S FACTOR (kg/m^3)**	**(m^3/hr)**	**(Losses t/hr)**	**Plume A**	**Plume B**
Trailing Suction Hopper (limited overflow)	15	655	9.82		5
Trailing Suction Hopper (without overflow)	7	655	4.58		3
Cutter Suction	6	357	2.14	14	
Cutter Suction (reduced oscillation and rotation speeds)	3	357	1.07	7	
Backhoe (without mud screen)	15	119	1.79	12	
Backhoe (with mud screen)	7	119	0.83	6	

Source: EIS Category II – Panama Canal Pacific Entrance Channel Widening and Deepening. ACP, 2007. Made by PB Consult.

The last column in Table 7-10 shows the suspended solid concentrations in two passive plumes (ACP / PB Consult, 2007): Plume A has a water depth of 10 m, a plume width of 30 m and an average current speed of 0.1 m/s; and Plume B has a similar depth and width as Plume A, but a dredging speed of 3 knots. It is also assumed that the passive plume for both plumes contains 10% of the discharge.

The volume of dredged and excavated material throughout the years, from 1950 to the present, is about half of what will be produced during the construction of the Third Set of Locks (60 million m^3). However, dredging activities during that period have not had any permanent effect on water quality, which has been rated good by the large number of studies conducted on water quality in the Canal watershed. The results of water quality studies, especially those made by Gonzalez, *et al*. (1975) and the ACP (2006), and others including Zaret (1984), Heckadon-Moreno, *et al*.1999a and 1999b, TLBG/TYLI 2001a and 2001b, Simmons, *et al*. 2002, CATEC 2003, and CEREBUP 2003, conclude that the water quality is good, with isolated variations influenced by seasonality in rainfall and the proximity of populated areas. It is thereby concluded that despite the volume of material that has been dredged and discharged in the water throughout the years, the quality of the water is suitable. Furthermore, CEREBUP (2003) concludes that even though Gatun Lake "is an artificial system that has undergone several modifications in almost 100 years, the water quality is excellent."

The level of suspended solids in Gatun Lake varies depending on the location of the sampling site and season of the year. The west side of the Lake is always clearer due to its depth (as wave action prevents the suspension of fine sediment from the lake bed). To the East, waters are muddier as they are shallower but also as a result of permanent ship traffic and dredge work. During the dry season, the contrast between the deep waters of the Lake and the navigation channel is much more pronounced. The range of suspended solid values in the Lake is around 1-78 mg/l (Panama Canal Master Plan, ACP, 2006).

Gonzalez, *et al*. (1975) mentioned by ACP / PB Consult (2007), indicated that the waters of the Bay of Panama remain constantly muddy and the lowest Secchi values (<3 m, maximum turbidity) always occur in the area of Balboa and the approach channel to the locks; more variable conditions occur towards open waters (Secchi visibility of up to 7 m). In a study completed by the University of Panama in 1993-1994, values of suspended solids and Secchi depth were recorded that confirmed a relationship between Secchi depth and the content of suspended solids. Both variables show a seasonal variation; turbidity and the content of solids are lower in the middle of the dry season.

Natural processes, water releases from the Canal, and marine activity maintain a constantly muddy water plume in the Canal entrance zone, where the level of suspended solids appears to remain at concentrations fluctuating between 10 and 30 mg/l. This fluctuation may be considered as "typical reference levels", against which the impacts from dredging operations and the depositing of material (ACP / PB Consult 2007) can be evaluated.

Data taken from Gatun Lake in 2004/2005[16] reflect that the operation of the cutter suction dredge Mindi (when dredging clay close to Barro Colorado Island) produced a persistent plume with concentrations of about 25-40 mg/l (ACP / PB Consult, 2007). Accordingly, expected concentrations of suspended solids due to dredging during the construction phase will be twice the reference values in the worst-case scenario. Moreover, suspended solids will remain at that value range as dredging will be continuous.

The characterization of sediments to be dredged is relevant to determine the clay, muck, sand, and gravel content, inasmuch as the effect on turbidity will depend on their corresponding percentages; the greater the amount of fine sediment, the greater the turbidity. In 2006, sediments from the Canal bottom in a section of the Pacific Side were characterized (16 samples). PB Consult (2007) indicated that 50.4% of the weight was clay (particles smaller than 2 μm), 29.2% mud (from 63 to 2 μm), 15.8% sand (from 2 mm to 63 μm), and the remaining 4.6% gravel (> than 2 mm). Therefore, sediments on the Pacific Side contain a high percentage of clay. Another reported aspect was that once placed in motion, the sediment types found in the Bay (sludge with some fine sand) will move as suspended mud, dispersing through the water column and reaccumulating on the ocean floor in areas and momenta of reduced aquatic energy. ACP / PB Consult (2007) concluded that it is probable that currents found in the Bay may be important in terms of dispersion of sediments placed in motion, rather than being the cause of erosion.

The main findings of the sediment characterization report show the following (PB Consult, 2006):

- ✓ The analyses of sediment particle sizes confirm the existence of a predominantly muddy and fine sand environment, consistent with the lack of strong currents.
- ✓ Concentrations of trace metals in sediments in the Canal are mostly related to natural diffuse sources. Some concentrations of metals occur locally, but not at levels requiring the implementation of strict corrective dredging practices.

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16 ACP ESMPAC water quality monitoring data. See diagram in Parsons Brinkerhoff Dredging Working Paper June 2006.

- ✓ PCB concentration levels found in sediments were extremely low.
- ✓ Concentrations of pesticides were found in most of the sediment samples, but were mostly of a low level.
- ✓ Different polycyclic aromatic hydrocarbons were found in Canal sediments, especially in the Port of Balboa, though at low levels.
- ✓ Tributyl tin was found in low to moderate concentrations in samples collected within ship anchorage areas.

The PB Consult report (2006) concludes that "in general, if dredging is performed properly, taking suitable measures to check for suspended sediment plumes, the chemical concentrations identified in sediments will not cause harmful effects."

2) Excavation

Earth movement to construct the new access channels to the locks has been estimated at 83 million m^3. If control measures (barriers, filter screens, slope stabilization, etc.) are not implemented in the course of the excavation process, particularly during intense rainfall, runoff will carry solids into the Canal, deteriorating its water quality as well as contributing to siltation.

Ground excavation has been carried out in the area since the construction of the Canal. Recent Canal widening work in the Gaillard Cut section and Cartagena Hill required major cuts of material. As previously mentioned, the effect of the cuts on water quality is especially evident during precipitation and runoff processes. Excavation will be made in the Pacific as well as the Atlantic area, but volumes will be greater in the former. Nonetheless, when comparing the effects on water quality from ground excavation with dredging, the first are minimal.

3) Disposal of dredged material in the water

Dredged material will be deposited in areas of both the Atlantic and Pacific Oceans (marine disposal), as well as Gatun Lake (lacustrine disposal). Backhoe dredges and self-propelled or towed barges typically sail to the disposal site, where the hull (bottom) of the vessel is opened. Other equipment dispose of material in different ways; some vessels split in two, while others have hull-mounted discharge pipes. Coarse material (fragmented rock) is discharged in this manner. Low density viscous materials (basically sand suspended in water or sediments) are preferably deposited on land.

In the course of disposing dredged material in the water, particles will be dispersed that will affect the quality of the water. In 2005, ACP took water samples from eight sampling locations (surface, mid-depth, and bottom) at the disposal site for dredged material located at the entrances to the Canal on the Pacific Side and 1 km to the south, southwest, west and east (in a circle), to determine the suspended sediments (TSS), as well as turbidity, conductivity, and salinity. Field measurements were taken of pH, temperature, conductivity, salinity, turbidity, and total dissolved solids. The area was previously overflown in order to visually identify the direction of dispersed sediment (they could barely be seen at 0.4 miles of the discharge site), and to select the sampling sites. The results showed that:

- ✓ Turbidity: At a distance of 1 kilometer away in all directions, turbidity decreased notably, and the highest concentrations were reported on the bottom. After 30 minutes and at 500 meters to the south of the site there was a decrease from 34.2 NTU, 41.8 NTU, and 109.9 NTU, at the surface, mid-depth, and bottom of the discharge site to 0.5 NTU, 0.1 NTU, and 21.6 NTU, respectively.
- ✓ Total Suspended Solids: Concentrations of total suspended solids decrease in a south-southwesterly direction after disposal. Minor concentrations were reported eastward, 120 minutes after discharge.

To evaluate the specific effect of the disposal of dredged and excavated material in the marine and Lake disposal sites, two simulation models were used that fit the physical characteristics of each discharge site. The model was used for marine disposal sites, and the STFATE model for Gatun Lake, both described below (URS Holdings, Inc. - Riada Engineering, Inc., 2007).

- **HydroTrack Simulation Model**

The HydroTrack mathematical model used for the disposal sites on the Atlantic and Pacific Sides (Rodriguez & Garcia, 1998) simulates the discharge and path of sediments dredged from water bodies.

This model determines the velocity field due to winds and tides through a numerical solution in finite differences for flow equations with two-dimensional free surface (Garcia & Kahawita, 1986; Uribe & Garcia, 1986; Garcia, 1993b, Rodriguez & Garcia, 1998). To that end, the generation of a mesh was required made up of calculation cells completely covering the study zone. The model calculates temporary variations of velocity and elevation of the water surface in each calculation cell.

Borderline conditions are the tide elevations in the open contours, and zero flow conditions are the ground contours limiting the study zone. The model also requires data on wind velocities, bathymetry and bottom friction coefficients.

- **STFATE Model**

Disposal sites in Gatun Lake have different hydrodynamic conditions than those located on the Pacific and Atlantic Ocean coasts. At this location, geostrophic currents and tides do not exert influence on lacustrine currents as these are determined by a combination of navigation actions within the Lake, hydric input, losses through the locks, and wind action, the effect of which is the production of waves, giving rise in turn to a reflection of these waves on the Lake banks.

Accordingly, it was decided to perform the simulation of sites belonging to the Lake using the STFATE model (Short-Term FATE of dredged material disposal in open water) (Johnson et al., 1994), developed by the U.S. Army Corps of Engineers based on the DIFID model (Disposal From an Instantaneous Discharge) originally developed by Koh and Chang, 1973. STFATE is a coupled model based on the hydrodynamics of the location, sediment transportation, and bathymetric changes, and is used to estimate the short term response of the sediments in the area close to the discharge, after their disposal from a barge or hopper into a body of water, whether dispersive or non-dispersive.

The model simulates the disposal process by dividing it into three phases:

- Convective descent, during which the cloud of material drops under the influence of gravity and its initial momentum is due to gravity;
- Dynamic collapse, which occurs when upon descent, the cloud has two possible outcomes: impacting against the bottom or reaching a neutral flotation level where descent is delayed and horizontal dispersion dominates; and
- Passive diffusion transport, when transport of material and diffusion is dominated by the hydrodynamics at the disposal site.

The results obtained for the marine and Lake disposal sites will be discussed further on in this section.

For the purposes of disposal into both oceans, the least favorable scenario assumes a discharge of material with a 100% sediment concentration using a hopper barge making three daily trips to the disposal site. The maximum daily volume was estimated at 3,220 m^3 distributed in 3 trips (1,073.33 m^3 per trip) every 4 hours, assuming an operating day of about 12 hours. To allow the model to estimate long-term effects, runs were made at each site with continuous discharges until attaining a dynamic equilibrium of the sedimentation and turbidity plume induced by the discharge of solid material. That equilibrium point was obtained after approximately 120 hours, and the sedimentation and turbidity cloud established at that point was considered indicative of conditions expected to prevail over the long-term operation.

On the Atlantic Side, the main circulation patterns exerting an influence on hydrodynamics are governed by the interaction effects from tides, geostrophic currents and winds. The operation of the locks and discharge flows constitute an important influence on the hydrodynamics of Limon Bay. Wind conditions coming from the NNW have an influence on the displacement of waters moving predominantly in a west-east direction, producing velocity field vectors in a direction more parallel to the coast than the fields generated from NNE wind conditions. NNW wind conditions will produce a more widespread impact area over the coastal zone and the plume of solids generated as a result of suspension phenomena.

Bathymetric data used to determine ocean depths are available in the Nautical Charts and listed below:

Table 7-11

Bathymetric Data – Atlantic Side Simulation

Drawing No.	Description	Scale	System of Coordinates	Drawing Date
26068	Panama Canal Port of Cristobal	1:15000	WGS-84	Dec 30, 2000
3111	Atlantic Entrance to the Panama Canal including adjacent ports	1:15000	WGS-84	Jun 06, 2002
1400	Outside approaches to the Port of Cristobal	1:75000	WGS-84	Jun 01, 2000

Source: Study on the Dispersion and Deposition of Sediments Dredged from Zones of Interest of the Panama Canal. URS Holdings, Inc. - Riada Engineering, Inc., 2007.

The study zone is located between coordinates N:1034100, E:611000 and N:1059000, E:643100, and it covers the entire exit area of the Panama Canal toward the Atlantic Ocean, with depths from 0 to 60 m (Figure 2, in Annex 5). The calculation mesh (Figure 3, in Annex 5) encompasses the entire zone from the breakwater at the Panama Canal exit to the Atlantic Ocean to the entrance of Portobelo Bay to the east. Cells measure 200 m by 200 m, and the disposal point is located at coordinates N:1037315, E: 616646.

The granulometric distribution of discharged solids was obtained through measurement and sampling field work carried out on the Atlantic Side as part of a sediment characterization study made for the Panama Canal Authority[17], that is, using data obtained for soft sediments that were located to determine their physical and chemical characterization. The average percentages of particle sizes used for the Atlantic Ocean show a predominant content of fine particles (mud and clay). The following table reflects the mean properties of solids in this area considered for our discharge volume.

Table 7-12
Mean Properties of Solids – Atlantic Side Simulation

Atlantic	Gravel (%)	Sand (%)	Mud (%)	Clay (%)
	1.6	30.2	44.1	24.1

Source: Task Order #31. Sediment Characterization Studies. Final Report. PB Consult, 2006.

For the purposes of the study corresponding to the disposal of dredged material in the Breakwater sector in the Atlantic Ocean, the maximum concentrations in the area after 5 days of continuous discharge fluctuate by about 90 mg/l. The sedimentation area covers 1.20 km^2, comprised mostly of sedimentation with a thickness of a few millimeters. The plume of suspended solids moves eastward due to current action, arriving with low concentrations (2 mg/l) at the coast to the east of the Panama Canal exit (URS Holdings, Inc. - Riada Engineering, Inc., 2007).

The average particle sizes used for simulating solids discharges in the Pacific Side show a predominant content of fine particles (mud and clay) (PB Consult, 2006). The following table reflects the average properties of solids on this Side, that were considered as discharge material at disposal sites of the Pacific Ocean.

Table 7-13

Mean Properties of Solids – Pacific Side Disposal Site Simulation

Pacific	**Gravel (%)**	**Sand (%)**	**Silt (%)**	**Clay (%)**
	46	15.8	29.2	50.4

Source: Task Order #31. Sediment Characterization Studies. Final Report. PB Consult, 2006.

17 Task Order #31. Sediment Characterization Studies. Final Report. PB Consult, 2006.

In Panama Bay, hydrodynamics depend on three types of currents: tides with elevations of approximately 5 m wide) Figure 33, Annex 5; the sea current known as Colombia ocean current from the south, moving parallel to the coast; and the winds, with a magnitude in the zone described as moderate to soft[18]. The prevailing winds come from the north, with an occurrence of 55%; winds from southwest have an occurrence of 25%. The dominant northern winds show mean magnitudes of 4 m/s[19] at the site.

The bathymetric data used to determine ocean depths are available on the following nautical charts:

Table 7-14

Bathymetric Data – Pacific Side Simulation

Drawing No.	Description	Scale	System of Coordinates	Drawing Date
21605	Gulf of Panama to Piñas Bay	1:20000	WGS-84	July 29, 1995
21601	Gulf of Panama Morro de Puercos to Panama	1:20000	WGS-84	June 17, 1995
1401	Southern Approach to the Panama Canal	1:30000	WGS-84	March 13, 2003

Source: Study of the Dispersion and Deposition of Dredged Sediment in Panama Canal Zones of Interest. URS Holdings, Inc., Riada Engineering, Inc., 2007.

The study area is located between coordinates N:951000, E:637000, and N:993000, E:695000. It covers the entire area of the Panama Canal exit to the Pacific Ocean, showing depths between 0 and 40 m (Figure 34, Annex 5). A calculation mesh with cell sizes similar to those of the Atlantic Ocean (Figure 35, Annex 5), was made to run the model.

ACP / PB Consult (2007) evaluated the potential effects of depositing dredge material at the three Pacific disposal sites, i.e., Palo Seco, Tortolita, and Tortolita South. Palo Seco is a very

18 "Hydrodynamic Impact Assessment." Report A – Punta Pacifica, Panama. Delft Hydraulics. April 1999.

19 "Environmental Evaluation of Options for the Construction of the New Locks and Deepening of the Atlantic and Pacific Entrances of the Panama Canal – SAA-117484." Final Report, New Atlantic Side Locks. The Louis Berger Group, Inc. May 2004.

shallow disposal site (0 to 5 m under the MLWS), where the wave action tends to be an effective agent in the erosion of fine sediment during a great part of the year[20]. Tortolita is a disposal site with very variable depths (5 to 10 m under the MLWS). In the more shallow part of the area, the wave action is an effective undermining agent during certain times of the year, and in the deeper parts, sediments are much more stable. Tortolita Sur is a site where depths vary between 10 and 14 m under the MLWS. The site has received much volume of dredged material during the history of the Canal, and there is a low mound forming on its bed.

In the case of the study of the deposits of dredged material at the Palo Seco area in the Pacific Ocean, the maximum concentrations in the area obtained after five days of continuous discharges are approximately 2,100 mg/l with maximum sediment thicknesses of 1,000 mm and mean deposition rates of 200 mm/d. The sedimentation area is 1.20 km^2 and shows mostly very small sediment thicknesses in the order of a few millimeters. At this site, depths are quite low, which obstructs sediment dispersion; as a consequence, concentrations are more than the other disposal sites (URS Holdings, Inc. – Riada Engineering, Inc., 2007).

From the point of view of sediment transportation, if the 0.434Mm^3 of dredged material planned for deposit at Palo Seco were to disperse in a uniform layer over the bed of the site, it would be raised 0.8m (ACP /PB Consult 2007). Despite the fact that it would create a small elevation in the bed level, a new discharge (if it were to be mainly of fine gravel, sand, and silt) would become unstable under extreme conditions at the site and, as years go by, the deposited material could move to deeper water or to other adjacent areas. This would cause a gradual local elevation of sediment levels on the ocean bed and benthic instability during the transition period that may probably last several years before a profile equilibrium is restored (ACP /PB Consult 2007).

In the case of the Tortolita area on the Pacific Ocean, the maximum concentrations resulting from the disposal of dredged material are approximately 144 mg/l, with maximum sediment

[20] Jaime Rodriguez, ACP Survey Dept. *Pers comm..;* taken from PB Consult 2007.

thicknesses of 820 mm, and mean deposition rates of 150 mm/d. The sedimentation area is 2.90 km^2 with very slight thicknesses in the order of a few millimeters (URS Holdings, Inc. – Riada Engineering, Inc., 2007). If the 2.428 Mm^3 of dredged material that will be deposited at the Tortolita site, mainly muck and sand from the outside of the banks of the approach channel, were to spread uniformly at the site, this load would raise the bed by 1.4 m. The quality of the water at the Tortolita site would be affected minimally by the discharge of the material.

On the other hand, if the 2.428 Mm^3 of dredged material that will be discharged at the Tortolita site, mainly muck and sand from the outside of the banks of the approach channel were to disperse uniformly at the site, this load would raise the bed by 1.4 m, although it would be much faster to concentrate the discharges at the deeper sections of the water (0.5 km^2) to prevent the waves from carrying the loose material back, because active plumes may form that could quickly take the spoils in the direction of the ocean floor. The quality of water at the Tortolita site would be affected minimally by the discharge of the material.

At the Tortolita disposal site, the maximum calculated concentrations from the disposal of dredged material are approximately 42 mg/l; the maximum sedimentation thicknesses are of 70 mm, and the mean deposition rates are 150 mm/d. The sedimentation area is of 2.20 km^2 with very slight sediment thicknesses in the order of a few millimeters (Riada Engineering, Inc., 2007). Therefore, if the 4.126 Mm^3 of loose material to be deposited at the Tortolita South site, mainly rock fragments with very little muck, sand, and gravel components from the rock blasting and backhoe dredging areas were to disperse uniformly at the site, this load would raise the bed by 4.3 m, reducing the depths between 6 and 10 m MLWS. As this material consists mainly of rock fragments, it is not probable that the prevailing wake flows and currents will be able to move it. Rock and sediment discharges at with Tortolita South will be done from hopper barges moved by tugboats. If this were done through a gate or slot in the bottom of the barge, the discharge of these materials would happen mainly as a density flow, with a quick transfer to the ocean floor. The Panama Canal Authority[21] has measured some of the concentrated suspended solids present around a hopper dredge that is discharging at the Tortolita Sur disposal site, and

[21] ACP 2005.

these measurements have confirmed that the impact on water quality is minimal. Consequently, it can be concluded that in the Pacific Ocean the plume of suspended solids is predominantly carried in a southeastern and southwestern direction, over a relatively wide area north of the Gulf of Panama, but in low concentrations.

The above paragraphs describe the effects on the quality of water when dredged material is discharged at the sites on both oceans. The magnitude of the potential impact, although high, will depend on the disposal site depth and the currents, although its effect on the quality of water will be temporary, since sooner or later solids will sediment, even taking into account that the dredging program will last several years.

Eight different aquatic disposal sites have been identified: four in Gatun Lake, three in the Pacific Side, and eight on the Atlantic Side. Dredged material has been discharged in Gatun and the marine disposal sites, except in Monte Lirio (a Gatun Lake site). The simulations and results for the four Gatun Lake disposal sites are described below.

The physical process simulated includes a daily discharge of 3,220 cubic meters in three events, each in four hour intervals per each site: Monte Lirio, Frijoles, Peña Blanca East, and Peña Blanca West. The model was run for a 24 hour period and in all cases it was established that after 24 hours, the final conditions were similar to the starting conditions (Riada Engineering, Inc., 2007). The conditions and results for each one of these sites are shown briefly below:

<u>Monte Lirio</u>

The location of the disposal site simulated for Monte Lirio is in the area north of Gatun Lake, bordering with solid ground to the north, with the railway embankment causeway to the north and east, with Juan Gallegos Island to the south, and with the Lake area next to the approach channel from the exit to the Atlantic Ocean to the west. The site has a surface of approximately 230 hectares, and is delimited by a polygon with the following approximate coordinates:

E: 623.111 N: 1.024.625

E: 624.084 N: 1.022.928

E: 625.117 N: 1.023.609

E: 624.139 N: 1.025.260

It is expected that this site will receive material from the dry excavation of the new Atlantic Post-Panamax locks, which defines the characteristics of the sediment to be simulated, i.e., its granulometric distribution and fine grain proportion of the mix. For this purpose, the results used were those from the samples taken for the measurement and sampling campaigns (PB Consult International, 2006) conducted by the Panama Canal Authority, taken at the designated sites or near the future excavation or dredging.

According to the above, the following mean granulometric distribution was defined for this study site:

Table 15

Mean Properties of Solids – Simulation of Monte Lirio Disposal Site in Gatun Lake

Mean Distribution	**Gravel (%)**	**Fine Sand (%)**	**Silt (%)**	**Clay (%)**
	1.6	30.2	44.1	24.1

Source: Task Order #31. Sediment Characterization Studies. Final Report. PB Consult, 2006.

Panama Canal Nautical Chart No. 3098 on a scale of 1:35.000, referred to World Geodetic System 1984 (WGS 84) Datum prepared according to U.S. Government charts between the years 1990 and 2000, and based on surveys made between 1985 and 1994, edited on October 3, 2002, was used to determine the geographic location of the site. The data on the bathymetry performed for this disposal site received from the Panama Canal Authority were included in the chart. Likewise, a mesh was set over this chart with 30 x 42 cells, 61 x 61 m each, as well as the site location at coordinates N:1 .024.355 and E:623.349 (Figure 118, Annex 5).

The discharge simulated for Monte Lirio produces a maximum instant concentration of 8,600 mg/l at 3 m deep, which is quickly reduced in such a way that after four hours, the maximum concentration is 12 mg/l. Thus, the cumulative effect of the second discharge occurring after four hours is insignificant (Figure 122, Annex 5). The turbidity cloud of 1.l8 hectares (Figure 120, Annex 5) moves with the current on a southeasterly direction and the ecosystem area influenced by suspended solid levels above 50 mg/l one hour after the discharge of solids. The figures in Annex 5 show how the area over 50 mg/l is drastically reduced by hour 2, and at hour 5, the maximum value is barely 12 mg/l. Then, at hour 5 hour and hour 9, the turbidity cloud is similar to that at hour 1, and at hour 12 the effect is again insignificant.

<u>Peña Blanca East</u>

The Peña Blanca East disposal site is located in the central zone of Gatun Lake, bordering to the north with Las Brujas Islands and Juan Gallegos Island, with Bohio Peninsula to the east, with Islas Brujas Islands to the west, and with Agua Clara Bay to the south. To the north it is surrounded by the Banana channel, to the east by Bohio Reach, and to the south, by Peña Blanca Reach. The site has an approximate surface of 464 hectares and is defined by a polygon with the following approximate coordinates:

E: 620.512 N: 1.027.630
E: 620.722 N: 1.017.594
E: 622.117 N: 1.017.967
E: 623.583 N: 1.017.212
E: 624.754 N: 1.017.437
E: 623.965 N: 1.015.473

It is expected that this site will receive material from the excavation and dredging of the Gaillard Cut Plug or the north section of the Pacific works, or of the Intermediate Plug of the Pacific works, the north approach channel of the Pacific works, and the deepening of Gaillard Cut, which defines the characteristics of the sediment for simulation, that is, the granulometric distribution and the proportion of fine grains in the mix. For this purpose, the data used were the results of the samples obtained during the measurement and sampling campaigns (PB Consult International, 2006) conducted by the Panama Canal Authority and taken at the designated sites or near the future excavation or dredging.

According to the above, the following mean granulometric distribution for this study site was defined:

Table 7-16

Mean Properties of Solids – Simulation of Peña Blanca East Disposal Site in Gatun Lake

Mean Distribution	**Gravel (%)**	**Fine Sand (%)**	**Silt (%)**	**Clay (%)**
	2.5	12	46	39.5

Source: Task Order #31. Sediment Characterization Studies. Final Report. PB Consult, 2006.

Panama Canal Nautical Chart No. 3098 on a scale of 1:35.000, referred to World Geodetic System 1984 (WGS 84) Datum prepared according to U.S. Government charts between the years 1990 and 2000, and based on surveys made between 1985 and 1994, edited on October 3, 2002, was used to determine the geographic location of the site. The data from the bathymetry performed by this disposal site received from the Panama Canal Authority were included in the Chart. Likewise, a mesh was set over this chart with 60 x 36 cells of 61 x 61 m each, as well as the site location at coordinates N:1.016.778 and E:622.386 (Figure 128, Annex 5).

The discharge simulated for Peña Blanca East produces a maximum instant concentration of 10,740 mg/l at 3 m deep, which is quickly reduced in such a way that after four hours, the maximum concentration is 47 mg/l. Therefore, the cumulative effect of the second discharge occurring after four hours is insignificant (Figure 132, Annex 5). The turbidity cloud moves with the current on a northeasterly direction, and the ecosystem area influenced by suspended solid levels above 50 mg/l one hour after the discharge of solids is of 1.7 hectares (Figure 120, Annex 5). The figures in Annex 5 show how the area over 50 mg/l is drastically reduced by hour

2, and at hour 4, the maximum value is barely 12 mg/l. Then, at hour 5 and hour 9, the turbidity cloud is similar to that at 1 hour, and at hour 12 the effect is again insignificant.

Peña Blanca West

The Peña Blanca West disposal site is located in the central zone of Gatun Lake, southeast of the Peña Blanca East disposal site, bordering with the latter to the north, on the east with the Barro Colorado, and to the east and south with solid ground. Bohio Reach and Peña Blanca Reach intersect at the north entrance of the Bay. The site has an approximate surface of 283 hectares and is defined by a polygon with the following approximate coordinates:

E: 622.902 N: 1.014.673
E: 622.816 N: 1.011.578
E: 623.963 N: 1.011.187
E: 623.579 N: 1.012.656
E: 624.184 N: 1.014.012

It is expected that this site will receive material from the same Peña Blanca East site, that is, from excavation and dredging of the Gaillard Cut Plug or the northern section of the Pacific works, or of the Intermediate Plug of the Pacific works, the northern approach channel of the Pacific works, and the deepening of Gaillard Cut, which defines the same characteristics of the sediment for simulation, as those for that site.

According to the above, the following mean granulometric distribution for this study site was defined as follows:

Table 7-17

Mean Properties of Solids – Simulation of Peña Blanca West Disposal Site in Gatun Lake

Mean Distribution	**Gravel (%)**	**Fine Sand (%)**	**Silt (%)**	**Clay (%)**
	2.5	12	46	39.5

Source: Task Order #31. Sediment Characterization Studies. Final Report. PB Consult, 2006.

Panama Canal Nautical Chart No. 3098 on a scale of 1:35.000, referred to World Geodetic System 1984 (WGS 84) Datum prepared according to U.S. Government charts between the years 1990 and 2000, and based on surveys made between 1985 and 1994, edited on October 3, 2002, was used to determine the geographic location of the site. The data from the bathymetry performed for this disposal site received from the Panama Canal Authority were included in the Chart. Likewise, a mesh was set over this chart with 41 x 78 cells of 30 x 61 m each, as well as the site location at coordinates N:1.013.280 and E:623.596 (Figure 128, Annex 5).

The discharge simulated for Peña Blanca West produces a maximum instant concentration of 23,300 mg/l at 3 m deep, which is quickly reduced in such a way that after four hours, the maximum concentration is 18 mg/l. However, due to the characteristics of the disposal site where the estimated velocities are of 0.015 m/s, and the closing produced by the bay, the sediment plume of the first discharge still remains at the original site, and this effect is overlapped by the second discharge (Figure 139, Annex 5). This situation is shown 5 hours after the first discharge, where a maximum concentration of 854 mg/l is shown for a depth of 6 m (Figure 143, Annex 5). It is observed that the mesh seems to be insufficient to simulate the distribution of sediment at the site, and makes an unreal cut of the image for placing it within the disposal site. What is certain is that the mesh cannot be extended beyond the limits selected due to the presence of firm ground, and the model does not have the ability to accumulate sedimented material along the outside of the banks simulating a wall. The variables used to simulate this scenario practically do not cause any movement of the plume, and it remains enclosed in the bay. The ecosystem area influenced by suspended solids above 50 mg/l one hour after the discharge of solids is of 5.2 hectares (Figure 140, Annex 5).

Frijoles

The Frijoles disposal site is located in Frijoles Bay in the southeastern section of Gatun Lake, and borders to the north and to the east with solid ground, to the west with Barro Colorado Island, and to the south with the navigation channel connecting Gamboa and Gaillard Cut. It is surrounded, on the west by Buena Vista Reach, and on the south by the connection of Tabernilla

Reach with Buena Vista Reach. The site has a surface of approximately 282 hectares and is defined by a polygon with the following coordinates:

E: 628.811 N: 1.013.201
E: 630.593 N: 1.014.688
E: 630.970 N: 1.017.967
E: 630.542 N: 1.014.183
E: 630.901 N: 1.012.655

It is expected that this site will receive material from the same sites as Peña Blanca West and East, that is, from the excavation and dredging at the Gaillard Cut Plug or north section on the Pacific Side, from the Intermediate Pacific Plug, from the northern approach channel on the Pacific, and from the deepening of Gaillard Cut, which has the same characteristics of the sediment to be simulated as those of such sites.

According to the above, the granulometric distribution is as follows:

Table 7-18

Mean Properties of Solids – Simulation of Frijoles Disposal Site in Gatun Lake

Mean Distribution	**Gravel (%)**	**Fine Sand (%)**	**Silt (%)**	**Clay (%)**
	2.5	12	46	39.5

Source: Task Order #31. Sediment Characterization Studies. Final Report. PB Consult, 2006.

Panama Canal Nautical Chart No. 3098 on a scale of 1:35.000, referred to World Geodetic System 1984 (WGS 84) Datum prepared according to U.S. Government charts between the years 1990 and 2000, and based on surveys made between 1985 and 1994, edited on October 3, 2002, was used to determine the geographic location of the site. The data from the bathymetry data performed for this disposal site received from the Panama Canal Authority were included in the

Chart. Likewise, a mesh was set over this chart with 31 x 36 cells of 60 x 61 m each, as well as the site location at coordinates N:1.014.195 and E:623.182 (Figure 128, Annex 5).

The discharge simulated for Frijoles produces a maximum instant concentration of 34,120 mg/l at 6 m deep, which is quickly reduced in such a way that after four hours, the maximum concentration is of 41 mg/l. However, due to the characteristics of the disposal site, where due to velocities estimated at 0.03 m/s and the closing produced by the bay, the sediment plume of the first discharge still remains at the original site, this effect is overlapped by the second discharge (Figure 149, Annex 5). This situation is shown 5 hours after the first discharge with a maximum concentration of 818 mg/l for a depth of 6 m (Figure 153, Annex 5). As in the case of the Peña Blanca West, the variables used to simulate this scenario practically do not cause the movement of the plume, which stays enclosed in the bay. The ecosystem area influenced by suspended solid levels above 50 mg/l one hour after the discharge of solids is of 2.7 hectares (Figure 150, Annex 5).

The above paragraphs describe the effects on the quality of the water when dredged material is deposited at the disposal sites on both oceans and in Gatun Lake. The magnitude of the potential impact, despite being high, will depend on the depth of the disposal site and the current despite the fact that its effect on the quality of the water will be temporary, as sooner or later the solids will sediment, even when taking into account that the dredging program will last several years.

Dredged material has been discharged previously at the Gatun and marine sites, with the exception of Monte Lirio (a site in Gatun Lake).

4) Discharge of dredged material on land

The disposal sites on land receive sediment through pipes. The pipes can only be used to transport low density viscous material (basically suspended sand in a large volume of water and sediment); therefore, they are not adequate for large rock fragments.

Control measures need to be applied at land disposal sites for dredged material (such as berms, sedimentation ditches, etc.) so that the effluent from the site will not carry a high concentration of solids. Were these transported into the Canal, they would deteriorate the quality of its waters, as well as contribute to its siltation. Due the characteristics, volume, and physical and chemical characteristics of the sediments (PB Consult 2007), it is estimated that the water that infiltrates will not affect the quality of underground water.

The magnitude of the potential impact is estimated as high, and its effect on the quality of water is considered temporary, as the solids will be retained. Dredged material disposal will go on for several years and will be done at 15 disposal sites, of which seven will be new ones and the remaining eight have been previously used. The depositing of dredged material on land has also been a common practice in channel maintenance work.

5) Aquatic disposal of excavated material

Despite depositing the material in low volumes and taking other measures, particles are dispersed that will negatively affect the quality of water. In general, the material from land cuts will be discharged on land. However, one part will be discharged in water. This material will consist mainly of rock fragments, and therefore, its effect on the quality of water will be less than if sediment were discharged.

The magnitude of the potential impact is estimated as medium, and its effect on the quality of water is considered temporary, since the solids will sediment, even when the discharge of the material goes on for several years.

The effects of disposing of excavated material in water at the Monte Lirio site, which will comply with the conditions mentioned above, were discussed previously as part of the section to the disposal of dredged material in water.

6) Deposit of excavated material on land

This is a usual activity in the rehabilitation of roads and other types of (urbanization) projects, where the excess material from earth movement is discharged at adequate sites. Differently from dredged material deposited on land, the excavated material does not contain water, and therefore solids will not be carried into receiving bodies. Nonetheless, if intense rain does fall during the discharge process, and no control measures are taken, the runoff will carry solids into the Canal or into its tributary streams, deteriorating their quality and silting them.

The magnitude of the potential impact is estimated as medium, and its effect on the water quality is considered temporary since the solids will be retained. Disposal will be done for several years, and at various disposal sites.

7) Diversion of Cocoli River and Rio Grande River (southern branch)

The diversion of Cocoli River, whose waters drain into Miraflores Lake at the present time, will be done by excavation an artificial channel until it discharges into the Pacific Ocean. The required earth movement may affect the quality of the water of the receiving body, as during excavation and the deposit of excess material, solids may be transported as a result of rainfall and runoff process, especially during the time of rains in the areas with the most slopes. The magnitude of the impact is considered as moderate and it is estimated that it can be controlled easily with the soil conservation measures suggested in the Environmental Management Plan.

With regard to the Rio Grande River (southern branch), it currently receives water from the Sierpe River, Conga Creek, and unnamed tributaries that drain into Miraflores Lake. The expansion of the T6 disposal site will result in the loss of the natural river channel (its southern branch) and its affluents. This river channel is smaller than the Cocoli River channel. The required earth movement could affect the quality of the water in the receiving body, because when dredged and excavated materials are disposed of at the T6 disposal site, solids could be transported due to the rainfall and runoff processes, especially during the rainy season in areas with the steeper slopes. However, it is considered that the effects of erosion can be controlled with terrace management, and this requires that the Panama Canal Authority prepare the appropriate drawings. The magnitude of the impact is considered moderate and it is estimated that it will be easily controlled with the soil conservation measures suggested in the Environmental Management Plan.

8) Construction of hydraulic works, office operation, work shops and field installations, exploitation of borrow banks, and operation of aggregate crushing and concrete plants

The impacts of the activities covered by this section on water resources are described below:

- ✓ Construction of hydraulic works (locks and water saving basins) will be done on land, which could affect the quality of the water of the receiving body if control measures are not applied during intense rainfall. The magnitude of the potential impact is estimated as medium, and its effect on the quality of water is considered temporary.
- ✓ If not treated, sewage from offices, work shops, field facilities (6,000 workers during the peak year and somewhat less during the rest of the seven years of construction), at least one on the Pacific Side and another one on the Atlantic Side and at work fronts, will deteriorate the water quality of the receiving bodies. The magnitude of the potential impact is estimated as low, and its effect on the water quality will be temporary.
- ✓ If hydrocarbon spills at work shops and work fronts areas are not prevented and controlled, they will also deteriorate the water quality of receiving bodies. The magnitude of the potential impact is considered low, its effect on the quality of water temporary, and its duration will be over the seven years of construction work at work shops and work fronts.
- ✓ According to Panama Canal Authority requirements, the Project requirements for aggregates to prepare concrete and for other uses such as select backfill will be covered with excavated materials, mainly on the Pacific Side. However, it is not ruled out that the contractors may find it more suitable to use aggregates provided by third parties or from authorized quarries. The magnitude of the potential impact on the quality of water is considered medium, its effect temporary and its eventual duration will be of seven years, although it will occur at various sites.

- ✓ If not treated, the fine aggregates produced during the crushing production process, as well as during the washing of the concrete plant equipment, will affect the quality of the water of the receiving body. The magnitude of the potential impact is considered low, its effect on the quality of the water is considered temporary, it will last throughout the seven years of construction, and will occur at various sites.

In summary, the magnitude of the potential impact is estimated to be high because of the volume of the material to be dredged; its effect on the quality of the water is considered temporary because the solids will sediment, and although the dredging and the depositing of material into the water will go on for several years, it will be done along the navigation channel (lineal). Also, the dredging and the depositing of material into the water from navigation channel maintenance has been a periodic activity, and the water quality data record shows that there has been no sustained increase in the concentration of solids due to these or other activities.

In synthesis, due to the factors mentioned above on turbidity (determined according to the suspension of solids) and trace metals as indicators of the rate of change in water quality, it is concluded that the impact on it will be negative, of a direct effect, and of a high probability of occurrence. The effect of the maximum disturbance will be very rapid and of a very high magnitude, and will have a long duration (throughout the construction period). On the other hand, it is considered that it will have very low cumulative effect and synergy, and therefore, it will be of a moderate significance (**-5.54b**).

Operations Phase

The Project activities that will generate impacts on the water quality during the operations phase will be almost the same as during the construction phase, but of much lower magnitude because they will be due to maintenance, and the dredged or excavation volumes will be quite less. Also, these are activities that are being performed since the Canal has been in operation. In addition, when the Third Set of Locks starts its operations, the fluctuation range of the level of Gatun Lake will increase. The major activities that have the potential to generate impacts during the operations are as follows:

1) Maintenance dredging;
2) Excavation (landslide prevention and slope maintenance);
3) Disposal of dredged material in water (marine, estuarine, and lake);
4) Disposal of the dredged material on land;
5) Disposal of the excavated material in estuarine and lake waters;
6) Disposal of the excavated material on land;
7) Fluctuation of the level of Gatun Lake; and
8) Operation of the Canal, which will include lockages, ship transits, and pier activities.

Of the activities listed above, the first six are similar but of less magnitude than those to be performed during the construction phase, and whose effect on water quality has already been discussed. Therefore, the description below covers only the effect on the quality of water due to the changes in the fluctuation of the level of water of Gatun Lake, and the operation of the Third Set of Locks.

a. Fluctuation in the level of the water of Gatun Lake

The operation of Canal with the Third Set of Locks and the increase in the current level of Gatun Lake will raise the current range of its fluctuation, which in turn may add solids from the Lake banks. The operating level of Gatun Lake is between 24.8 meters (81.5’) and 26.7 m (87.5’) PLD; the upper level is consistent with the peak of the rainy season and the lower level is consistent with the dry season; the historic record is 25 cm less, with 10 cm more at the operating level.

b. Operation of the Third Set of Locks

The water quality could be affected by the typical activities that take place at ports and navigation channels, and by the possible increase of chloride ions in the areas adjacent to the new Gatun locks. The transit of ships involves the risk of possible spills of hydrocarbon residues being that could be dragged into the Canal by rainfall or runoff, as well as the resuspension of sediment on the bottom of the navigation channel. The number of ships will not increase significantly, as what will happen is that the new ships that will transit the Canal will carry more cargo (more than twice as the present ones). Also, if not treated, the sewage will affect the quality of the receiving water body, which in this case will be the Canal. The risks described previously are potential ones, due to the fact that to date, the Panama Canal Authority has adequately managed rain water and sewage from its facilities, as well as controlled and prevented spills from ships during their transit of the Canal, which it will continue to do in the future.

Other aspects relative to the quality of the water of Gatun Lake during the operations phase are related to chloride concentrations in the water.

The studies that have been conducted (ACP, 206; URS, 2005; Delft Hydraulics 2005), show that, although its physical and chemical composition varies depending on the place it is evaluated, the quality of the water of Gatun Lake as an artificial lake is good to excellent. According to the Delft reports, the largest concentrations of chloride in the Lake have been measured in the areas adjacent to the locks (with salinity levels of <0.1 ppt throughout the year, and 0.2 ppt in the area immediately adjacent to the Gatun Lake during the dry season), which are well below the OMS standard for drinking water and the aquatic wildlife standards reported by URS (2005).

The possible increase of chloride ions in the areas adjacent to the new locks as a result of their operation is a matter of the utmost importance. The various studies made by the Panama Canal Authority about the potential increase in the chloride content of the waters of Gatun Lake as a result of the operation of the Third Set of Locks[22] show that it will not increase significantly.

[22] URS Holdings, Inc., January 2005. Technical Memorandum No. 8. Tropical Lake Ecology Assessment with Emphasis on Change in Salinity of Lakes, which makes an exhaustive review of the following studies, among others: "Salt Water Intrusion Analysis, Panama Canal Locks, Report F," by WL Delft Hydraulics, who conducted a simulation of the current and future operation of the locks, and attempted to forecast the level of salinity at different points of the Lake; Seattle District U.S. Army Corps of Engineers Lake Washington Salinity Control Measures – 1982; U.S. Army Engineer Waterways Experiment Station, Mixing of Salinity – Stratified Water by Pneumatic Barriers; and U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), Salinity Intrusion in the Panama Canal, February 2000.

Nonetheless, the most recent studies made have established a series of recommendations for the design of a program to monitor chloride ion concentrations in the Lake that may ensure and preserve the quality of water within the required levels for its use as a source of drinking water for the cities of Panama, Colon, and the population around the Lake.

As part of the studies commissioned by the Panama Canal Authority, Delft WL Hydraulics performed measurements of salinity and its variations at the marine ends of the lock entrances, upstream through the locks, and in Gatun Lake, to establish the existing conditions. Delft developed a numerical model and calibrated it against the field records obtained. This model was then extended to include the use of the proposed new locks and to simulate various vessel traffic scenarios. Delft also investigated the application of different measures to minimize the possible intrusion of chloride ions and evaluated their individual effectiveness and cost, and made recommendations to the Panama Canal Authority for their inclusion in the numerical models. The preferred mitigation measures were incorporated to the numerical models, and runs were made for the purpose of obtaining signs of the possibility of an increase in chloride ions in the direction of Gatun Lake and Miraflores Lake through the proposed and existing locks. The results of these investigations are contained in a series of reports prepared by Delft and submitted to the Panama Canal Authority.

The analyses made show that the salinity values reported by Delft for the Canal Expansion Project are below the limits established by international organizations with regard to chlorides and related parameters. These values were obtained for the maximum capacity of 12 lockages per day for 150,000 ton vessels. On the basis of this, it is concluded that the Panama Canal Expansion – Third Set of Locks Project, within the study horizon and even beyond it with the expanded Canal operating at its maximum capacity, will not affect the quality of the water of Gatun Lake.

Gatun Lake will preserve its condition of tropical fresh water with stable systems, and the water will remain within the standards for levels of quality the water appropriate for its filtration and consumption by the population.

In summary, it is estimated that the significance of the potential impact will be low due to the fact that the activities will be the same as those that are being performed at the present time, which have not shown to cause any relevant effect on the quality of the water, although the chloride concentration must be monitored due to the operation of the new locks and their water saving basins.

In view of all the above, the impact will be negative, direct, with a high probability of occurrence. The time the effect will take to reach the maximum disturbance will be very slow, the magnitude will be medium, and the duration will be permanent; there will be a very low accumulation and synergy. Therefore, the significance rate will be low (**-2.72).**

7.3.14 Alteration of Water Flow Regime

Construction Phase

The activities during the construction phase that could potentially alter the surface and/or ground water flow regime (affecting the infiltration and/or runoff rate) are: the deposit of excavation and dredging material on land, the diversion of the Cocoli and Rio Grande (South branch) rivers, the construction of the hydraulic works, office operations, work shops, and field facilities and quarrying.

a. Deposit of dredged material on land

When dredged material is deposited on land, the rate of rainfall infiltration drops due to the soil compaction, and runoff increases in proportion to the reduction in aquifer recharge. During the discharge process, part of the water contained in the dredged material will infiltrate the subsoil.

Heavy equipment mobilization activities during the preparation and movement of the pipes to be used to discharge material at the disposal sites on land will produce a slight compacting of the soils. Also, the ground at the disposal sites will be altered when the dredging material is discharged, and some of its physical characteristics may become altered by compacting, fragmenting, and deterioration. The potential soil erosion that may be expected during dredging material discharge activities at the disposal sites would be due to the fact that the new soil surfaces would be unprotected and could break up, thereby becoming more readily erodible due to the effect of wind and rain. The water table at these sites could stop oscillating and come to the surface after the material is discharged.

The development of the impact will be medium, the infiltration reduction rate will be permanent, and its magnitude will depend on the elevation and the area occupied by the material to be discharged.

b. Deposit of excavated material on land

Just like the previous activity, discharging the spoils material will reduce infiltration and, consequently, will increase runoff. Unlike the dredged material discharged on land, the excavated material does not contain water, and therefore, no water will infiltrate during the discharge process.

The development of the impact will be medium and of a permanent duration; its magnitude will depend on the height and the area the material to be discharged will occupy. As was previously pointed out, the dumping sites have been or are in use; therefore, the effect on the change in infiltration and/or runoff rate will be minimal.

c. Diversion of the Cocoli and Rio Grande (South branch) Rivers

The diversion of the Cocoli River will mean a change in the drainage pattern and, consequently, in the runoff. The development of the impact will be fast, of a permanent duration, and a medium magnitude.

The diversion of the Rio Grande River (South branch) will mean a change in the drainage pattern and, consequently, in the runoff. The development of the impact will be fast, of a permanent duration, and a medium magnitude.

d. Construction of hydraulic works, offices, work shops and field facilities, and quarrying

The impacts of the activities included under this section are described below:

- The imperviousness of the subsoil for the construction of hydraulic works (locks and reservoirs) will reduce the infiltration and affect runoff. The development of the impact will be slow, of a permanent duration, and a medium magnitude.
- The imperviousness of the subsoil due to the installation and operation of offices, work shops and field facilities will reduce infiltration. The development of the impact will be slow, the duration temporary, and the magnitude low.
- Quarrying will affect infiltration if no restoration measures are taken. The development of the impact will be slow, the duration permanent, and the magnitude low.

In summary, the impact will be negative, direct, and with a low occurrence probability. The time the effect will take to reach a maximum disturbance will be medium; likewise, the magnitude will be medium, although the duration will be permanent, and the accumulation and synergy will be very low. Therefore, the significance rate will be low (**-1.20**).

Operations Phase

The infiltration and/or runoff rate will be mainly affected by the following two activities during the operation of the Project: the deposit of the dredged material on land and water, and the fluctuation of the new water level of Gatun Lake. The manner in which the disposal of both the dredged and excavated material during the construction phase will affect the infiltration and/or runoff rates has been described above. In the operations phase, the volumes to be deposited will be considerably lower and, consequently, their effects will also be lower.

a. Deposit of dredged material on land

With dredged material is disposed of on land, although in lesser volumes than during the construction phase, the rainwater infiltration rate will drop, and the runoff will increase proportionally to the reduction in the aquifer recharge. During the deposit process, part of the water contained in the dredged material will infiltrate the subsoil. The development of the impact will be fast and the infiltration rate reduction will be permanent, although it will probably be happen at an existing disposal site, and its magnitude will be low.

b. Fluctuation of the Gatun Lake level

A result of the new maximum level of Gatun Lake will be a seasonal flooding of new areas. Currently, the maximum water surface of this lake covers a surface of approximately 45,000 hectares, and therefore the infiltration rate along its banks will increase. The development of the impact will be a medium one and its duration temporary due to the seasonal fluctuations of the Lake level; in general, the magnitude will be low.

In synthesis, the significance of the impacts on the infiltration and/or runoff rate due to the effect of the Project activities during the operations phase will be very low. The impact will be negative, direct, with a low occurrence probability; the time the effects will take to reach a maximum disturbance will be medium; the magnitude will be low despite a permanent duration; and the accumulation and synergy will be very low. Thus, its significance rate will be low **(-0.98).**

7.3.15 Alteration of Drainage Pattern

Construction Phase

In the construction phase, the activities that could potentially affect the drainage pattern will be the deposit of the dredged material on land, the deposit of the excavated material on land, the diversion of the Cocoli and Rio Grande (South branch) Rivers, the construction of hydraulic works, the operation of Contractor areas, and quarrying.

a. Deposit of dredged material on land

When dredged material is deposited on land, the morphometry of the disposal site is changed and, depending on the volume deposited, the drainage pattern of the microbasin is affected and, consequently, the runoff as well. As was previously mentioned, seven of the fifteen sites that will be used to deposit the dredged and excavated material on land are being or have been used previously as disposal sites. Therefore, the drainage pattern in these sites has already been altered.

Insofar as the disposal sites on land, if it is assumed that the material to be deposited on land is evenly distributed throughout the site, calculations can be made to determine how much their elevation will increase. Table 7-19 shows the increase in elevation of the Victoria (17), Velasquez (19) and Farfan (20) sites. Their retaining walls must be made higher in order to contain all the material and only let excess water out through an established outlet.

Table 7-19

Estimated Increase in the Elevation of Disposal Sites on Land

Disposal site	Volume (*Loose*)	Area	Elevation (Volume/Area)
Victoria	0.65 Mm^3	0.24 Km^2	2.75 m
Velasquez	2.012 Mm^3	0.85 Km^2	2.35 m
Farfan	1.309 Mm^3	1.45 Km^2	0.9 m

Source: Table 9-9 of the Category II EIS – Widening and Deepening of the Channel of the Pacific Entrance of the Panama Canal, PB Consult 2007.

At the disposal sites, the deposit of sediments from the Pacific zones will not cause a drastic change in the conditions of the existing surface because, as described in other studies, the Farfan and Velasquez Rivers and Victoria Creek contain brackish waters of poor quality due to their history (PB Consult 2007).

b. Deposit of the excavated material on land

Just like the above mentioned activity, the deposit of excavation material will affect the shape of the land and, consequently, the drainage pattern. The development of the impact will be fast, its duration will be permanent, and its magnitude low.

c. Diversion of the Cocoli and Grande (South branch) rivers

The diversion of the Cocoli River will bring about a change in the drainage pattern. The new course of the river is shown in Figure 3-14. It will pass between two disposal sites (Victoria and Rousseau) before discharging into the Pacific Ocean. This diversion involves the loss of approximately 1,300 m of the original riverbed, and the construction of a new riverbed of approximately 3,500 m. The development of the impact will be fast, its duration will be permanent, and its magnitude medium. It is considered as of a medium magnitude because the affected portion of the Cocoli River will be replaced with a new riverbed.

The diversion of the South branch of the Grande River and its tributaries will result in a change in the drainage pattern. The expansion of disposal site T6 will cause the modification of the Rio Grande River basin. During the use of disposal site T6, a careful control of the terracing will be necessary to control the effect of the runoff. Canalization of the Rio Grande River and its tributaries will be done to divert it toward Gaillard Cut. The development of the impact will be fast, its duration permanent, and its magnitude medium. The magnitude is considered medium because the affected portions of the Rio Grande River and its tributaries will be replaced with new channels, and because the course of the river has been previously affected to a greater degree (also, part of this river has been canalized). Consequently, the loss of this habitat is of a medium magnitude due to the fact the new channels will allow for the restoration of the habitat and for similar riverine extensions to remain within the basin.

d. Construction of hydraulic works

For the construction of the Pacific navigation channel and locks, it will be necessary to divert the Cocoli River once again, and this will affect the drainage pattern of its lower basin. This will require the release of water through the spillway, which is currently discharged south into

Miraflores Lake (and the Pacific Ocean). The development of the impact will be fast and of a permanent duration, and the magnitude will be medium.

In sum, the magnitude of the potential impact is estimated as a low one, since the same sites on land will be used to discharge the dredged and excavated material. Therefore, the effect on the drainage pattern will be minimal.

In view of the above, the impact on the drainage pattern as an effect of the Project construction work will be negative, direct, with a medium probability of occurrence. The time the effect will take to achieve its maximum disturbance will be medium; its magnitude medium albeit of a permanent duration, and the accumulation and synergy will be very low. Thus, its significance rating will be low (**-2.40**).

Operations Phase

The depositing of dredged or excavated material from channel maintenance and Canal improvement work will affect the drainage pattern. The previous section described how this will happen; therefore, during the operations phase the volumes to be deposited and the effects of same will be minor. Also, the dredged and excavated material disposal sites will be the same ones that are currently being used. There will only be an increase in the size of the area and in its elevation. The following is a description of the effects expected in the drainage pattern during the operations phase.

a. Deposit of dredged material on land

Depositing the dredged material on land will change the morphometry of the disposal site. The effect on the drainage pattern of the microbasin, and consequently, the runoff, will depend on the volume deposited. The development of the impact will be fast, of a permanent duration, and low in magnitude.

b. Deposit of excavated material on land

Just like the above activity, the deposit of spoils on land will affect the landscape. The development of the impact will be fast, of a permanent duration, and of a low magnitude.

In sum, given that the same sites will be used to deposit the excavated material on land, the impact on the drainage pattern as an effect of Project activities in the operations phase will be negative, direct, with a medium occurrence probability. The time the effect will take to reach its maximum disturbance will be medium, the magnitude will be low although of a permanent duration, and the accumulation and synergy will be very low. Therefore, its significance rating will be low (**-2.08**).

7.4 Impact on the Biological Environment

A total of twelve (12) types of potential impacts were identified that may affect the biological environment (flora, fauna, protected areas, and fragile ecosystems), all of a negative character. Of these impacts, all except the loss of forestry potential are present in both Project phases (construction and operation). The impacts during the construction would mostly be potential impacts of a negative character, located on the area of direct influence, but of a low intensity and temporary, because once the construction phase is completed the environment will revert to its original condition.

The impacts are determined by the activities that will take place during the construction and operations phases of the Project and by the conditions existing in the Direct Impact Area. Some of the impacts may occur in marine areas, others in civil works construction sites, and still others in rivers and lakes. The components of the affected areas according to the identified zones where these impacts will take place, and the breakdown of the impacts during the construction and operations phases are presented below.

7.4.1 Loss of Vegetative Cover

In order to determine the extent of any possible changes and loss of vegetative cover, the proportion of the various types of vegetative cover in the Direct Impact Area and the Project was estimated. This analysis considers the fact that in the Project footprint, the vegetative cover will be completely removed to make room for the locks, channels, disposal sites for excavated or dredged materials, the work areas required for Contractors, and subsequently, for the operation of the Project by the ACP. Although it is expected that the disposal areas will eventually acquire a secondary vegetation growth and an ecological succession, it may be said that in the short run, they will also be devoid of their vegetative cover.

Construction Phase

a. Clearing, Grubbing, and Stripping

Due to the specific type of impact, the loss of vegetative cover will occur mainly during the construction phase, when it will become necessary to make space for the structures associated with the Project. Generally, the loss of vegetation is associated with the existing vegetation and the surface required by the temporary and permanent Project structures.

As may be seen in Table 7-20, the land surface of the Direct Impact Area covers a total of 3,202.8 hectares, covered mainly by pasture and grassland (54%), secondary forests (26.9%), underbrush and stubble (10.9%), and urban use (5.1%).

Table 7-20

Surface by Type of Cover in the Direct Impact Area (Ha)

	ZONE 1		ZONE 2		ZONE 3		ZONE 4		ZONE 5		ZONE 6		TOTAL	
CATEGORY	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**
Urban Use Areas	1.6	0.64	28.10	5.95	1.3	10.74	26.2	3.07	51.6	4.54	55.9	11.76	164.7	5.1
Mature Secondary Forests					4.1	33.88	7.7	0.90	15.2	1.34		0.00	27.0	0.8
Intermediate Secondary Forests	76	30.19	190.30	40.32			159.4	18.66	250.7	22.05	161.1	33.88	837.5	26.1
Mangrove									13.3	1.17	24.8	5.22	38.1	1.2
Underbrush and Stubble	50.8	20.18	7.50	1.59	0.8	6.61	86.8	10.16	93.4	8.21	111	23.34	350.3	10.9
Pasture and Grassland	122.3	48.59	242.20	51.31	4.3	35.54	524.3	61.36	712.7	62.68	122.7	25.80	1728.5	54.0
Soil without Vegetation	1	0.40	3.90	0.83	1.6	13.22	50	5.85	0.2	0.02		0.00	56.7	1.8
TOTAL	**251.7**	100	**472.00**	100	**12.1**	**100**	**854.4**	**100**	**1137.1**	**100**	**475.5**	100.00	**3202.8**	100.0

Source: URS Holdings, Inc. from ACP Remote Sensors Unit data. 2005

Of those 3,202.8 hectares of land, the ground surface occupied by the Project footprint as such is 1,957.65 hectares, covered mostly by pasture and grassland (58.11%), intermediate secondary forest (23.33%), and underbrush and stubble (12.16%). The rest are urban use areas (3.59%), ground without vegetation (1.08%), and only 0.71% is covered by mature secondary forest (Table 7-21).

Table 7-21

Areas by Category of Cover Directly Affected by the Project Footprint (Ha)

Total Footprint	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5		Zone 6		Total	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Urban Use Areas	0.00	0.00	4.28	1.62	1.21	20.35	3.72	0.99	60.99	6.43	0.00	0.00	70.21	3.59
Mature Secondary Forests	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.09	13.55	1.43	0.00	0.00	13.88	0.71
Intermediate Secondary Forests	52.02	25.40	81.93	30.89	4.12	69.02	81.83	21.74	192.24	20.25	44.56	28.54	456.69	23.33
Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.32	1.40	6.67	4.27	19.99	1.02
Underbrush and stubble	48.40	23.64	4.82	1.82	0.28	4.71	54.57	14.49	76.56	8.07	53.40	34.20	238.03	12.16
Pasture and Grassland	104.34	50.96	174.11	65.65	0.35	5.92	214.86	57.07	592.47	62.42	51.48	32.98	1137.62	58.11
Ground without Vegetation	0.00	0.00	0.07	0.03	0.00	0.00	21.16	5.62	0.00	0.00	0.00	0.00	21.23	1.08
TOTAL	**204.76**	**100.0**	**265.22**	**100.0**	**5.96**	**100.0**	**376.46**	**100.0**	**949.14**	**100.0**	**156.11**	**100.0**	**1957.65**	**100.0**

Source: URS Holdings, Inc. from ACP Remote Sensors Unit data. 2005

From this table it may be deduced that, in total, 13.88 ha of mature secondary forests, 456.69 ha of intermediate secondary forests, 19.99 ha of mangrove, 238.03 ha of underbrush and stubble, and 1,137.62 ha of pasture and grassland will be lost, making it a total area of 1,866.21 ha where the vegetative cover will be lost.

In the Atlantic Coast Zone (Zone 1), the entirety of the land areas whose vegetative cover will be affected (204.76 hectares) corresponds to the Mindi and Tanque Negro (north and south) disposal sites and their access roads. This area is mostly covered by pasture and grassland, highly intervened secondary forest of the tropical lowland ombrophilus latifoliate evergreen type, and underbrush.

In the Gatun Locks Zone (Zone 2), the 265.22 hectares (see table 7-19) associated with the Project footprint correspond mainly to the locks, water saving basins, channels, and Contractor work areas and ACP facilities. Only 27.5 hectares correspond to disposal sites in the Mindi area. In this zone, the vegetation that will be removed consists mainly of pasture and grassland, secondary forest of the tropical lowland ombrophilus latifoliate evergreen type, and underbrush and stubble.

The Gatun Lake Zone (Zone 3) footprint has very little surface on land, only 5.96 hectares, of which 4.12 are intermediate secondary forests. The rest consists of urban areas, pasture, grassland, underbrush, and stubble.

In Zone 4, due to the works undertaken in the Gaillard Cut area, there is very little natural vegetation and the landscape is dominated by white straw and some highly intervened secondary forest zones, underbrush, and stubble. In this zone, the Project footprint (376.46 hectares) is associated almost 100% with the disposal sites (sites T2, T3, T4, T5 and a small part of T6), some of which have unexploded ordnance. Sites T2, T3, T4 and T5 are in use and do not represent new areas. 57% of this area is covered with grassland, mainly white straw, and the other types of cover, in decreasing order, are secondary forests, underbrush and stubble. A little less than 6.0% is bare soil.

The Pacific Side (Zones 5 and 6) is in a zone of intermediate secondary forests of the tropical lowland semideciduous type that has been heavily intervened previously. The land area of the DIA in these two zones adds up to 1,612.6 hectares, which are currently covered mostly by pasture and grassland dominated by white straw (51.8%), followed by a highly intervened young secondary forest (25.5%), and underbrush and stubble (12.7%). The rest are urbanized (6.7%) and small mangrove areas (19.99 hectares), and mature secondary forest (13.55 hectares), which represent less than 2%. However, only 1,105.25 hectares will be directly affected by the Project footprint, most of which corresponds to excavated/dredged material disposal sites (662 hectares), and the rest is divided between the surface that will be occupied by the locks and channels (167 hectares), and the facilities in Contractor work areas, highways, and Roads (198 hectares). Of the area directly affected by the Project footprint, the largest part corresponds to grassland dominated by white straw (58.3%), followed by young secondary forests (21.4%) and underbrush and stubble (11.7%). The rest are urbanized areas (5.5%), and only 1.4% to mature secondary forest.

To summarize, the implementation of the Panama Canal Expansion-Third Set of Locks Project does have an ecological cost from the vegetation point of view, because will lead to its loss. Therefore, this impact is considered adverse, direct, and of an inevitable occurrence of fast development. The impact will also be of a medium magnitude and long duration, since the green areas where the vegetation will be removed will not recover for a long time. When weighing all these attributes, the result is a medium or moderate significance (**-4.20**).

Operations Phase

As pointed out above, the loss of vegetative cover is an impact that will mostly occur during the construction phase. However, during the operations phase, activities will take place on vegetative cover for the maintenance of the disposal sites, which could affect its natural regeneration.

The raising of the maximum operating level (MOL) of the Gatun Lake will result in the temporary rise of the waters up to the 27.13 m mark, an increase of 45 cm over the current MOL of 26.67 m. The impact on the vegetation will depend, mainly, on the duration of this rise in the Lake level, the seasonal fluctuations in water level, and the type of the existing vegetation. In general, the current vegetation along the shores of Gatun Lake is made up of species adapted to fluctuating water level conditions with some tolerance to temporary flooding. Although some species of herbaceous and woody plants may be lost in the zones subject to the raising of the water level, they will be replaced by tolerant species.

This impact is considered as negative and direct, because it will influence the existing vegetative cover. The impact is of certain occurrence, slow development, and low and temporary magnitude because there will always be a continuous recovery of the vegetation by means of the ecologic succession and adaptation process. The weighing of these attributes results in a low significance level of (**-2.06**).

7.4.2 Loss of Forestry Potential

Construction Phase

When vegetative cover removal to implement a Project includes the removal of harvestable tree species with diameters that can produce commercial logs, there is a reduction in forestry resources, apart from the loss of the vegetative cover as such. The significance of this resource is mostly determined by the volume of the timber and the proportion of the available forestry resources.

Considering that there are no forestry plantations or natural forests for forestry use within the Project's DIA, an analysis was made of the canopy cover along the Project footprint, according to CEREB-UP (2005) data.

The density and total estimated number of forest species of commercial value along the Project footprint are shown in Table 5-24 (Chapter 5 – Biological Baseline). This Table shows that the total number of trees of commercial value along the Project footprint is of 9,343 individuals, and the forest species with the highest representation are the Jobo (*Spondias mombin*) with 2917 trees, the Espave (*Anacardium excelsum* or wild cashew), with 2,128 trees, and the Tachuelo (*Zanthoxylum panamense*) with 1,089 trees.

The impact is adverse, with a low significance degree (**-3.24**). Its adverse character is based on the fact that by removing the forest cover areas, a part of the local forestry potential will be lost. The impact is direct because it comes with the clearing, grubbing, and stripping activities in construction areas; its occurrence is considered inevitable; the maximum disturbance is reached in a period of not more than six months; therefore, its development was rated as fast. The loss of woodland cover in the Project footprint represents a minimal proportion of the woodland cover area in the entire Specific Study and Direct Impact area; consequently, the impact was rated as of a low magnitude; the duration of this impact is already permanent because the built areas will not regain forestry potential.

Operations Phase

It is not anticipated that forestry plantations will be affected due to the increase in the level of Gatun Lake during the operations phase; therefore, this impact is considered neutral. However, it is recommended that a more in-depth study be prepared to assess the impacts that the raising of the maximum operating level (MOL) of Gatun Lake may have over the vegetation, mainly, the duration of the level increase, the seasonal fluctuations of the water level, and the type of existing vegetation, as well as the mitigation measures that may be necessary.

7.4.3 Loss of Terrestrial Habitat

The loss of habitat is directly associated, not only with the loss of vegetative cover, but also with the type of vegetation that will be eliminated and its use by wildlife species, especially by those under some special management category. It is not expected that this impact will occur in the operations phase because no conditions are expected to justify the additional removal of vegetation, which is one of the requirements for the loss of habitat.

In order to assess this impact, it must be taken into account that the Panama Canal Watershed is considered a zone of great biological diversity. Its geographic and ecological position allows for a great variety of biological resources, the most conspicuous of which are forests and macroscopic fauna.

Construction Phase

Although the areas to be affected by the Project already show a significant degree of alteration and disturbance due to the routine Canal activities, this impact is considered of importance partly due to its cumulative character, as it assumes the occurrence of direct and indirect impacts on the flora and fauna to be caused during the construction works phase. The loss of vegetative cover, mainly in the secondary forest areas, as well as of the underbrush will cause a habitat reduction for the fauna of the area in direct proportion to the area of each type that will be eliminated. These activities will also result in direct and indirect effects on flora and fauna species, some of which are listed under the category of protected or special national and international interest, and endemic. However, it is considered that the availability of habitat in adjacent areas does not significantly affect their populations.

This impact has been rated as being of an adverse character and with a direct effect during the construction phase. Its occurrence will be inevitable; the maximum disturbance will be reached quickly, with a low magnitude and a permanent duration. The level of environmental significance of this impact is considered moderate (**-3.87**).

Operations Phase

The raising of the maximum operating level (MOL) of Gatun Lake will result in the temporary rise of the waters up to the 27.13 m mark, a 46 cm increase over the current MOL of 26.67 m. Generally, it can be expected that land vertebrates will be displaced to higher zones with the increase in seasonal water levels.

The raising of the water level could create new temporary habitats of very short duration (one or two months) in shallow waters in low profile zones, such as the Gatun River zone, which may favor some species of vertebrates such as caymans, capybaras, and many species of water fowl.

No significant loss of island areas is expected in Gatun Lake that could affect sensitive fauna populations. During the operations phase, the impact of land fauna habitat loss will be inevitable during some months, it will be of slow development, very low magnitude, and permanent duration, resulting in a low significance level of (**–2.24**).

7.4.4 Direct Impact on Fauna

The direct impact on species of fauna, particularly on less mobile species, is possible during the construction phase of the Project and, on a lesser scale, during the operations phase. During the latter, the impact may be potentially associated with the Canal maintenance activities and channels that require excavation, dredging and deposit of material in a periodic fashion.

Construction Phase

During the construction phase, activities such as clearing, grubbing, and stripping, earth movement, blasting, installation of base layers, paving, installation of temporary works (work shops, offices, etc.) and the movement of heavy equipment, may result in the direct elimination of wildlife specimens. Although most of the higher bird species, mammals and large reptiles may flee from the work area, the majority of smaller and less mobile species such as amphibians and small reptiles will probably be unable to do so.

Fauna that would be mostly affected by the alteration and destruction of their habitat includes arboreal animals, diurnal and nocturnal, such as monkeys, squirrels, and opossums, nesting birds and iguanas, as an effect of the felling of trees. Likewise, burrowing and semiburrowing animals, as well as those of the leaf litter (living on the soil surface), among them agouti pacas, snakes, and frogs, will be affected by the felling of trees and/or by earthmoving activities and heavy duty vehicle traffic. Also, in the case of some of the reptiles (crocodiles and caymans living in lagoons that will be drained and filled with excavated or dredged material); it is probable that they will be affected temporarily.

Therefore, this impact has been rated as negative, direct, of inevitable occurrence, very fast in manifesting its effects, with a moderate magnitude but of short duration. Its significance level is rated as low (**-2.56**).

Operations Phase

In the operations phase, once construction activities cease, wildlife specimens that had distanced themselves from their habitats may return to them. No conditions for their re-colonization will be left in constructed areas; however, the disposal areas for excavated materials will continue to improve as the ecological succession process moves ahead. To the extent these sites are used once again for the deposit of excavated and dredged materials from maintenance works, such returning species may be affected, although the impact will be less than that during the construction phase. This impact will undoubtedly be of a much lower magnitude, because it will be limited to the disposal sites used periodically.

This impact has been rated as adverse, direct, of a certain occurrence, with a fast disturbance effect, a low magnitude, and of medium duration. The significance level of this impact has been rated as low (**-1.16**).

7.4.5 Disturbance to Wildlife

In addition to the direct impacts on the habitat and the fauna, particularly the less mobile species already mentioned, the increase of human activity as result of the construction may have effects on wildlife, such as poaching by workers and the increase of noise and light during the scheduled night work. However, the species existing in the areas affected by the Project have a wide distribution in adjacent areas, as well as in the rest of the national territory. Although some of the species that will be affected have been listed as being under the special interest, endemic, or protected category at national and international levels (CITES, IUCN and protected by Panamanian laws), the Project will not place any of the flora and fauna species identified in the environmental studies in risk of extinction.

Special interest species reported in the inventories (Louis Berger, 2004; CEREB-UP, 2005) include the howler monkey, the squirrel monkey, the jaguarundi, the white tail deer, the capybara and the white nosed coati, the osprey, the gray-headed chachalaca, the pale-vented pigeon and the black-bellied whistling-duck, the green iguana, the crocodile, the cayman and the Mesoamerican slider.

Construction Phase

The activity of machines, equipment and personnel during the construction phase will cause an increase in sound levels and changes in the lighting regime; there may also be air pollution from airborne particles and gases from vehicle traffic, as well as soil pollution from accidental spills of chemical substances such as fuel, oil, asphalt, paint, and even organic waste and garbage. These disturbances will be mostly reflected in the distancing of the animals from the construction area. They will interfere with the daily activities of the various species, such as feeding, rest, mating, predator-prey relationship, nesting, etc., and interrupt the normal development of their behavior, frightening them away towards distant sites in search of a new habitat.

This impact will be negative, direct, of very probable occurrence, and will reach its maximum effect very fast but at a low magnitude due to the limited number of species and their population density; it will also be of a medium duration. This impact will be greater in zones 2, 4 and 5, where there is a fragment of more preserved forest in the DIA that maintains, according to fauna samplings, a greater wealth of species than in the rest of the areas with other types of vegetative cover. The significance level of this impact is low (**-1.50**).

Operations Phase

During this phase, the impact would be directly generated by the activity around the works and the maintenance. The most important impact will be that from noise and lighting at nighttime. The expanded Canal will operate continuously 24 hours, and the noise associated with the activities from the transit of vessels, locks support equipment, and artificial lighting could generate disturbances to animal species with nocturnal food search and mating habits.

Under these conditions, it is probable that this impact will occur after the works are completed, with a medium term development, a low magnitude, and permanent duration. If this impact occurs, it will have a low significance level (**-1.30**).

7.4.6 Increased Wildlife Road Kill Risk

The environmental aspect that affects fauna the most is the loss and degradation of the habitat that alters the distribution and behavior of the species. However, it is possible that during the construction phase as well as during the operations phase there will be a direct impact (mortality) due to wildlife species being run over in traffic associated with Project activities.

Construction Phase

This impact could happen to a certain extent as a result of truck and vehicle traffic for the transportation of personnel, materials and equipment, as well as the transportation of spoils disposal sites. To a great extent, it is the height of these vehicles that makes it difficult to see small animals on the road, causing the death of amphibian, reptile and even bird and mammal wildlife specimens.

It is assumed that the main access to the Pacific locks site will be from the Inter-American Highway through the Bruja-Borinquen Road toward the Cocoli area. An access alternative with certain restrictions may be from the new Centennial Bridge on the west side of the alignment channel, or crossing the existing Miraflores Bridge to the east side of the new locks. The second alternative involves roads with high vehicle traffic, which reveals that the crossing of animals has been somewhat limited along those roads. Therefore, the impact would be of a higher consideration along the temporary routes that will be enabled within Project areas mainly for trucks, machinery, heavy equipment, and vehicles for the transportation of materials, equipment and personnel, as well as for the transportation of spoils and garbage to disposal sites. This will intensify the probability of animal road kill that will affect their population density or numbers of individuals by species.

The impact will be negative and direct. It will occur along the alignment and in the access areas inside the direct impact area, mainly in zones 2, 4 and 5, with a mixed fauna typical of grassland-underbrush-secondary forest, where a higher number of activities will concentrate which are risky for wildlife. The impact has a high probability of occurrence; its effect on the fauna will be fast, and its magnitude moderate with a medium duration. The environmental significance level of this impact is considered low (**-2.64**).

Operations Phase

During the operations phase, this impact can occur on a lower intensity, for the reasons described under the construction phase. In this regard, the impact is classified at the same level as during the construction, with the exception that it will be permanent for the duration of Project operations with a higher rate during nighttime (the hours of activity of most animals), and close to areas with natural vegetation. Road kill may occur mainly in those sections close to the disposal sites; however, nighttime deposits are not normally done at the disposal sites.

This impact is negative and direct. Its occurrence is very probable, with a very fast effect, of low magnitude, and over a permanent duration. The significance level of this impact was low (**-2.90**).

7.4.7 Increased Poaching

As has been mentioned previously, the Panama Canal Watershed is considered a zone of great biological diversity. The most important data presented previously must be reiterated in this section. The geographic position of the Watershed and its ecology allows for a proliferation of biological resources, the most conspicuous being its forests and macroscopic fauna. There is a great amount of base information on the land biotic environment of the area of influence of the Canal Expansion Project.

Several mammal species of special interest (national and/or international) were identified in the studies undertaken in 2004 and 2005 in the areas that will be affected during the proposed Canal expansion. Species of interest identified in these areas include the howler monkey, the squirrel monkey, the jaguarundi, the white tail deer, the capybara and the white nosed coati (Louis Berger, 2004). With respect to the conservation status of the species, several species of interest were observed during the studies conducted in 2003, 2004 and 2005. Birds of special interest include the osprey, the gray-headed chachalaca, the pale-vented pigeon and the black-bellied whistling-duck. 79 threatened species were recorded, 10 of them endangered (CEREB – UP, 2003). Regarding amphibians, several frog and toad species of special interest were identified in the zones of the new alignments on the Atlantic and Pacific Sides. Reptile species of interest include the green iguana, the crocodile, the cayman, the Mesoamerican slider, and the common boa.

Construction Phase

A certain number of workers on daytime and nighttime schedules will be needed during this period, and this can generate poaching. Wildlife Law 24 prohibits this activity; additionally, Dir. Res. 002-80 considers some of the species present in the area as endangered and prohibits their hunting. Fauna species more susceptible to impact from poaching include the armadillo, Central American agouti, white tail deer, agouti paca, Central American spiny rat, Dice´s cottontail, pigeons, black-bellied whistling duck, gray-headed chachalaca and the green iguana.

If poaching by workers were to take place, the impact would be negative and direct. Its occurrence is very probable, with very fast effects, of medium magnitude and short duration, resulting in a significance level of (**-1.74**)

Operations Phase

During this phase, the impact would not be generated by the operations. It is expected that since the Project will not allow free access to the general public and will have a high degree of security in place, this will act as a barrier and impede or restrict access to poachers to a great extent. However, the regional population growth caused as an indirect impact of the Project will lead to a slight increase in poaching compared to current levels. Therefore, the significance level of this impact during the operations phase is rated as very low (**-0.48**).

7.4.8 Alteration of the Aquatic Resources of Rivers and Creeks

The effect of the Direct Impact Area on live organisms in rivers and creeks is mostly determined by the changes in the drainage pattern and the associated sediment transportation. Changes in the drainage pattern affect the rivers and creeks on the west bank of the Miraflores Lake, including the Cocoli and Rio Grande Rivers and their tributaries, as was previously mentioned (Section 7.3.15), which, in turn, depend on the erosion increase during the construction phase. Thus, both effects are expected to occur mostly during the construction phase.

Construction Phase

a. Canalization and Diversion

As mentioned in the description of the Project and its activities, the diversion of the Cocoli and Rio Grande (South branch) Rivers is necessary to build the chambers and water saving basins of the Pacific locks and its approach channels without the risk of flooding. It is proposed that the Cocoli River be diverted to the Pacific Ocean, and the Rio Grande River to Gaillard Cut. The canalization of the diverted segments will alter the habitat of the biological communities along them because their natural channels will be replaced with concrete channels (see Figure 7-2). Considering the length of the drainage network in the Canal Watershed and the length of the natural channels of the rivers to be diverted, the impact is considered as being very low in magnitude. Additionally, the T6 and Cocoli (proposed) disposal sites will occupy considerable areas of the Rio Grande River and the Cocoli River valley watersheds.

b. Sediments

Regarding the amount of sediment that arrives at the Watershed network and its possible effect on the aquatic communities of the rivers and creeks receiving it, the impact is high in the sections of the currents closer to the areas that are eroded. The effect of the transportation of high sediment volumes through the Watershed system is translated into an increase in turbidity that reduces the penetration of light and photosynthesis. Also, the deposit of material changes the profile of the channel and the distribution of puddles and canyons, modifying the habitat and the availability of food or nesting sites for the fish species and other aquatic organisms. However, with the exception of the T6 and Cocoli disposal sites, Project activities do not affect the basins of the rivers and creeks. The canalization of the lower sections of the Rio Grande and Cocoli rivers will not affect the sediment loads of these rivers.

c. Assessment of the Impact

None of the species in these rivers and creeks is considered endangered and there is ample habitat availability for their existence in adjacent sites. Therefore, in the general context of the

Canal Watershed network and of the areas adjacent to it that drain into both oceans, the effect is of a low magnitude.

Based on this analysis, the significance level would be low (**-3.08**). This value is obtained from the assessment of an effect with a certain occurrence, fast development, low magnitude and permanent duration.

Operations Phase

a. Gatun Lake Dam Deposits into the Lower Chagres River

The Chagres River flows into the Atlantic some 12 km downriver from the Gatun Lake dam. Along the lower course of the Chagres, there are floodable forests of griseb (*Prioria copaifera*) that are of special interest due to their restricted geographic distribution in the country (ANCON-TNC, 1996 b). The higher operating capacity of Gatun Lake and the deepening of the navigation channel will allow a continuous operation of the Canal and the Third Set of Locks under a wider range of weather conditions, a fact that will allow the discharge of adequate flows to maintain the lower Chagres River ecosystem.

b. Suspended Sediments

It is expected in the operations phase, the effect of the sediment arriving at and transported through the Watershed system will return to the value it had prior to the construction of the Project. Therefore, the effect is expected to be concentrated in the diversion of the aforementioned rivers.

c. Assessment of the Impact

The effect on the biological communities of the fluvial ecosystem during the operations phase is considered as being of a certain occurrence, fast development, very low magnitude and permanent duration, for a low significance level of (**-2.54**).

7.4.9 Alteration of the Aquatic Resources of Gatun Lake

Gatun Lake is an artificial lake that has been in existence for almost a century, and has developed its own ecology and aquatic biodiversity comparable to those of natural lakes. The Lake provides an adequate habitat for many species of Panamanian fauna; the group of mammals includes otters (*Mustela longicaudis*) and manatees (a species introduced in the Gatun Lake, for the control of aquatic vegetation). The Lake provides birds with food and habitat, both to species that permanently inhabit the area, as well as to migratory species; reptiles include crocodiles, caymans, and freshwater tortoises. The Lake also contains a large variety of species such as phytoplankton, zooplankton, fish (native and introduced) and bentonic organisms, mainly the group of the macro-invertebrates (mollusks and crustaceans). There is a diversity of aquatic insects (more than 50 species), some of medical importance.

Project activities with a higher potential to influence the environmental conditions of Gatun Lake are the widening of the navigation channels, the deposit of excavated and dredged material, the increase in its maximum operation level, and the increase of cargo traffic through the expanded Canal.

Construction Phase

a. Dredging and excavation

During the construction phase, there will be an alteration of the lacustrine resources present in the Direct Impact Area of the Project, mainly due to the deposit of excavation and dredging materials. It will also require clearing, grubbing, and stripping, and earth movement. All this will result in an increase in sediments or suspended solids in the water column.

It is expected that the most important effect for the turbidity levels or the increase in suspended solids in the water column will come from the deposit of dredged or excavated material. To estimate its potential effect, we simulated the effect of this deposit in the water column using the HydroTrack model described in section 7.3.13, Deterioration of Water Quality. This model collected and analyzed the existing information, establishing that the disposal sites found within the area of Gatun Lake (Monte Lirio, Peña Blanca East, Peña Blanca west and Frijoles) present hydrodynamic conditions characterized by relatively low water velocities (Riada Engineering, Inc., 2007).

Generally speaking, the increase in the volume of sediment in the water column generates high levels of turbidity that limit the penetration of light and alter the speed of the exchange of gases of the biotic community with the water itself. If this condition takes place for long periods of time, it can have negative effects on: 1) the micro and macroscopic aquatic flora, by altering the photosynthetic processes; 2) the bentonic fauna, because sediments may affect the filtering systems of various organisms for respiration or feeding, especially those with little or no mobility; and 3) the biota, by reducing the amount of oxygen in the water column profile as result of a lower photosynthesis.

Due to the above, it is important to consider the effect of the volume of sediment deposited upon the bentonic community in the Lake bottom. To that end, a limit of 1 mm per day was established as the critical area. This limit was established based on the biology of bentonic organisms, for which the effect of 1 mm or more of deposition per day has a considerable metabolic cost (McClanahan and Obura, 1997; Rogers, 1983).

By means of simulations conducted with the model, the distribution of the thickness of the material sedimented after 24 hours was established by using this critical 1 mm thickness as the control parameter. Subsequently, this sedimentation pattern induced for each workday and projected to all points within the boundaries of the polygon that defines each disposal site. For the Monte Lirio disposal site, it was estimated that at some point an area of approximately 530 hectares would be receiving a flow of sediment higher than 1 mm per day. For the Peña Blanca East disposal site, it was estimated that at some point an area of approximately 1015 hectares would be receiving a flow of sediment of more than 1 mm per day. For the Peña Blanca West disposal site, it was determined that at some point an area of approximately 579 hectares would be receiving a flow of sediment higher than 1 mm per day and, finally, for Frijoles, it was estimated that at some point an area of approximately 468 hectares would be receiving a flow of sediment of more than 1 mm per day. These data represent lake areas that are slightly more than 1% or 2% of the total surface of Gatun Lake (URS Holdings, Inc. - Riada Engineering, Inc., 2007).

An additional effect of the increase of suspended sediment is the release of soluble nutrients into the water column and the risk of eutrophization that could alter water quality by favoring the growth or proliferation of floating weeds such as the water hyacinth (*Eichhornia*) and water lettuce (*Pistia*), because these plants will efficiently use those released nutrients. At disposal sites where the depth is considerably reduced there is also the possibility of favoring the growth of the Esthwaite waterweed (*Hydrilla*). This plant is present in the Lake and is limited by the effect of the penetration of light and pressure to areas with a depth of less than 10 meters.

b. Blasting

It is estimated that 10% of the Gatun Lake channel will require drilling and blasting prior to its widening and deepening. The drilling and blasting volumes in Gatun Lake are estimated at 3.35 Mm^3. However, the environmental assessments and ACP experience in Gaillard Cut and at Canal entrances show that these impacts are not significant in terms of the mortality caused. Also, although there is a detailed catalog of the aquatic species found in the Canal waters, no endangered species have been found that deserve special attention in that assessment.

c. Assessment of Impact during the Construction Phase

For a clearer idea of the magnitude of this impact, a computerized simulation was made of the suspension and dispersion of sediment resulting from dredging activities and the disposal of dredged and excavated material at the Monte Lirio, Frijoles, Peña Blanca East and Peña Blanca West sites. The description of the model used and the results obtained on the suspension and dispersion of sediment are found in section 7.3.13, Deterioration of Water Quality.

When assessing the impact of the various effects during the construction phase, it can be said that it will be negative, direct and indirect, with a certain occurrence probability, and of fast development, moderate magnitude, and short duration on the freshwater fauna and flora, since it will happen mainly due to the impact on water quality. In this phase, the significance is medium or moderate (**-3.50**).

Operations Phase

a. *Dredging*

During the operations phase, the importance of suspended sediments in the water column diminishes because the intensity of all the activities that produce them is drastically reduced when construction is completed.

b. *Raising of the Maximum Operating Level*

In general, the effect of raising the maximum operating level of Gatun Lake will manifest itself by a larger flooded area over some weeks when the dam is at its maximum capacity, and in a greater fluctuation of the water surface during the year. It is not expected that the impact of these two factors will be of a high magnitude on the biological communities due to the fact that the additional area that would be flooded is an area that sporadically floods during some weeks of the season with higher rainfall. It is possible that this will slightly increase the load of nutrients into the lake during the first years as the chemical properties of the soils in the area reach equilibrium with the flooding process. However, this is not deemed as a considerable impact capable of affecting the structure and function of the biotic community in the dam.

The effect from the fluctuation in water levels is due not only to the increase of the maximum operating level but also to the deepening of the navigation channel (see Figure 7-3). In the current situation, the Gatun Lake level may fluctuate between 24.69 m PLD (81.0’) and 26.67 m PLD (87.5’) and continue operating with a 14 m draft. Under the new conditions after the Project is completed, the fluctuation of the level may be of up to 2.44 m (8.0’) because it will be able to fluctuate between 27.13 m PLD (89.0’) and 24.69 m PLD (81.0’). In general, the effect of a greater fluctuation of the level reduces both the populations of submersed root plants of the hydrilla type, and of bentonic organisms (Wetzel, 2001).

Although this could be beneficial from the point of view of the control of the hydrilla population, it could also facilitate the growth of some groups of organisms such as Chironomidae fly larvae (*Antillocladius* sp.) because when the water level rises again, there would be a large amount of organic matter available to them in an environment with little oxygen that favors their development.

c. Increase in Lockage Volume

Finally, perhaps the most important risk derived from the increase in cargo traffic with the expanded Canal is the increase of chloride ions from the operation of the new and existing locks. However, the studies and mathematical models simulations conducted during the conceptual design phase indicate that with the proposed scheme of three chambers per lock and three water saving basins per chamber, there is no significant increase risk of changes in the condition of the freshwater in Gatun Lake associated with the operation of both sets of locks.

d. Assessment of the Impact During the Operations Phase

In summary, effects on the biological community of Gatun Lake during the Project operations phase are very unlikely, of a very slow development, medium magnitude, and a duration that is also medium. Thus, it is estimated that during the operations phase, the impact on the biological resources of Gatun Lake will be of a very low significance level (**-0.48**).

7.4.10 Alteration of Aquatic Resources of Miraflores Lake

The construction of the approach channel north of the Pacific locks requires the construction of four dikes (the Borinquen dikes) that will reduce the Miraflores Lake area on its west banks (see Figure 3-14 in the Project Description). Also, the water residence time in the dam will change drastically with the Project implementation. The first of these effects happens in the construction phase, while the second manifests itself once the Project begins its operations. Both effects are described in the following paragraphs.

Construction Phase

In the first place, it will be necessary during the construction to install a steel sheet pile wall to isolate the western part of Miraflores Lake and excavate to remove the existing mud and soft material. This is necessary to fill it in with good quality material that will serve to support the Borinquen dikes. The total reduction of the Miraflores Lake surface is approximately 12.7% (36 hectares) of its current area. One part is directly occupied by the Borinquen dams, while the other part that will be isolated from the main body of the dam will be used as disposal site for excavated or dredged material.

Because the whole shoreline zone will be eliminated, this alteration will do away with the entire sessile biological community existing on the west banks of Miraflores Lake. This zone will eventually be reestablished alongside the Borinquen dams.

On the other hand, although the construction also reduces the amount of water that flows into Miraflores Lake, this reduction is minimal compared to the flow from Pedro Miguel lockages. The change in the average water residence time is not much because largest volume of water flowing through Miraflores Lake actually comes from Pedro Miguel lock operations for the transit of vessels through the Canal (1,250 MMC per year in average)[23], and not from its own drainage basin (65 MMC per year in average)[24].

Therefore, the impact on the biological resources of Miraflores Lake during the construction phase of the Project is considered of an adverse character because a part of its shoreline zone will be eliminated. This impact is an inevitable occurrence, with a very fast development and a high magnitude because a part of the ecosystem is totally affected, and of a permanent duration. This assessment defines this impact as one of a medium significance level, at (**-5.78**).

23 In the 10-year period analyzed in the Master Plan, the average amount of water used for the transit of vessels was 2500 MMC/year. It is assumed that half of this flow passes through the Pedro Miguel locks into the Miraflores Lake, and finally flows into the Pacific Ocean through Miraflores locks.

24 Regional Plan (Nathan-Intercarib and Associates) prepared in 1997.

Operations Phase

Once the Project begins to operate, the expected changes in the water flow through Miraflores Lake are even greater. This is because a large part of the traffic of vessels through the Canal will no longer pass through Miraflores Lake. Therefore, the water volume that will no longer flow through this dam will be directly proportional to the fraction of traffic that is funneled through the new Pacific locks. The water saving advantages with the use of the water saving basins, and the greater draft available for the vessels suggest that during the operations, the priority will be to use the new locks even for many of the vessels capable of transiting the current Canal.

Given that there is no precise information on the proportion of water that will be discharged in the future through the existing Pedro Miguel locks, it is appropriate to show how the water flow through Miraflores Lake can drop under several possible operation schemes.

Table 7-22

Effect of the Proportion of Ship Traffic through the New Pacific Locks, on the Water Input into Miraflores Lake

Water Source	Current Condition	Future Condition[25]: % of discharge per transit in the new Pacific lock			
		25%	50%	75%	100%
Watershed (MMC/year)	65.0	32.5[26]	32.5	32.5	32.5
Transits (MMC/year)	1250.0	937.5	625.0	312.5	0.0
Total Flow (MMC/year)	1315.0	970.0	657.5	345.0	32.5
Reduction in Input (%)	---	26.2	53.7	73.8	97.5

Source: URS Holdings, Inc.

25 Assuming that the amount of water used for the transit of vessels remains constant. Although this is not correct over the long range, it serves to illustrate the effect of a reduced water input into Miraflores Lake.

26 It is assumed that the diversion of the Rio Grande and Cocoli Rivers will reduce runoff from the basins by approximately half.

The reduction of the water input from Gatun Lake will increase the average water residence time in Miraflores Lake. Also, assuming that 75% of the traffic is funneled towards the new locks, the change in the total amount of water that will flow through the Lake will be significantly reduced (from 1315 MMC to 345 MMC per year), and its water renewal time will increase from approximately 2 months to almost 11. This may increase the risk of eutrophization in Miraflores Lake; given that there will be less dilution of the waters coming from Gatun Lake. In general, the levels of nutrients are greater in the runoff from areas with less rainfall and a higher urbanization rate (Wetzel, 2001), as is the case of the Miraflores Lake basin with respect to the entire Panama Canal Watershed. Data collected by the ACP in 2004 (ACP, August 2006[27]) indicate that the Gatun Lake water is of better quality than that of Miraflores Lake. A comparison in the concentration of phosphates (PO_4), which is the best indicator of eutrophization risk, shows that in 2004, the average concentration of phosphates in the Miraflores Lake surface water (16 µg/l) was 78% higher than the concentration of phosphates in the surface water at the Paraiso water intake (9 µg/l), the station that is representative of the water that flows from the Gatun Lake system toward Miraflores (ACP, August 2006[28]). These data confirm the expectation that the levels of nutrients in the Miraflores basin runoff are greater that those in the Canal basin. What this means is that per unit of area, the Miraflores basin which contributes water generates a greater load of nutrients than that from Gatun, and that the reduction in the flow of water from Gatun Lake into Miraflores Lake will increase the concentration of nutrients.

Regarding salinity, it is not considered that it will increase significantly in Miraflores Lake. This was determined by a simulation with a detailed model of the saltwater intrusion risk conducted by specialized ACP consultants. Salt intrusion in Miraflores Lake was documented very early during Canal operation and has remained more or less at the same levels. With less traffic there will be less water to dilute the seawater going through the locks, but there will also be less such intrusion because there will be less traffic. Therefore, it is expected that the salinity levels will remain similar to the current ones.

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27 Water Quality Report. Panama Canal Watershed. Years 2003-2005

28 Water Quality Report. Panama Canal Watershed. Years 2003-2005

After this analysis, it is considered that the true risk is that the degree of eutrophization of Miraflores Lake will increase. This is an impact considered as being of an adverse character, of probable occurrence, and of a slow development, high magnitude, and permanent duration. With this assessment, this impact has a low significance level (**-2.35**).

7.4.11 Alteration of Marine Coastal Ecosystems

At the Atlantic and Pacific ocean entrances and the sites directly adjacent to them, Project activities that may have an effect on the coastal marine ecosystems include, mainly, the dredging to widen the navigation channels, and the deposit of dredged material at marine disposal sites. Also, the increase in vessel traffic will also be a source of possible effects on marine ecosystems.

As was mentioned in section 7.3.13, Deterioration of Water Quality, the destination of the sediments that are disposed of in coastal water bodies mainly depends on the geostrophic currents and currents generated by the wind and tides, the operation patterns of the deposits, and the properties of the sediments. The oceanographic conditions of the zone play a determining role in the destination of the deposits. Factors such as turbulence, density gradients, and the differences in water column speeds influence the initial dispersion, the subsequent transportation of the materials in the water column, and their deposition on the sea floor.

Construction Phase

a. Dredging and deposit of material

During the construction phase, the main risk for the marine coastal ecosystems comes from the sediment that becomes suspended as a result of dredging and excavation material deposit operations. The generation of high levels of turbidity may have adverse effects on the marine coastal community because it restricts the penetration of light and reduces photosynthesis. This impact on bottom organisms has some significance when new unaltered areas are used, particularly in underwater sites, which is not the case here.

On the Atlantic Side, these activities are located in Zone 1 where both the channels to be dredged and the disposal site known as West Breakwater are located. On the Pacific Side, these activities are in Zone 6 where both the channels to be dredged and the disposal sites known as Palo Seco, Tortolita and Tortolita South are located.

During the construction phase, another risk could be the impact on marine coastal ecosystems from the increased sedimentation, which could have adverse impacts on the coralline formations and marine grasses that deserve high consideration.

b. Underwater Blasting

For this activity, the effect of the Pacific entrance blasting works on fish and other aquatic animals was considered. However, the environmental assessment and ACP experience at Canal entrances show that these impacts are not significant in terms of the mortality caused or the impact on important fishing resources. Also, although there is a detailed catalog of the aquatic species found in Canal waters, no endangered species have been found that deserve special attention for this assessment.

The use of explosives is not considered necessary at the Atlantic entrance. On the Pacific Side, the blasting activities will occur mainly in Zone 6, where both the navigation and southern approach channels are located.

c. Spills of Pollutants

An additional risk during the construction phase is associated with the possibility of accidental spills of polluting materials that could have adverse impacts on marine coastal fauna and flora. In every infrastructure work there is the risk of runoff of oil byproducts or other polluting substances that can affect the biota, depending on the extent and type of the spilled substance. During the construction phase, this risk would be a factor due to the presence of vessels and dredges in the Canal, along with the risk of accidents with dredging equipment. This risk can be considerably reduced with the proper implementation of the ACP contingency plan prepared in accordance with MARPOL specifications and customized for the Panama Canal: the Panama Canal Ship Oil Pollution Emergency Plan (PCSOPEP).

d. Impact Assessment

According to the information available, most of the materials to be dredged will be inert. To measure the extent of the possible impact of the suspension, dispersion and sedimentation of particulate material on the marine coastal ecosystems, a simulation was made with a computer-assisted numeric model, of the possible behavior of this material and its effect on turbidity and sedimentation. Prior to running the model, the possible areas that could be more sensitive to the dispersion and sedimentation process were identified.

These included the barrier type coral reef at the East Breakwater on Punta Margarita identified on the Atlantic Side, located over 5 km away from the West Breakwater site. This coral reef zone extends along the coastline to Las Minas Bay. In turn, in Zone 6 on the Pacific Side, its three marine disposal sites have been used in the past. The Palo Seco site is between the coast and Changame Island; Tortolita is found due south of Changame Island and west-northwest of Tortolita Island; and the Tortolita South site is located southeast of Tortolita Island. Due to a lack of sensitive habitats close to the Palo Seco and Tortolita South sites, no significant impacts are expected.

According to the simulation results of the case study on the deposit of dredged material at the Atlantic Breakwater Site, maximum concentrations in the area after 5 days of continuous discharge will be approximately 90 mg/l, maximum sedimentation thicknesses will be 750 mm, and mean deposition rates will be 150 mm/d. The sedimentation area is 1.20 km^2 and shows mostly a few millimeters of sedimentation thicknesses.

In the Atlantic Ocean, the plume of suspended solids is transported eastward because of the action of currents that reach the east coast of the Panama Canal entrance with low concentrations. Sedimentation over 1 mm/day occurs once the system achieves a dynamic equilibrium between the deposit of solids and the sedimentation process, and it covers a surface of approximately 112 hectares (Figure 30, Annex 5). The area outside the disposal site polygon does not include sensitive areas of coralline and bentonic communities.

For the case study on the deposit of dredged material at the Palo Seco area on the Pacific Side, the maximum concentrations in the area obtained after 5 days of continuous deposits are approximately 2100 mg/l with maximum sedimentation thicknesses of 1000 mm and mean deposition rates of 200 mm/d. The sedimentation area is 1.20 km^2 and it shows mostly very small sedimentation thicknesses in the order of a few millimeters. Depths are very low at this site, which prevents the dispersion of the sediment and, consequently, concentrations are higher than those at other disposal sites.

When assessing the impact on marine coastal resources in the direct influence area during the construction phase, it was found to be of an adverse character, direct and indirect, of a certain occurrence, with a fast development, a medium magnitude and a medium duration on the aquatic fauna and flora because it will affect the quality of the water initially. Once restored, fish and macro-invertebrate populations will return to their normal state. In the construction phase, the significance level is medium or moderate (**-5.60**).

Operations Phase

When the Expansion Project is completed, the risk of adverse impacts on marine coastal communities will be similar to the current ones, with an increase due to the higher traffic through the Canal. This means that there will be slight increase in navigation channel maintenance work, as well as in the risks associated with ship traffic as more and larger ships transit the Canal. During the operations phase, it is expected that with the increase in the number of transits there will be an increased risk of spills of pollutants[29]. However, this risk can be considerably reduced with the proper implementation of the ACP contingency plan prepared in accordance with MARPOL specifications and customized for the Panama Canal: the Panama Canal Ship Oil

[29] According to information provided by ACP, the history of spill incidents is mostly associated with the collision of ships at the entrance to the locks, the number of which have dropped in the past years, in addition to MARPOL requirements that tankers be fitted with double hulls.

Pollution Emergency Plan (PCSOPEP). The ACP Pollution Control Unit is prepared to respond to emergency situations caused by hydrocarbon spills (PB Consult, 2006).

In this regard, the impact on aquatic resources during the operations phase is of an adverse character, direct and indirect, of a certain occurrence, medium development, moderate magnitude and permanent duration. Therefore, this impact is rated as having a medium or moderate significance level (**-4.16**).

7.4.12 Impact on Protected Areas

Construction Phase

The land surfaces of the Protected Areas that are included in the Project Direct Impact Area are outside the footprint of the areas subject to construction activities. Likewise, there will be no direct impacts on the Protected Areas during the construction phase. No significant impacts are expected in the Protected Areas due to noise, emissions, or dust generation during the construction phase.

The Barro Colorado Island Natural Monument covers Gatun Lake water surface areas, including the existing route of the main Canal navigation channel. This aquatic area will be subject to the impacts on Gatun Lake as previously mentioned in Section 7.4.9.

During the construction phase, the impact on the Protected Areas will be of an adverse character, indirect, of a certain occurrence, with a medium development, very low magnitude and long duration. Based on this, this impact has a low significance level of (**-2.04**).

Operations Phase

The Protected Areas are not directly adjacent to the Gatun Lake water surface, because ACP property occupies the area up to the 100-foot mark. The area subject to temporary flooding will only get to the 89-foot mark. Canal operation activities will not directly or indirectly affect the Protected Areas any differently than they do at the present time. A possible general increase in the region's human population due to the economic growth expected with the Canal Expansion could, however, increase poaching pressures in the Protected Areas. The impact on the Protected Areas during the operations phase is of an adverse character, indirect, of a very probable occurrence, with a medium development, very low in magnitude and a long duration. Therefore, the significance level of this impact is rated as low during the operations phase (**-1.12**).

7.5 Impacts on the Socioeconomic Environment

Regarding the socioeconomic environment, a total of sixteen (16) potential impacts were identified. For the construction phase, eleven (11) of them are considered as direct impacts and the remaining five (5) as indirect impacts, while for the operations phase the number of potential direct impacts drops to five (5), and indirect impacts increase to nine (9).

7.5.1 Stimulus to the National Economy

Construction Phase

The main effect of the approval of the Project will be the stimulus to new investments in Canal complementary sectors. This means that the main effect of the Project on domestic demand will occur as the result of indirect, induced, and parallel impacts generated by the Canal, particularly in the sector known as the "Canal Conglomerate[30]." Investments calculated at US$5.25 billion during this phase will have an impact on the Gross Domestic Product (GDP) similar to the current impact of Conglomerate exports, and will be reflected mainly as a considerable increase in the demand for goods from the construction supply sector (rock, sand, cement, steel, etc.). They will also be reflected indirectly on the salary expense multiplier (with an increase in liquidity or cash); a demand for household goods and services; an activation of commercial sectors such as food sales; and services rendered to the staff of the various construction

[30] Impact of the Panama Canal Expansion Project on Domestic Inflation and the Some Supply Markets. INDESA – 2007.

companies, such as telecommunications, private transportation, private security, clothing, and industrial equipment, etc. The impact during this phase is considered as positive, indirect, of a very high magnitude, high accumulation and synergy, and with a medium significance level (**+4.80**).

Operations Phase

During this phase it is estimated that by 2025, Panama Canal contributions to Panama's total exports will be 19.5% more than with the Non Expansion alternative. Additionally, for that same year, fiscal revenues would be 31.8% higher with the expansion than without it. In spite of the extent of such contributions, they are considered secondary when compared to the additional economic movement that will be generated by the conglomerate of interrelated services and activities derived from the operation of the Canal, which at an aggregate level may achieve an additional annual GDP growth of 26%[31]. Although most of the initial effects of the Canal Economic System *(SEC*) on the economy will be reflected on the tertiary sector of the economy, such as commerce and services, they will also have an impact on sectors such as industry and agriculture.

In addition to the macroeconomic benefits mentioned above, the results of a revenue distribution simulation conducted by INTRACORP (2006) has forecasted that, as result of the Canal expansion, the number of people under the poverty level would drop by more than one hundred thousand by 2025. Complementarily, an additional increase in employment is estimated at 0.5% to 0.75% starting in 2015, with the generation of approximately 200,000 additional jobs by 2025. Consequently, it is considered that during that phase the Project, the impact on the Panamanian economy will be positive, indirect, of a very high magnitude, permanent duration, with very high accumulation and synergy and a high significance (**+6.40**).

[31] INTRACORP ESTRATEGIAS EMPRESARIALES, S.A. 2006. Study of the Economic Impact of the Panama Canal on the National Environment.

7.5.2 Increase in Panama National Treasury Revenues

Construction Phase

During this phase, no additional revenues as result of the Project construction activities will be generated for the Panama National Treasury[32], other than those directly expected. However, there will be revenues derived from the operation of the Canal and other related activities such as an increase in customs fees, company profit taxes, etc. Therefore, this impact is considered as indirect, positive, of a very high magnitude, and very high accumulation and synergy, reflecting in a high significance level of (**+6.80**).

Operations Phase

According to calculations made by ACP 2006a, by 2025 the expanded Canal will be able to contribute total resources to the Panama National Treasury of up to B/. 4.19 billion in payments per net ton and public service fees, as well as surpluses. Additionally, it has been estimated that during the first 11 years of operations, the total contributions to the Government of Panama will be US$8.5 billion more than what would be contributed if the Canal were not expanded.

In view of the above, this impact is considered indirect, positive, of a very high magnitude, accumulation and synergy, for a high significance level (**+7.42**).

[32] INTRACORP ESTRATEGIAS EMPRESARIALES, S.A. 2006. Study of the Economic Impact of the Panama Canal on the National Environment.

7.5.3 Job Generation

Construction Phase

It is estimated that the economic boom that will occur during the peak years will generate between 6,500 and 7,000 new direct jobs (mechanics, technicians, specialists, heavy equipment operators, and professionals in various disciplines such as project management, works supervision, design, inspection, surveys, finance, accounting, procurement, logistics, security, maintenance, planning and information technology, etc.), aside from approximately 28,500 to 33,000[33] indirect jobs. This would allow an unemployment rate drop to 3.4% by 2025[34], which would be four points below the current level. Consequently, the impact of this Project on national employment is considered positive, direct, of a medium magnitude, very high accumulation and synergy, and of a medium significance (**+4.71**).

Operations Phase

During this phase, the requirement for additional personnel experienced during the peak construction years will drop to levels close to the current ones, with the exception of an additional requirement for the operation of the new locks and routine maintenance activities. Consequently, the greatest impact on employment will be caused mainly by the expansion of the activities of the conglomerate of complementary services and activities due to the increase of Canal transits. An example of this are port activities, which will require more personnel because it will be possible to serve larger vessels that cannot be handled under the current limitations. As was previously mentioned, an additional employment growth of 0.5% to 0.75% is estimated by 2015, and approximately 200,000 additional jobs will be generated by 2025.

Consequently, the impact of the Project on employment is considered as positive, indirect, of a very high magnitude, accumulation and synergy, and a high significance level (**+6.40**).

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33 Panama Canal Master Plan. ACP, 2006.
34 INTRACORP ESTRATEGIAS EMPRESARIALES, S.A. 2006. Study of the Economic Impact of the Panama Canal on the National Environment.

7.5.4 Increase in Population and Migration Flows

The population growth forecasts shown in the Socioeconomic Study Area (SESA) will not only be due to the Canal Expansion Project, but also to the growth of the economy in general and the real estate sector specifically. This implies that the workers who will participate directly in the construction will not be the cause of a significant migratory movement.

Construction Phase

According to the migration study performed by INTRACORP in March 2007, the forecast for the 2000-2025 period shows an average annual population growth rate of 3.3% for the metropolitan areas of the Pacific and Atlantic Sides, compared to the 2.5% experienced in the 90s. Thus, by 2025 the population in the metropolitan areas will be almost 4 million, or 67% of the total population of the Republic of Panama. This forecast is 30% higher than that of the Metropolitan Plan published in 1997.

The East Pacific Urban Zone is the one showing a higher density. It is estimated that it will double its population to 600,000, increasing its density especially by using the Canal area, which can only provide just over one third of the 3,000 hectares required for such population. With a proper management of the relationship between the protected areas (Camino de Cruces Park and the Metropolitan area) and the urban area, and investments in infrastructure, a balance can be struck with the rest of the Central Urban Ensemble. The East Pacific Urban Zone is the only zone with abundant land, beyond its expansion needs. These lands are found in several forms; Juan Diaz, Cerro Viento, and Pedregal-Gonzalillo have lands that are accessible, developed and close to the centers of the city of Panama. Although less served, but always accessible through the Inter-American Highway (INTRACORP, 2007), there is more land available farther to the east.

The District of Arraijan, in the West Pacific Urban Zone, is currently showing the highest growth and is destined to maintain and even increase it. This is due to a series of factors which include the fact that it is located between La Chorrera and Panama, and near to the recently opened access to the Centennial Bridge (which may encourage the opening of new areas for expansion); and its proximity to the development going on in Howard, and to Canal work sites. The demand for space is greater than the availability of land. In this case, it is twice as much: 9,000 new hectares are needed, compared to the 4,500 available (INTRACORP, 2007). The city of Arraijan has the potential of being on the way to become a satellite to the city of Panama, with a population close to 600,000 by 2025.

La Chorrera could also experience a significant growth in support of the ensemble projected for the Panama West Zone, where Arraijan leads with its dynamic expansion. This area has the advantage of abundant adequate areas outside the Canal Watershed, it grows along the Inter-American Highway (like Chilibre does on the Transisthmian Highway), and may eventually become connected through Puerto Caimito, with Vacamonte, Veracruz, and Howard. With this, the population of La Chorrera would reach 400,000 by 2025.

In the Atlantic Urban Zone, the city of Colon has been experiencing a sustained diminishment as a city, with a slight growth in the direction of the Transisthmian highway. Nonetheless, it is expected that this trend may start reversing around the start of the Canal expansion works, because it has the land to support a sustained growth. Moreover, the areas designated for urban development are surrounded by forests that reach the banks of Gatun Lake and could encourage growth in a higher density than the one projected, spilling over to the west in the direction of Sherman, and north to Portobelo (INTRACORP, 2007).

The Transisthmian Corridor Zone is also within the Canal Watershed and has a linear settlement pattern alongside the main highway between the cities of Panama and Colon (INTRACORP, 2007). Law 259 allows low density urban uses in this zone, and therefore an increase in population is expected of more than 200,000 in the areas adjacent to the highway, adding some 6,000 hectares for urban use by 2025.

The Gatun Lake Zone is one with the lowest population density in the Socioeconomic Study Area (SESA). 14 of its 19 corregimientos have a density of less than 25/km². It is expected that the population will reach 35,000 by 2025 and that its occupied surface will increase to 1,200 hectares, mainly because of tourism and recreational activities along the shores of Gatun Lake, and not because of permanent human settlements. Construction in Colon of a bridge over the Canal may change the scenario along the northern shores of the Lake (INTRACORP, 2007).

Therefore, given the estimated requirements for growth and space, the impact on the population and migratory flows during the construction and operations phases is considered negative and of an indirect character, with a medium magnitude, accumulation, and synergy, and thus a low significance level for the construction phase (**-2.76**).

Operations Phase

During the operations phase, it is expected that the same conditions present during the construction phase will prevail. However, considering the data that reflects the expected population growth for the construction phase, space requirements may become more pressing. Therefore, the impact during the operations phase is considered negative and of an indirect character, of a medium magnitude, accumulation, and synergy, and a medium significance level of
(**-3.63**).

7.5.5 Changes in Land Use

Construction Phase

It is very probable that the space demand as result of this phase, for new settlements in some of the zones of the Socioeconomic Study Area will cause a direct pressure on their existing natural resources, by competing for space for uses that currently provide productive and environmental services, even to the Panama Canal. Likewise, it is expected that the economic boom resulting from the Project and its conglomerate will create a demand for new space in the Metropolitan Region.

Consequently, given the estimates of direct and indirect labor and space requirements, the impact during this phase is considered of a negative character, direct, of a low magnitude, low accumulation and synergy, and a low significance level of (**–2.86**).

Operations Phase

By 2015, the impact of the Project on land use dynamics will not depend as much on its operations as on the development of activities that are complementary and/or additional to Canal operations, such as those of the Canal Conglomerate, the residential boom, and the performance of the economy in general which, as previously mentioned, will experience a significant growth. Likewise, another change in land use may take place in the Gatun Lake area. Due to the increase in the Lake level, some agricultural or forestry use zones may be permanently flooded, a situation that may affect the economic activities of some of the residents or owners engaged in these types of activities. Nonetheless, we must not disregard the fact that this change in land use can also be beneficial to residents engaged in fishing activities, as the rise in Lake levels would imply less transportation restrictions and better fishing opportunities.

Consequently, the impact during this phase is considered negative, indirect, of a medium magnitude, accumulation and synergy, and a medium significance level of (**-3.51**).

7.5.6 Impact on Vehicle Traffic due to an Increased Demand for Transportation

Estimates of the overland transportation demand as well as the Project impact on the road network with the existing transportation system were developed as part of this Study. The main aspects evaluated were magnitude, division by mode, and spatial distribution, as determined by the accelerated growth in economic activity, including real estate development, tourism, and the Canal expansion.

Cargo transportation was excluded from the analysis because, according to available information, excavated and dredged material will not be moved over the West Pacific Urban, East Pacific Urban, or Atlantic Urban zone road network because the disposal sites on land and water are located in the vicinity of the Project areas and internal roads, as well as aquatic routes, will be used for this purpose[35].

The 06:00 – 08:00 a.m. morning schedule was used as the period to analyze the various routes, as these are the peak hours that also coincide with the starting time of one of the Project work shifts. An occupancy rate of 1.6 persons per vehicle was applied for trips in privately owned vehicles, which is a reasonable average according to the known trends for the city of Panama. In the case of trips by public transportation, an occupancy rate of 50 persons per vehicle was used. An equivalent factor of two (2) was used for each public transportation unit. This means that a bus has twice the effect on the road network than an automobile, because it occupies more space and is not as efficient in accelerating and braking[36].

Additionally, it was assumed that each employee hired has a number of dependents with trips of an extent and mode similar to those of the rest of the population. Travel is estimated with a peak trip period per employee, as all workers on the same shift arrive during that interval. The transportation mode will vary depending on their income level, which in this case creates a hypothesis about their place of residence, and there are typical mode division indicators available for each sector being considered.

[35] Analysis on the subject of transportation made by Contrans Group for the Canal Expansion EIS (2007).
[36] Highway Capacity Manual. Transportation Research Board, Washington, D.C., U.S. 2000.

Construction Phase

An additional overland transportation demand for this phase will occur between 2007 and 2014. Two simultaneous work fronts are considered; one on the Atlantic Side and another one on the Pacific Side, with a total of 6,000 workers split into two shifts.

The Atlantic Side work front would generate a daily movement of 1,500 persons during the peak morning period, that is, 480 trips in privately owned vehicles (300 vehicles), and 1,020 trips by public transportation (20 buses); while the associated population would generate 289 trips in privately owned automobiles (181 vehicles), and 616 trips by public transportation (12 buses).

In turn, the Pacific Side work front would generate the same number of daily trips as the Atlantic front during the peak morning period, grouped in 487 trips in privately owned automobiles (304 vehicles), and 1,013 trips by public transportation (20 buses); while the associated population would produce 644 trips in privately owned automobiles (403 vehicles) and 767 trips in public transportation (15 buses).

The overall peak hour transportation demand in the city of Panama (East Pacific Urban Zone), takes place under practically total saturation conditions of the main road system, with the exception of the Centennial Bridge and its access roads, the Panama-Colon Highway, and Madden Road beyond the Centennial Bridge, according to analyses of simulations with the model for the city of Panama. Moreover, by extrapolating the volume of vehicle flows to the 2009-2010 period, the following indicators have been estimated that portray the current situation: a mean distance of 16 km is traveled per trip, the average time is over 70 minutes, and the average traveling speed is 13 km/h. (Annex II - Transportation).

In the case of the **Atlantic Urban Zone**, it shows its highest traffic flow into Colon over the Transisthmian Highway during the peak morning period with volumes close to full capacity in the sections closest to the city. The rest of the roads show a level of service improved by the expansions that have been made to it to facilitate cargo traffic. However, road operations are not fluid due to the high percentage of heavy duty vehicles. It is estimated that the situation will improve significantly in the future after the scheduled expansions and major maintenance are completed, as well as with the completion of the Panama – Colon Expressway.

Bolivar Highway, the access road to the works from Colon, has only one lane per side, no shoulders, and irregular pavement, which translates into a limited road capacity. Notwithstanding, it operates fluidly due to the low intensity of the current traffic. Bolivar Highway is expected to become the access route to the Atlantic works front. It is estimated that there will be over 600 vehicles traveling in each direction, due to the joint effect of urban development and the Canal Expansion Project. This translates into volume/capacity ratios of over 0.40, which mean a very manageable degree of involvement. The route that connects the towns on the west side of the Canal with the city of Colon through the Gatun Locks Bridge will probably be affected by the construction activity. A ferry service across the Canal is in the implementation process and could solve the traffic problem west of the locks. With proper planning, the interference from maritime traffic would be low.

On the basis of the demand estimates made[37], traffic between Colon and Panama would be in the order of four thousand equivalent vehicles[38] (06:00-08:00 a.m.) in the direction of the city of Panama, and 12 thousand equivalent vehicles in the direction of the city of Colon, distributed between the Transisthmian Highway and the future Expressway. The maximum number the Transisthmian Highway could handle in two hours would be the equivalent of six thousand vehicles in each direction. Therefore, in the direction of the city of Colon, the rest could be handled by the Expressway (six thousand in two hours), which also represents an important degree of involvement for the future Expressway. At Pedro Miguel, Madden Road, traveling in the direction of the city of Panama, would also reach full capacity. Westbound traffic would be distributed almost equally between the Pan-American Highway and the Centennial Bridge, because the former is unable to handle the growth in volume. In this context, the Centennial axis would reach a volume – capacity ratio beyond 0.80.

[37] Analysis on the subject of transportation made by Contrans Group for the Canal Expansion EIS (2007).

[38] Equivalent vehicles refers to the sum of passenger automobiles, plus heavy duty vehicles (buses and trucks) with their respective equivalence factor.

In summary, the total number of daily trips made by workers employed in the Canal Expansion works and by their associate population will be 5,316, of which 1,900 (36%) would be made in privately owned automobiles, and 3,416 (64%) using public transportation. These trips would represent 1.1% of the total trips over the system by 2015, 0.9% of the trips in privately owned automobiles, and 1.3% by public transportation, involving 1,188 privately owned automobiles and 68 public transportation units.

Another important aspect to consider during this phase is that it is expected that Contractors may set up a special bus service for workers to reach their work sites. During the peak construction years, this service may mobilize an estimated 6,000 workers per day. It must be pointed out that similar numbers traveled to and from these areas during the operation of the U.S. military bases.

Consequently, the estimated transportation demand allows the assumption that during this phase the Project will generate a negative, direct impact, of a low magnitude and accumulation, moderate synergy, and with a low level of significance (**-3.14**).

Operations Phase

With respect to the future situation, demand estimates for 2015, despite the fact that they do not depend directly on Project operation, generally translate into a heavier involvement of the road network.

It is considered that the greater demand for transportation during the years following the construction will also be accompanied by better financial means to improve road infrastructure. In this regard, despite the forecasted increase in demand for the use of the road infrastructure, important improvements are being considered to this aspect over the medium range, such as the construction of an overpass to replace the current crossing through the Gatun locks, which will result in a noticeable improvement in the flow of vehicles to and from the communities located along the eastern shores of the Gatun Lake. This allows the assumption that during this phase of the Project a negative, indirect, located impact will be generated, of a medium magnitude, accumulation and synergy, and a low significance level of (**-2.21**).

7.5.7 Impact on Public Infrastructure

Construction Phase

The areas where the construction works will take place are located in areas under the exclusive administration of the Panama Canal Authority; therefore, any utility infrastructure to be relocated or modified belongs mainly to ACP. This infrastructure includes mains and potable water distribution pipes that feed the Panama-Pacific Special Economic Area (SSAPP), Farfan, Palo Seco, Veracruz, the former Rodman Naval Base, Cocoli, Horoko, and areas of Arraijan, as well as sewerage, ACP high voltage transmission towers and lines from the Miraflores thermal power plant, some power transmission lines belonging to ETESA out of the La Chorrera substation (230-3A, 230-4B lines), and part of Borinquen Road, drain culverts, minor buildings, fences, and power line posts.

On the Atlantic Side, specifically in the Jose Dominador Bazan townsite, eight buildings belonging to the Ministry of Economy and Finance, of which four are occupied by the Ministry of Housing, will be transferred to the ACP for Contractor use.

Additionally, during the construction of the Project, limitations may be imposed on the use of the crossing through the Gatun locks, a situation that can affect the daily activities of the Colon Lower Coast (Costa Abajo) communities.

Considering the above, this impact is rated as negative, direct, of a low magnitude and accumulation and non-existing synergy, with a low significance level of (**-1.12**).

Operations Phase

During this phase there are no plans to perform works that may cause additional impacts on the existing public infrastructure, and therefore, no new impacts to the public infrastructure are expected.

7.5.8 Impact on Structures

Construction Phase

In spite of the fact that all areas adjacent to the Canal are, by constitutional provision, for the exclusive use of ACP, there are communities settled under the 30.48 m (100′) PLD level mark around Gatun Lake, along the boundaries of the Direct Impact Area of the Project. Some structures in these communities are located under the 27.1 m (89′) PLD level mark, at the proposed maximum operating level; therefore, they could be affected at the end of each rainy season when the Lake reaches its maximum operating level[39]. It must be pointed out that no increases in the Lake level over those reached during construction are expected during the operations phase. For this reason, although fluctuations may occur during Project operations, the impact is analyzed for the construction phase when the initial impact would take place.

In March 2006, ACP conducted a topographic survey to validate the preliminary information supplied by Moffatt & Nichol / Golder, 2005. This survey, performed in 47 communities located on the banks of Gatun Lake, identified a total of nine (9) dwellings, 57 structures of other types (public and private docks or piers, water intakes, etc.) that could be affected with the raising of the maximum operating level of the Lake (see Table 7-23).

[39] Panama Canal Master Plan

Table 7-23

Potential Impact on the Gatun Lake Structures

Community	Structure	Elevation	Coordinates
Ciricito	Pier	26.8	601097 997628
Cuipo	Dwelling	27.08	604164 1003833
	Toilet 1, Four Square Church (4 stalls)	27.1	604290 1003686
	Toilet 2, Four Square Church (4 stalls)	26.9	604261 1003691
	Pier	27.04	604262 1003709
	Water intake	26.6	604233 1001718
	Pier	27.1	604493 1003495
	Water intake	26.5	604364 1003395
La Arenosa	Dwelling	26.6	615438 999610
	Dwelling	27.1	615283 999612
	Dwelling	27.1	614611 999014
	Dwelling	26.9	615395 999289
	Dwelling	26.8	615505 999494
	Community Board (Terrace)	27.0	615428 999587
	Pier	26.6	615438 999610
	Pier of the Panama Merchant Marine Vocational Institute	26.5	614843 998909
	Pier of the Panama Merchant Marine Vocational Institute. On dry land.	26.9	614815 998836
	Dwelling pier	26.8	615428 999390
	Water intake	27.0	615573 999301
La Leona	Private dwelling pier	26.9	615835 998352
	Private dwelling pier	27.1	616003 998304
Coca Cola	Private dwelling pier (part of the lake closed with buoys)	26.8	

Community	Structure	Elevation	Coordinates
	Dwelling pier	27.1	615195 996866
	Dwelling pier	27.0	616398 997145
Campo Alegre	Dwelling	27.0	608887 1002963
	Hut	26.0	608882 1002377
Lagarterita	Pier	26.6	619215 1003920
	Storage	26.6	619215 1003920
	Pier	26.3	618977 1003700
	Pier	27.0	619143 1003879
Escobal	Pier	26.7	614086 1011033
	Pedestrian bridge	26.7	613855 1010929
Los Cedros	Pier	27	602861 1000039
Arrecifal	Pier	26.7	603887 999468
Los Laguitos	Pier	26.8	605487 9943112
	Storage	26.7	605248 994814
La Represa (La Laguna)	Pier	26.9	627892 999808
	Pier	27.0	627881 999728
	Fence with cement and cyclone fence	27.1	627881 999728
	Pier under construction	26.8	627881 999728
	Pier	27.0	627708 999845
	Boat garage (cement structure)	27.0	627767 999859
	Pier and water intake	27.1	628045 999468
	Eco-forest pier	26.7	628900 1001942
Pueblo Nuevo	Cement stairs	26.8	628175 998856
	Pier	27.1	628298 998875
	Pier	26.8	628394 998847

Community	Structure	Elevation	Coordinates
Isla del Sonido del Silencio	Hut	27.1	633158 1006650
	Huts	27.0	633158 1006650
Limón	Cyclone fence with concrete base.	26.8	629974 1023337
	Cyclone fence with concrete base (in back of dwelling)	26.2	629898 1023307
	Pier (Community)	27.1	629991 1023490
Nueva Providencia	Pier (private)	26.5	629787 1023584
	Pier (private)	26.8	629685 1023652
	Piers (private)	26.8	629626 1024413
	Shed Pier	26.3	629441 1023900
Santa Rosa	Community Stop	26.7	647918 1015381
La Represa (Atlantic)	Hut	26.9	627904 1031530
Barro Colorado Island (STRI)	Pier	27.1	627786 1013020
	Motor work shop and gasoline pump	27.1	627730 101304
	Carpentry work shop	27.1	627760 1012997
	Forest Ranger Office	27.1	
Península Gigante (STRI)	Pier	26.8	625739 1009043
	Generator shed	26.7	
Caña Brava	Dwelling	27.1	603890 1002936
Lagartera	Dwelling	27.1	619471 1007942
Total	**66**		

Source: ACP – Inventory of Infrastructures located at the 27.1 meters (89 feet) mark on Gatun Lake

Subsequently, in May 2007, URS made a validation of the existing information because it considered this impact as being of high social sensitivity. The results obtained showed the need to make a full inventory of all the structures existing along the banks of the Lake to allow a certain identification of the number of structures and dwellings that could be affected with the raising of the level of the Lake.

Regarding the impacts to structures during the construction of the locks and water saving basins, in the former town of Gatun (Atlantic Side) four (4) semidetached dwellings were identified, currently occupied by non-ACP persons. In the Cocoli area (Pacific Side), six (6) buildings were identified that are being used for spiritual retreats, which will be affected with the diversion of the Cocoli River. Currently, the owners of the structures involved have been made aware of this information. The Project includes resources to modify or relocate the structures that could be affected, and their owners will be appropriately indemnified or compensated.

In view of the above, it is considered that the impact of the expansion works during this phase will have a limited and specific effect on private infrastructures existing in some of the Socioeconomic Study Areas (SESA). Therefore, their impact is rated as negative, direct, of a moderate magnitude, without accumulation or synergy, and with a low significance level of (**-2.72**).

Operations Phase

On the other hand, there are no plans to make any additional increases in the operating level of Gatun Lake during the operations phase, and therefore, there will be no additional impacts to structures.

7.5.9 Property Revaluation

This impact refers to changes with an increase or reduction in the value of the properties as a result of Project works.

Construction Phase

There could be an increase in property values as a result of work performed during the construction phase near populated sites or communities such as Jose Dominador Bazan and

Gamboa, due to an increase of personnel in the area and a greater demand for goods and services by construction workers.

In view of the above, the impact is rated as positive, indirect, of a probable occurrence, with a slow development, medium magnitude, and low accumulation and non-synergic; therefore, it is of a low significance (**+1.30**).

Operations Phase

During this phase, the development of the Project will produce positive impacts, including the revaluation of land in areas such as Jose Dominador Bazan. This, and landscape changes with views of the new locks and transit activities through the expanded Canal, will add appeal to the surrounding land for the establishment of new activities.

Consequently, this impact is rated as positive, of a probable occurrence, indirect, of a medium magnitude, permanent duration, low accumulation and no synergy, for a low significance level of (**+1.40**).

7.5.10 Increase in Risk of Work-Related Illnesses

Construction Phase

Workers may have health problems during the construction phase that may include respiratory illnesses due to extended exposure to contaminating gases from internal combustion equipment and/or dust particles (less than 10 micras), or gastrointestinal diseases from the ingestion of bad water and/or contaminated food. Also, stagnant rainwater may lead to the breeding of mosquitoes that are potential vectors for the transmission of contagious diseases such as dengue and malaria. Despite this, it is not expected that the construction works will cause a significant impact on worker health.

Considering the enforcement of ACP occupational health and safety regulations, and the compliance with its sanitation and health programs to prevent contagious diseases that it requires from its Contractors, the impact of an increase in diseases is rated as negative, direct, of a probable occurrence, medium development and magnitude, of long duration because it could arise as long as the construction activities last, with very low accumulation and non-existing synergy, for a low significance level of (**-1.42**).

Operations Phase

In this phase, the large scale requirement for additional personnel will have ceased and, therefore, the risk of an increase in diseases due to the Project will be practically non-existent.

Thus, the impact of an increase in diseases during the operations phase is negative, direct, probable, of low magnitude, of very low accumulation and non-existing synergy, with a low significance level of **(-1.12**).

7.5.11 Increase in Risk of Work-Related Accidents

Construction Phase

Although routine maintenance work is ongoing in the Canal and projects have been undertaken to widen Gaillard Cut and deepen navigation channels at the entrances to the Canal (on the Atlantic and the Pacific Sides) and in Gatun Lake in recent years, the rate of fatal accidents has been very low. During the Project construction phase there will be the constant risk of accidents due to the use of heavy machinery and equipment, as well as the handling and transportation of hazardous and/or flammable materials and substances by Contractor companies. This risk increases based on the number of Project workers, as well as on the magnitude and duration of the works. Consequently, some increase is expected in the need for emergency and medical treatment of Project workers in the cities of Panama and Colon during the construction phase.

This will require that Contractors maintain first aid stations and an efficient ambulance service with paramedics for prompt transportation of emergency cases.

This impact is considered negative, direct, of a very probable occurrence, high magnitude, and long duration, as the risk will exist while construction work is ongoing, yet it will not be cumulative or synergic. In view of the above, it is rated with a medium significance level of (**-5.33**).

Operations Phase

In view of the strict safety standards in force at ACP, it is not expected that the additional number of jobs generated by the operations of the expanded Canal will increase the risk of accidents beyond that of the current operation.

Thus, the potential impact of the Project due to an increase in the risk of work-related accidents during this phase is considered negative, direct, of a probable occurrence, low magnitude, permanent duration, no accumulation or synergy, and of a low significance level of **(-1.45**).

7.5.12 Changes in Crime Rates

Construction Phase

Since the impact of migration is low, and the increase in direct and indirect employment levels has the effect of improving the quality of life and reducing criminality, a rise in the crime rate is considered very unlikely during the construction of the expansion Project.

With these assumptions**,** it is estimated that the impact on the security of the citizenry is negative and indirect, of very low magnitude, accumulation and synergy, and a very low significance level of (**-0.40**).

Operations Phase

During this phase, a potential increase of the crime levels would not be directly attributable to the Project, but rather to related activities, and would be negative, indirect, of very low magnitude, accumulation and synergy, with a very low significance level of (**-0.09**).

7.5.13 Public Service Overload

Construction Phase

The construction works will require more use of the public services available in the area by Contractor personnel and their dependents, such as water, electricity, telephone, and security, as well as other government services such as customs brokerage, work permits, etc. At the present time several buildings in Contractor areas are unoccupied and when construction begins, they must be rehabilitated and equipped with the basic utilities, which will generate a demand for them. Contactors may also require foreign labor who must comply with government requirements, causing an increase in work permits and customs applications.

With respect to the health infrastructure, it is not expected that the construction works will create a significant pressure on the installed capacity, because most of the labor will be of a local origin, and will acclimated be to the weather conditions in Panama. Moreover, the Environmental Management Plan establishes a series of standards to ensure good worker safety and health during their activities, and for this reason no pressure is expected on the existing health infrastructure.

Consequently, the impact of this phase on public services will be negative, indirect, of a low magnitude, accumulation, and synergy; and a low significance (**-3.24**).

Operations Phase

In the operations phase, the revenues generated by the Expansion Project will start stimulating growth in other economic sectors, for which the Government of Panama will have to provide more and better public service coverage. Historically, the demand for power has grown parallel to the country's economic performance (INDESA, 2007).

Regarding the requirement for additional electric power for the operation of the Third Set of Locks, the power will be provided by ACP itself, and it has sufficient installed capacity for this purpose; therefore, there will be no additional pressure for this resource.

In this regard, this impact has been rated negative, indirect, of a medium magnitude, accumulation and synergy, with a medium significance level of (**-3.45**).

7. 5.14 Increase in Waste Generation

Construction Phase

The significant increase in the number of employees required for this phase may generate more waste at the construction works and in adjacent areas, which can create pressure on the existing waste disposal system. Likewise, the a great number of heavy equipment and machinery units used in this phase will also generate non-organic, even hazardous, waste that will be necessary to dispose of adequately.

In view of the above, this impact is considered negative, direct, of a moderate magnitude and accumulation, low synergy and a medium significance level of (**-3.98**).

Operations Phase

Once the construction phase is completed, the operation of the expanded Canal will generate waste levels higher than those on record to date, due to a slight increase in the number of workers in the area and a larger number of tourists, as well as the use of more equipment in lockage and routine maintenance activities, with the attendant generation of waste.

As long as the policies set by the ACP with respect to the generation and treatment of waste are followed, it is considered that this impact will be negative; direct; of low magnitude, accumulation and synergy; and of a low significance level of (**-0.93**).

7.5.15 Increase of Tourism Flows

Construction Phase

Tourism is one of the economic activities with the most dynamic growth in the past years. The expansion works will not only not interrupt the current traffic of cargo and tourists, but will also generate additional interest both at home and abroad to visit the Canal and witness the magnitude of the expansion works.

Therefore, it is considered that this impact is positive, direct, with a medium magnitude, a low accumulation and synergy, and a low significance level of (**+2.48**).

Operations Phase

Once the Canal expansion works have been completed and the security restrictions imposed during the construction phase have been lifted, it is estimated that the interest in visiting these works will be even greater. Thus, this impact is considered direct and positive, of a medium magnitude, low accumulation and synergy, and a medium significance level of (+**3.64**).

7.5.16 Landscape Changes

As noted in the Socioeconomic Baseline chapter, the Socioeconomic Study Area covers industrial, natural, and urban landscapes, and it is the industrial landscape that predominates in the Direct Impact Area. This section seeks to evaluate is the "visual impact due to the alteration of the landscape." Therefore, for such an impact to occur, it must be observed or perceived by a receptor. From this point of view, impacts on the landscape that are not perceivable by a receptor are not considered a visual impact. Thus, there could be an impact on the landscape, but it may not necessarily be a visual impact because the areas are distant from possible "observers" or receptors.

Construction Phase

Based on what was explained above, the visual impact during the construction phase will be evident mainly in the industrial landscape adjacent to the Project area. Although there will be alterations to the landscape due to new physical elements (locks, dikes, channels), the resulting landscape or visual perception will be consistent or compatible with the existing landscape. The changes that will be caused to the natural landscape mainly because of the configuration of the land and the construction of the Borinquen dikes would be seen mainly from viewing areas in the East Urban and West Urban zones. These changes will be associated with the excavations required on the Pacific Side, including the leveling of the Cartagena Hill.

It is clear that the physical elements of the Project will not affect or interrupt the urban landscape of the six zones analyzed by this Study. The sole exception will be the area of dwellings in the former town of Gatun that will be eliminated to make way for Project construction works, or incorporated to Contractor facilities. Thus, in view of their current state of neglect, they are not considered a landscape that is being properly utilized and therefore do not have a specific value.

Although construction activities will generate interest among the public in general and could become a tourist attraction, they are considered negative and direct an impact on the landscape because they will interrupt or alter the harmony of the landscape in the Project area. This impact will develop very slowly, with a low magnitude and a medium duration. It is not considered as having a cumulative or synergic effect, and is rated with a low significance level of (**-1.18**).

Operations Phase

During the operations phase there will be a visual impact due to the changing landscape with the transit of larger vessels that will be seen Socioeconomic Study Areas adjacent to the Project area. Urban landscapes will not be altered during Project operations.

Four locations for significant viewing locations were found from which the Project landscape may be seen: the Bridge of the Americas, Jose Dominador Bazan town (the former Fort Davis), the Miraflores Visitors Center, and the Centennial Bridge. The factors used to determine their importance were their proximity to major elements of the works and the number of persons that would view landscape changes from these locations at any given time.

To show a receptor's visual perspective, a photographic simulation was done of what the landscape would look like from these viewing areas once the works are completed. This analysis is reflected in Figures 7-4, 7-5, and 7-6 with views of the conditions before and after the works.

No simulation for a location at the Bridge of the Americas location was made due to its location from infrastructures, and because any such overlook would considerably limit the view of observers driving through this site. This must be analyzed from the perspective of the fact that the Bridge is one of the country's tourism symbols. Its location at the Canal entrance may allow aerial views with transiting Post-Panamax vessels that were previously unable to transit in the area. It will also allow the viewing of the new developments at the ports which are part of the benefits associated with the Canal Expansion Project. It is assumed that these viewing conditions will spark more interest in people to drive over the Bridge, thereby increasing the tourism value of the infrastructure.

In the Jose Dominador Bazan area, the view will be of the existing grassland being replaced by an industrial type landscape, as the area will become part of the route vessels will use to transit the Canal. Although these changes will change the existing vegetation, it is considered that they will have a positive effect on the residents because the value of their homes may increase with the tourism appeal generated by the Project. Also, they will experience less impact from the constant grassland fires (Figure 7-4).

From the Miraflores Visitors Center, the natural background landscape will be interrupted by an industrial landscape dominated by the Borinquen dikes and the new navigation channel to be used by Post-Panamax vessels. Although the background will be interrupted by views of the Project works, it is considered that the main landscape that constitutes the appeal of the Visitors Center is the Panama Canal and its locks, and for this reason the new landscape will be consistent with the current situation. The addition of this element to the landscape is considered a visitor attraction that will bring economic benefits for the Canal and the country in general (Figure 7-5).

The Centennial Bridge photographic simulation provided a clear view of the transformation of the natural landscape as a result of the leveling of the Cartagena Hill. It also showed that the resulting landscape will be similar to the previous one because it will consist of natural as well as industrial landscape elements. With this transformation of the natural landscape, a more continuous horizon will be viewed that will provide a feeling of openness and space (Figure 7-6).

The analysis of this impact in the construction phase is considered positive and direct for the reasons explained above. Its occurrence will be certain; its effect will be very fast, of medium magnitude and permanent duration. On the other hand, due to its visitor appeal and economic benefits, its effect is deemed moderately synergic and non-cumulative. The rating of these attributes is of a medium significance level of (**+5.50**).

7.6 Impact on Historical–Cultural Environment

Reportedly, four of the six Socioeconomic Study areas have archaeological deposits and/or historical sites that will suffer negative impacts due to the expansion works and because of the construction of temporary and permanent access roads, excavations and backfills, discharge of excavated and dredged materials, the construction of locks and basins, and the demolition of structures.

7.6.1 Impact on Known Historical and Archaeological Sites

Construction stage

In the Gatun Lake zone there will be an impact on some sections of the old Panama Railroad due to the construction of access roads and the water saving basin excavation, as well as the deposit of materials at disposal sites T2 and T3. The state of the former Culebra, Rio Grande River and Emperador townsites has changed since the times of the original Canal construction with the effect of Canal maintenance works and the widening of the Gaillard Cut. These towns were dismantled and currently do not exist. The bank has been moved over 200 meters, which means there will be no effect on their sites because they are no longer there.

In the West Pacific Urban Zone, specifically in the sections of the Project area, there will be an impact due to the excavation of the Third Set of Locks approach channel on the Pacific Side (Cocoli deposit) and the excavation of the new layout of Borinquen Road. The magnitude of the impact is certain; however, it is important to point out that prospecting and archaeological rescue have already done in these zones. An impact of equal magnitude and certain character will take place at the El Faro deposit with the future excavation to relocate the Cocoli River channel and the deposit of excavated material at this site (Cocoli South 2 Disposal Site). There will also be an impact from the Expansion Project excavation on #39 (a historical structure) from the construction of the water saving basins of the Pacific Side Third Set of Locks (Miraflores) over the remains of historical machinery at the #39 excavation area, and the deposit of excavation materials. The machinery is still visible today in the area adjacent to the #39 excavation site on the Pacific Side.

In the East Pacific Urban Zone, there will be no construction activities on the east bank of the Canal, and no impacts at the historic towns of Paraiso, Pedro Miguel, Gamboa, the archaeological remains of Cruces town, or Las Cruces Road dating back to colonial times.

In the West Pacific Urban Zone associated with the Project area, no archaeological sites are expected to be affected, because the remains of the pre-Columbian deposit at Farfan beach is distant from the Farfan disposal site.

Therefore, it is concluded that the construction phase of the Expansion Project will have a negative, direct, high magnitude impact of a moderate significance level (**-3.80**) on known archaeological sites.

Operations phase

No impact is expected on known archaeological sites during the operations phase, because by that time, the construction works that would cause such impact would have been completed.

7.6.2 Impact on Unknown Archaeological Sites

Construction stage

This impact was evaluated using the following sources:

- The description of places described in colonial chronicles;
- Historical and colonial maps (from the fifteenth century up to the twentieth century);

- Field data collected and other research conducted in areas with physiographic and climatic characteristics similar to those in the Canal areas where “patterns” have been detected; and
- Universal settlement patterns data (rocky shelters, proximity to water springs, hilltops, etc.).

There is a great gap in the research data on the Great Darien cultural region to which the Canal area belongs. Given the circumstances, some patterns identified in places outside the study area can be extrapolated to the Canal area, such as the information on settlement patterns obtained from the well known research done by Cooke and Griggs in the area of northern Cocle (Cooke et al 2001), which seems to be close in orography and weather. According to this report, Toabre and northern Cocle river basin settlements were characterized by the existence of small, dispersed communities and some villages (LP-16,LP-22,LP-29) where, according to Griggs[40], (1998) the natives were engaged in the making and bartering of goods (hatchets, salt, cotton blankets). The compilation of data on the environmental and cultural resources of the area of northern Cocle (Cooke et al. 2001; Griggs 2005) also shows that the pre-Hispanic settlement was more intense at higher elevations with cooler and healthier conditions.

After consulting the above mentioned sources and the corresponding analysis, it is concluded that the potential impacts of the Expansion Project on unknown archaeological resources during the construction phase will be negative and direct, of a medium magnitude, low accumulation and synergy and, therefore, of a low significance level of (-**2.90**).

Operations phase

No impact is expected on known archaeological sites during the operations phase, since it would end with the completion of the construction works.

40 *Archaeology of Central Caribbean Panama*. Ph.D. thesis. University of Texas

7.6.3 Impact on Indigenous Peoples

The total population of the Socioeconomic Study areas identified as belonging to some ethnic native group is very small, being practically non-existent in the villages of interest close to the Direct Impact Area. Inside the DIA there are no protected areas or sections with special dispositions for human groups. Consequently, it is considered that this will not apply to the Panama Canal Expansion – Third Set of Locks Project.

7.7 Transboundary Impacts

From this analysis, the conclusion is that no occurrence of transboundary impacts is expected, that is, beyond the borders of Panama. Nonetheless, there are a series of impacts that have been identified for the operations phase that may qualify as transboundary impacts because of their regional or global scope.

The identified potential impacts are mainly related to the increase in maritime traffic over through the international routes that will seek a link with the expanded Canal route, and the potential transit of deeper draft vessels (Post-Panamax). These aspects may cause the following impacts:

- An increase in the risk of accidents over international routes
- An increase in tolls for some countries
- Improvement in the reliability of shipping companies using the Canal route
- Reduction in maritime transportation costs with the use of Post-Panamax vessels
- Reduction of greenhouse gas emissions

The following are some considerations about each one of these potential impacts.

7.7.1 Increase in the Risk of Accidents over International Routes

Due to the increase in usage frequency of some maritime routes in international waters that may wish to use the Panama Canal route to travel from the Pacific to the Atlantic and/or vice versa, the risk of vessel accidents over such routes could increase, because of malfunctions or even inadequate vessel crossing operations on the high seas. At the present time there are no studies to reach any conclusions in this regard. If such risk materialized, it would be negative and direct impact with a magnitude that would depend on the type of accident and its possible consequences. It is clear, however, that due to the existence and compliance with navigation rules and good practices, such an impact would have a very low probability of occurrence and an immediate development, and would not have cumulative or synergic effects; therefore, its significance would also be very low (**- 0.24**).

7.7.2 Effect of an Increase in Tolls for Some Countries

The Environmental Feasibility Report of the Canal Expansion Program (ACP, PB Consult, 2006), states that at the request of ACP, studies were made to determine the impact an increase in tolls would have on various regional and global economies, and it concludes that "an increase in Canal transit costs would not have a high impact on the transit, although it will vary depending on the segment of Canal clients." The Feasibility Report also mentions that the impact on some specific countries such as Chile, Peru, Japan, the United Sates and others was analyzed, and the conclusion was that the general effect would be low.

On the other hand, the economic impact resulting from an increase in tolls was discussed during the IPC – ECLAC meeting of December 18, 2006 in Santiago, Chile, where representatives from countries and organizations made presentations on the topic. After consulting the ECLAC report about this event[41], it is clear that the expectation of the current users is that the Canal expansion

[41] http://www.eclac.cl/cgi-bin/getProd.asp?xml=/drni/noticias/noticias/8/27438/P27438.xml&xsl=/drni/tpl/p1f.xsl&base=/drni/tpl/top-bottom.xsl

should reflect a reduction in the cost of maritime transportation and not an increase, although the speakers expressed their understanding of the need for an increase in tolls.

Based on the analysis of the information available on this topic, it is concluded that the potential impact of the increase in tolls for some countries on regional and global economies will be negative and direct, of probable occurrence and slow development, of a low magnitude, permanent duration, low accumulation and synergy and, consequently, of a low significance level of (**-1.66**).

7.7.3 Improvements in the Reliability of Shipping Companies that Use the Canal Route

The possibility of offering transportation on larger vessels (Post-Panamax) and the expected reduction in waiting times of vessels transiting the Canal may allow shipping companies to expand their service coverage and offer shorter times for the transportation of goods between specific markets. Currently, however, there are no studies that allow quantifying such potential effects, or the transportation of items that will potentially benefit from them. In any event, the potential impact will be positive and indirect, of medium occurrence probability, slow development, permanent duration and low magnitude. If it were to happen, it would have a medium cumulative and synergic effect. As a result, the significance of the impact will be low (**+1.77**).

7.7.4 Reduction of Maritime Transportation Costs by Using Post-Panamax Ships

In the same context mentioned for the previous impact, the potential reduction of the transportation distances, the increase in the volumes that can be transported in Post-Panamax vessels and the potential reduction in transportation time for the goods and products involved, appear to imply a potential for the reduction in transportation costs.

However, this impact requires to be studied in greater detail. It is considered that such impact will be positive and indirect, and of medium occurrence probability, permanent duration and medium magnitude. If it were to occur, it would have a medium cumulative and synergic effect. As result of this, it is estimated that its significance will be low (**+2.23**).

7.7.5 Reduction of Greenhouse Gas Emissions

This impact was evaluated in section 7.2.1 of this chapter.

7.8 Methodologies Used According to the Nature of the Action Implemented, the Affected Environmental Variables, and the Environmental Characteristics of the Area of Influence Involved

7.8.1 Methodologies Used

One of the major purposes of an Environmental Impact Assessment (EIA) is to objectively identify the effects and repercussions caused on the socioenvironmental conditions existing at the site proposed for the development of the Project and its area of influence. In that regard, a critical task of an EIA consists of determining the type and intensity of the Project effects, and evaluating their repercussion on the evolution of the biophysical and socioeconomic conditions of the environment.

The methodologies used for both the identification and the analysis and assessments of the impacts were selected according to the provisions of Executive Decree 209, regarding: i) the character of the actions required for the construction and operation of the Third Set of Locks;
ii) the environmental variables that could be mostly affected considering the character of those actions; and iii) the environmental characteristics of the area of influence involved. These methodologies are described below.

7.8.1.1 Identification of Impacts

The identification process considers the possible interactions between the sensitive elements and receptors in the study area, and the character of the activities and processes associated with the Project construction and operations. The various interactions of the Project with the environmental variables that could be affected by such activities and processes (physical, biological, socioeconomic and historical-cultural components of the environment) and their environmental characteristics, determine the possibility of positive or negative impacts. The identification and evaluation of impacts is done using matrices and, in the process, their character is evaluated as positive or negative, probability of occurrence, duration, magnitude, and their cumulative and synergic effects.

In addition to the requirements of Decree 209, the evaluation of transboundary impacts was included at the request of the Project promoter (ACP).

The matrix procedure used is based on the traditional methodology to prepare Leopold matrices. For its application to an EIA, a modification to the Leopold matrix is proposed (Garmendia et al., 2005), whereby the activities to be developed as part of the Project (matrix columns) intertwine with the biophysical, socioeconomic and cultural elements (matrix rows).

The impact identification matrix groups the actions or Project activities in their different phases. These actions are defined in the Project Description chapter and include the major activities with the potential to generate impacts. In turn, the elements of interest (physical, biological and socioeconomic and historical-cultural), or the factors that could suffer impacts derived from the construction, operation, and/or abandonment of the Project are described in the Baseline Description. An Impact Matrix was used to identify the potential impacts (see attached Matrix 1).

7.8.1.2 Impact Assessment

The process for the selection of impact assessment methods involves the use of a methodology accepted by the National Environmental Authority (Autoridad Nacional del Ambiente - ANAM), as the main and determining criteria, opting for qualitative and quantitative interaction tables, linear project matrices, photographic analysis, and cartographic interpretation of the theme maps generated in the baseline. Specialists applied all these techniques, according to the case. These specialists participated in the assessment in order to provide an "expert judgment."

After the analysis and assessment, environmental impacts are evaluated and hierarchies are determined according to their positive or negative, and direct or indirect condition. Also, their significance level is considered (from a Very High to a Very Low significance). The significance of an environmental impact is determined on the basis of its magnitude, duration, development time, cumulative and synergic effects, as well as probability of occurrence.

A significance index was calculated for the quantitative assessment of the impacts based on their analysis. In turn, the rating and hierarchy of the impacts is based on the results of the impact assessment, which takes into account the Project activities, the existing (baseline) conditions, and the proper methodologies for each topic being assessed.

The method applied is an adaptation of the Relevant Criteria Method (Buroz, 1994; SWECO-INGENSA-CALI, 1997; Walsh Peru, S.A. 2005; Garmendia et al., 2005), whereby a series of impact indicators are calculated, and globalized through a function that provides a unique index called "Significance (S) Index", according to the following mathematical expression:

$$\boldsymbol{S} = \mathbf{CP\{a(De \times M/10) + b(Du) + c(A) + d(Si)\}}$$

Where:

- S: Score by significance level, expressed between 1 and 10
- C: Character of the impact: (+) positive = beneficial; or (-) negative = adverse
- P: Presence (probability of occurrence)
- De: Development
- M: Magnitude
- Du: Duration
- A: Accumulation
- Si: Synergy

a, b, c, d: Weighing factors (a = 0.6, b = 0.2, c = 0.10, d = 0.10)

The criteria or parameters that allow estimating the indices or numerical values of significance are described below:

Character (C): This parameter assigns a positive or negative arithmetic value to the significance of the impact according to the character of the impact, (beneficial or adverse).

Presence or Probability of Occurrence (P): This analysis allows the differentiation of the impacts that will unavoidably occur from those that are associated to have a certainty level of probability of occurrence. An impact may be of indefectible (or certain) occurrence, may have a very moderate probability of occurrence (it is not certain that it may present itself), possible probability (its occurrence is remote, although it cannot be ruled out), and unlikely.

Development (De): Evaluates the time the effect takes to achieve maximum disturbance, on a scale from immediate, very fast, and (<1 month), to very slow (>24 months).

Magnitude (M): This attribute rates the degree of alteration (extent or size) of the initial conditions or characteristics of the affected environmental factor (expressed in percentages in the rating table). It is the extent of the impact; that is to say, the measure of the quantitative or qualitative change of an environmental parameter, provoked by an action. The rating varies from very high (90-100) to very low (0-19).

Duration (Du): Qualifies the temporality of the effect independently from all mitigation actions. The impact could be of very short duration, from just a few days or less than one (1) year, up to permanently (>10 years), after the implementation of the Project.

Accumulation (A): Rates the effects generated by Project activities and by the activities of other implemented projects (such as the existing Canal) or of those to be implemented. The cumulative impacts are defined as environmental effects expected from the combined impacts of past, present, and reasonably expected future projects within the Project area.

Synergy (Si): This parameter rates the whole effect of the occurrence of several impact causing agents, which results in an impact greater than the simple sum of the individual effects caused by each one.

Based on the degree of the referred parameters or criteria, their numerical score will vary within the weighing intervals shown in Table 7-24. With those parameters, the feasible values for the significance index fluctuate between ten (10) and minus ten (-10), with the sign indicating whether the effects are favorable or adverse. The absolute value of the significance index will depend on the results obtained when assessing the impacts. The range of feasible values allows the grouping of both favorable and adverse impacts into six significance categories according to the shown in Table 7-25 below. Matrix 2 (attached) shows the weighing values for each parameter of the assessed impacts.

Table 7-24

Range of Values for the Parameters Considered in the Assessment of Significance Ratings

Parameters	Rating	Weight
Character (C)	Beneficial	1
	Adverse	-1
Presence or probability of occurrence (P)	Certain or inevitable	1
	Very probable	0.7 – 0.9
	Probable	0.4 – 0.6
	Unlikely	0.1 – 0.3
Development (De)	Very fast (< 1 month)	0.9 – 1.0
	Fast (1 to 6 months)	0.7 – 0.8
	Medium (7 to 11 months)	0.5 – 0.6
	Slow (12 to 24 months)	0.3 – 0.4
	Very slow (> 24 months)	0.1 – 0.2
Magnitude (M)	Very high	90 – 100
	High	70 – 89
	Médium	40 – 69
	Low	20 – 39
	Very low	0 – 19
Duration (Du)	Permanent (> 10 years)	10
	Long (7 to 10 years)	7 – 9
	Medium (4 to 7 years)	4 – 6
	Short (1 to 4 years)	2 – 3
	Very short (< 1 year)	1
Accumulation (A) or Cumulative Effect	Very high	9 – 10
	High	7 – 8
	Moderate	4 – 6
	Low	2 – 3
	Very low	0 – 1
Synergy (Si)	Very high	9 – 10
	High	7 – 8
	Moderate	4 – 6
	Low	2 – 3
	Very low	0 – 1

Table 7-25

Categories of Significance of Beneficial or Adverse Impacts

Attribute	Score	Range
Significance (S)*	Very low	**< 0.6**
	Low	**0.6 – 3.3**
	Medium or Moderate	**3.4 – 6.1**
	High	**6.2 – 8.5**
	Very High	**> 8.5**

(*) = Its value is the result of the score assigned to the other parameters in the rating.

7.8.2 Nature of Actions Implemented

The Canal Expansion -Third Set of Locks Project includes three large components:

i) The construction of two complexes of locks with three chambers or levels each, with three water saving basins per lock chamber or level. The Atlantic Side complex is located on the east side of the existing Gatun locks, and the Pacific Side complex is located southeast of the existing Miraflores locks. A significant portion of the excavations of the Third Set of Locks Project begun by the United States Government in 1939 will be used for the construction of both lock complexes.

ii) The construction of the new lock approach channels, and the expansion and deepening of the existing navigation channels; and

iii) The raising of the maximum operating level of Gatun Lake by approximately 0.45 m (1.5'), that will increase the current 26.7 m (87.5') PLD level to 27.1 m (89') PLD level. This Project component will increase the usable reserve capacity of the Lake.

All Project works and the temporary facilities required for the construction, as well as the excavated and dredged material disposal sites, are located within lands reserved for use by the Canal, according to the Land Use Plan prepared by the Interoceanic Region Administration under Law 21 of 1997. These lands were part of the former Canal Zone, a strip that had been assigned to the Government of the United States for activities related to the operation of the Canal and its defense.

The Canal Expansion Project with the Third Set of Locks involves the movement of approximately 133 million cubic meters (Mm^3) (83 Mm^3 excavated, 50 Mm^3 dredged) of material. The Project consists essentially of open pit excavation and dredging works in a studied and cleared geological area. The Project does not involve underwater or subaquatic construction.

The main activities of the Project during the construction will be the following:

- Mobilization and construction of temporary facilities for the works, borrow material, and the manufacture of aggregates.
- Construction of temporary and permanent access roads
- Cleanup, grubbing, and stripping
- Excavation and backfills
- Blasting
- Stabilization of slopes and cuts
- Dredging and deepening of navigation and approach channels
- Management of disposal sites for excavated and dredged materials
- Construction of locks and water saving basins
- Construction of the Borinquen dikes
- Raising of the maximum level of Gatun Lake level
- Mechanical and electromechanical installations, and control and navigation systems.

The construction of support installations includes a diverse series of structures and components to facilitate the access and transportation of materials and equipment, as well as their proper maintenance and the manufacture of aggregates and concrete, etc. The most important include the construction of a pier required on the Pacific Side and another pier on the Atlantic Side, as well as the installation of a crushing plant on the Pacific Side; at least two concrete plants (on the

Atlantic and Pacific Sides) each expected to produce some 2 million m^3 of concrete for the construction of the locks, water saving basins, and buildings adjacent to the locks.

The temporary facilities required include field offices, storages, work shops, first aid stations, mess halls, employee transportation stations, soils and concrete laboratories. Worker camps were not considered because of the proximity of Project locations to the country's major urban centers, but it was considered that workers would be provided transportation service.

Backfill materials, impervious dike nuclei, and manufacturing of aggregates will be mainly obtained from the excavations and processed at the plants described previously.

Twenty-three (23) sites have been chosen for the disposal of the excavated and dredged material, sixteen on the Pacific Side, and seven on the Atlantic Side. All sites are located within ACP operating areas.

During the operations phase, the main activities of the Project will include:

- Operation of Post-Panamax locks with water saving basins;
- Maintenance of locks with water saving basins;
- Management of the new operating level of Gatun Lake;
- Maintenance dredging of navigation channels and anchorages (marine and lake); and
- Management of dredging material disposal sites.

7.8.3 Affected Environmental Variables

The environmental variables that will be impacted during the construction and operation of the Project and the activities that will generate such impacts are shown in the impact identification matrix (Matrix 1). These variables have been grouped in the following elements:

- Physical: climate, air quality, water and soil

- Biological: land, fresh water, and marine flora and fauna; forestry resources; and protected areas
- Socioeconomic: population, health and education, goods and services, land occupancy and use, revenues and employment, production and productivity, security, national economy, and landscape
- Historical and cultural: archaeological and historical sites

The impacts on the physical environment identified and assessed in the EIA, are as follows:

- Microclimatic changes and the loss of carbon capture potential have been considered among those related to the climate.
- Those related to the air include the deterioration of air quality, increase in noise and vibration levels, and the increase in odor perception.
- Impacts related to the soil and basement (geology and geomorphology) include cave-ins, undermining, increase in landslide risk, increase in soil erosion, increase in sedimentation, soil compacting, soil pollution and loss of land use capability.
- The deterioration of water quality, the alteration of the water flow regime and the alteration of the drainage pattern have been considered among the impacts to water.

The identified and assessed impacts on the biological environment are as follows:

- The loss of vegetative cover, forestry potential, and land fauna habitat; the direct elimination of fauna; disturbance to wildlife; increase in wildlife road kill, and the increase in poaching are considered among those related to land flora and fauna.
- The alterations of aquatic resources in rivers and creeks in Gatun Lake and in Miraflores Lake, as well as the alteration of marine coastal ecosystems, have been considered as impacts along with those to freshwater and marine flora and fauna.
- The impact resulting from the potential impact to protected areas has also been considered.

The following impacts on the socioeconomic environment have been identified and assessed:

- Greater stimulus to the national economy, increase in Panama National Treasury revenues, and job generation
- Increase in population and migratory flows
- Changes in land use
- Impact on vehicle traffic due to an increase in transportation demand
- Impact on public and private infrastructure
- Risk of increase in work related illnesses and accidents
- Increase in crime levels
- Overload of public services
- Increase in waste generation
- Increase of tourism flows
- Impact on the landscape

The following impacts on the historical–cultural environment have been identified and assessed:

- Impact on known historical and archaeological sites
- Impact on unknown archaeological sites

In addition to the requirements of Decree 209, at the request of the Project promoter (ACP), the assessment of the transboundary impacts has been included, with an analysis of the increase in the risk of accidents in international routes, the increase of tolls for some countries, the improvement in the reliability of shipping companies that use the Canal route, the reduction of the cost of maritime transportation on post-Panamax vessels, and the reduction of greenhouse gas emissions.[42]

[42] This impact was assessed as part of the physical impacts.

7.8.4 Environmental Characteristics of the Area of Influence Involved

The concept of the study area, which is necessary to identify the possible effects of a project on the physical/biotic and social environment, is defined as the area where the impacts generated by the expanded Canal construction, operation, and maintenance activities may be manifested. Thus, an Environmental Study Area (ESA) and a Socioeconomic Study Area (SESA) were outlined to examine the effect of these activities, in view of their proximity and relation to these areas.

The ESA encompasses 421,868 hectares and was divided into three categories: a General Study Area (GSA) to cover the east and west sectors of the Canal Watershed with a surface of 267,190 hectares; the Specific Study Area (SSA) that covers a region of 142,604 hectares; and the Direct Impact Area (DIA) that is defined as the sum of the work, circulation, construction, operation and maintenance areas of the Project and covers a surface of 12,074 hectares within areas that are the patrimony of ACP and under its exclusive administration.

The SESA groups the areas that could be affected, in a positive or negative manner, in the socio-economic context and covers a geographic region slightly more extensive that the one used in the environmental structure. The SESA encompasses a surface of 454,050 hectares.

The baseline conditions of the areas where the Project will be developed are broadly discussed in sections 4, 5, and 6 of this EIA, which in turn were considered for the purpose of determining the impact that may be generated on the environmental features of the area where the Project will be developed.

The Project Direct Impact Area is located mainly within the area for the exclusive use by the ACP and includes mostly areas subject to the historical Canal construction, operation, and maintenance activities.