Update of Pacific Locks Conceptual Design and Harmonization of Atlantic Locks Conceptual Design

Actualización del Diseño Conceptual de las Esclusas del Pacífico y Armonización del Diseño Conceptual de las Esclusas del Atlántico

CONSORCIO POST PANAMAX

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Resumen Ejecutivo

Executive Summary

Update of Pacific Locks Conceptual Design and Harmonization of Atlantic Locks Conceptual Design: Triple lift lock system with 3x3 water saving basins

This report contains the conceptual design of a triple lift lock structure with 3x3 water saving basins for the new Post Panamax locks at the Pacific and Atlantic sides of the Panama Canal.

Reference is made to the 2002 report "Conceptual Design of a triple lift lock system at the Pacific side of the Panama Canal", part of contract SAA97462 awarded to CPP.

The actual study is the subject of a new contract SAA143351 awarded to CPP in November 2004.

The new design criteria for the lock structures are given in the report of task 2-Part A with reference P/A/2revA-v02 dated 29/04/05.

In general, following main modifications have been applied to the original Pacific design:
- reduction of lock width by 5m from 61m to 55m;
- reduction of vessel beam;
- tug boat assisted positioning system instead of locomotives;
- new channel alignment;
- new seismic conditions;
- reduction of minimum water depth (16.8 instead of 18.3m).

For the Atlantic design, the same lock system will be retained, but requires harmonization in order to cope with specific local conditions (geotechnical and seismic conditions, topography, Atlantic tidal levels, channel alignment).

The final reports contain following subtasks for both locks:

- a. Lock siting and Lay-out
- b. Lock Walls
- c. Emptying and Filling System
- d. Lock Operating Gates
- e. Culvert and Conduit Gates
- f. Operating Machinery
- g. Lighting
- h. Electrical Power and Power Requirements
- i. Entrance Walls
- j. Operating Structures
- l. Construction Plan and Schedule
- m. Quantities

For each of these tasks a separate report has been prepared, although for some specific tasks reference has been made to the original concept design (2002) especially when there are practically no changes made. Even so, for some tasks of the harmonization of the Atlantic locks, reference is made to the Pacific locks, as it is obvious that whenever possible the same concept has been retained for both locations.

Before resuming the results of these conceptual studies, it is important to remind that the design is especially based on following special criteria and requirements, as has been discussed on several occasions with ACP:

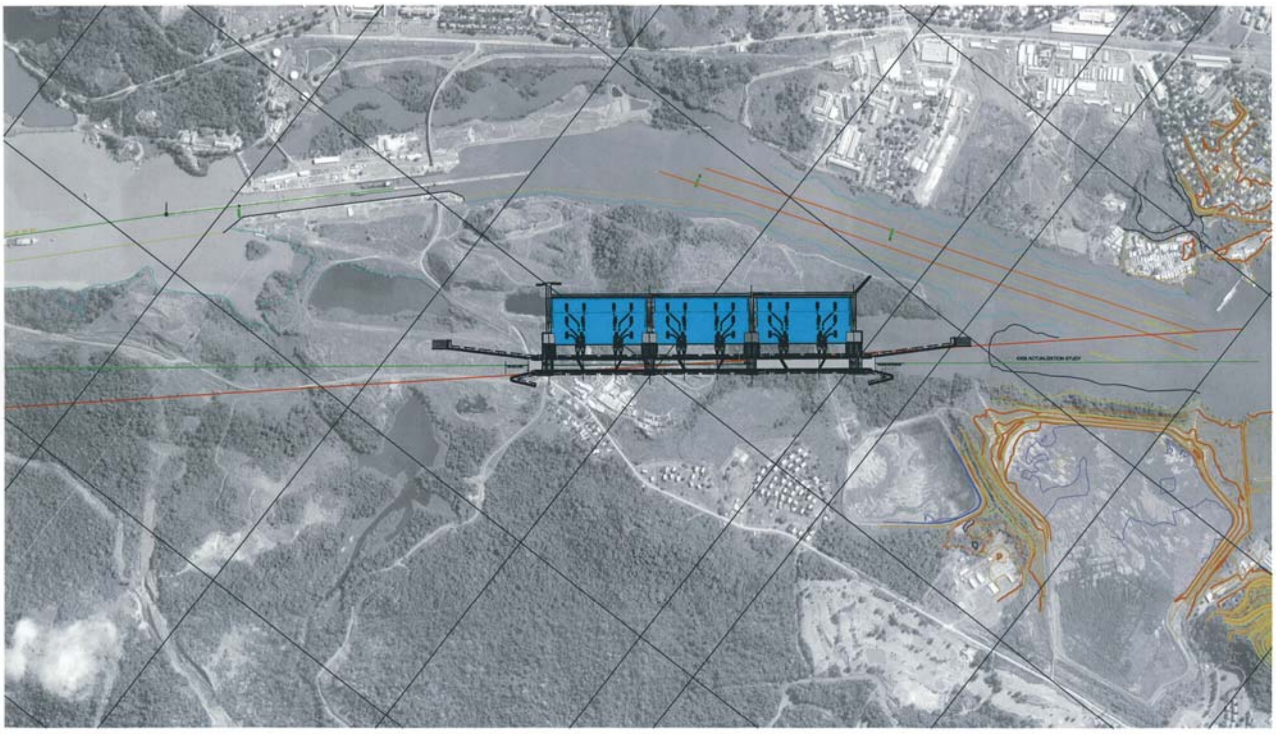
- The new locks are a demand driven system, and its operating times determine the capacity of the system.
- Reliability is another basic requirement, as any shutdown time means loss of income.
- Maintenance has to be kept to a minimum.
- Construction cost should be minimized.
- Operation facilities and systems should be kept simple and reliable.

Consequently, ACP has chosen a triple lift lock system, equipped with 3x3 water saving basins.

a. Lock siting and layout

PACIFIC ALIGNMENT AND LOCK SITING

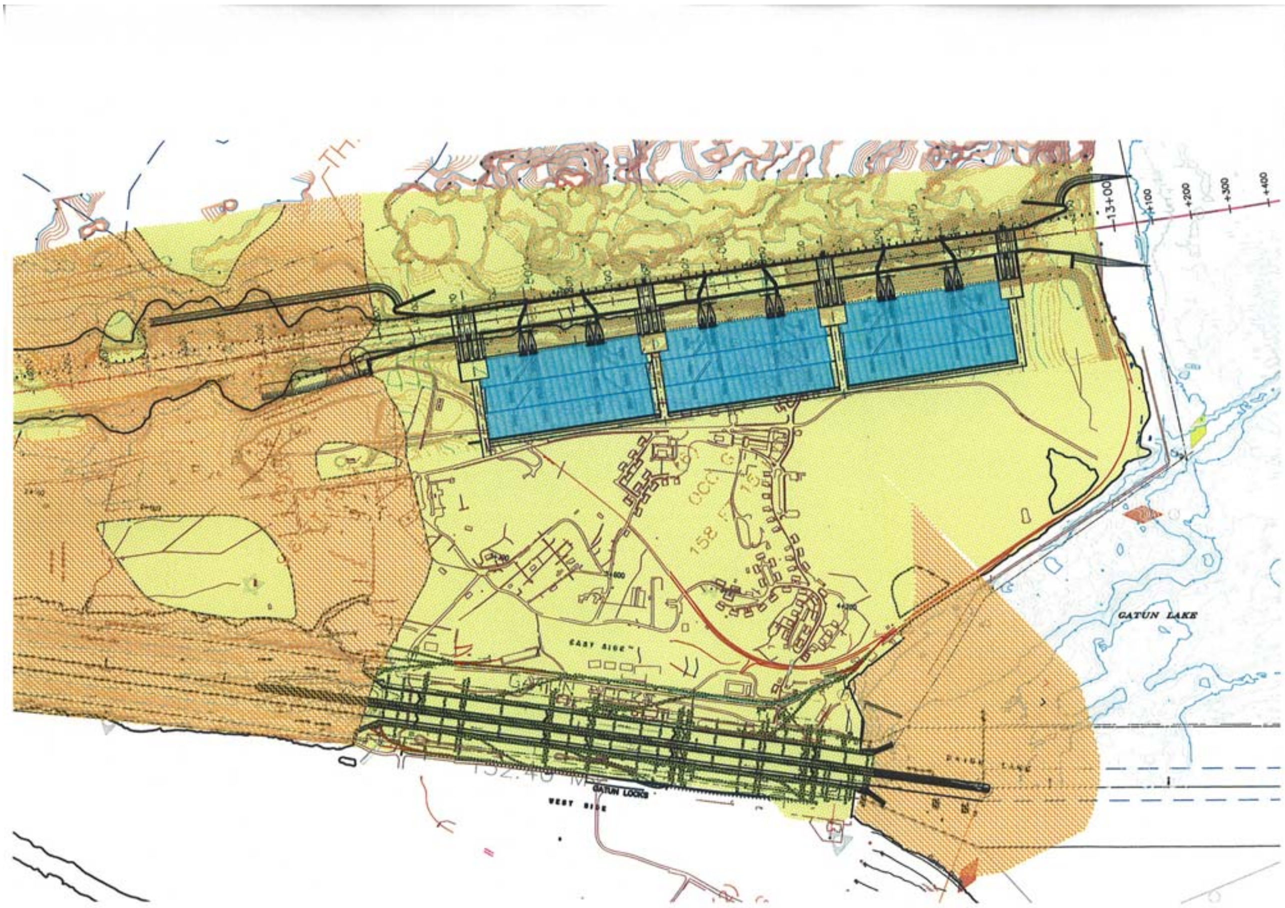
The ACP has done further investigation and analysis on this item in order to minimize the excavation volumes. The final result is a sligfhtly curved alignment which allows to shift the channel towards the existing Miraflores locks. At the same time, the lock structure can be shifted towards the Pacific Ocean, again reducing the lock excavation volumes. Nautical access conditions and geological circumstances remain practically unchanged when compared to the original study.



Aerial view of the lock siting at the Pacific side of the Panama Canal

ATLANTIC ALIGNMENT AND LOCK SITING

The ACP investigated the alignment at the Atlantic side prior to the actual study. An alignment has been retained that coincides with the 1942 third lock excavation, only a minor shifting of the axis to the Westside (direction of existing Gatun Locks) has been further evaluated. It was confirmed that this alignment is the best choice as far as excavation volumes are concerned.
This alignment is also very convenient from the nautical point of view: situated immediately near Gatun Lake at the southside, and connected to the Atlantic by a straight access channel.
Some special attention has been paid to the geotechnical conditions: the entire lock structure has been located in the Gatun rock formation; except for part of the Atlantic side entrance wall which is extending into the weak Atlantic Muck formation. In order to avoid working in bad soil conditions, it has been proposed to replace the gravity type entrance wall by flexible dolphins over the corresponding length.
It was found that excavation volumes for the Atlantic side are relatively high in comparison with the Pacific side. This is mainly due to the fact that the water saving basins require much more excavation.
Attention has to be drawn to the fact that the future 4th lane has not been taken into account when determining the lock alignment. The required excavations will be much larger than those actually determined for the third lane.



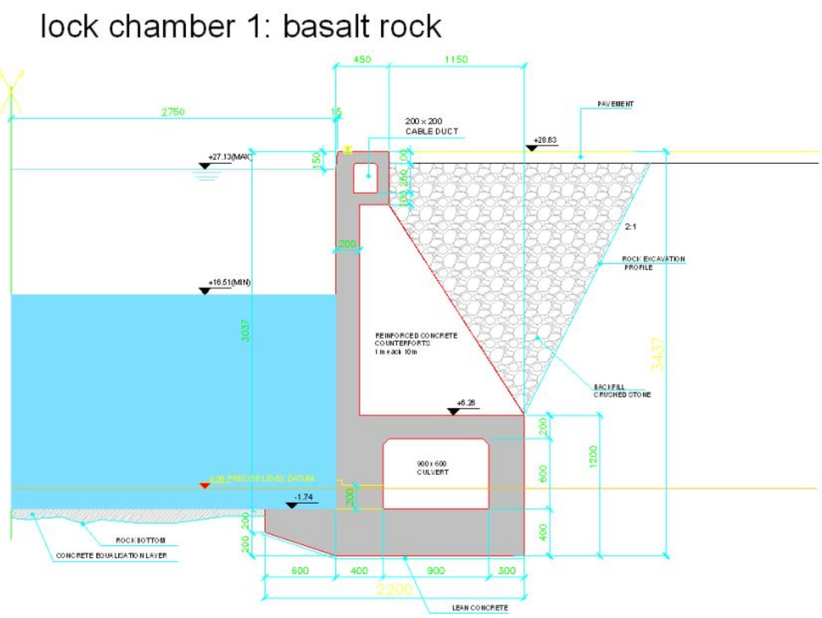
Aerial view of the lock siting at the Atlantic side of the Panama Canal

b. Lock walls

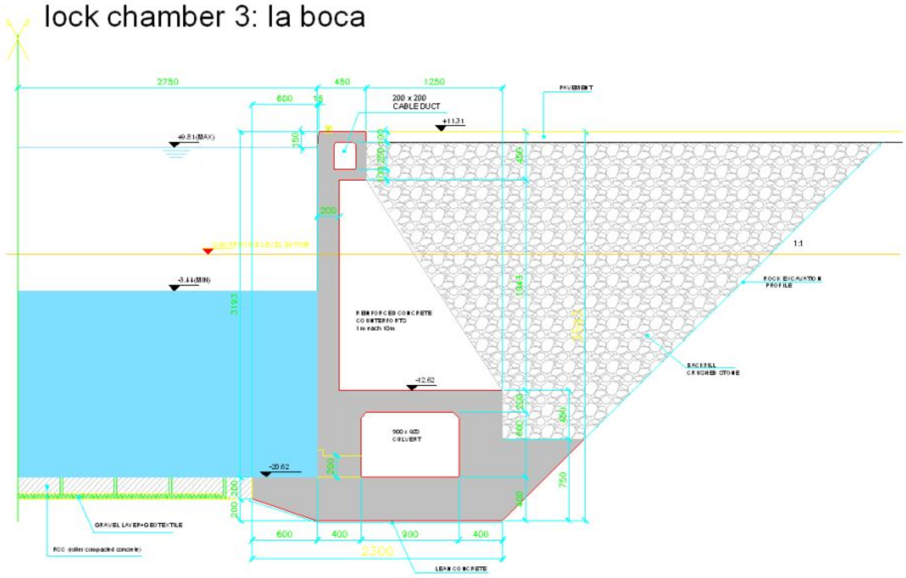
The choice of the lock wall type depends mainly on geo-technical and seismic conditions, loadings (water levels, sill levels) and filling and emptying system.
As the lock structure is situated mainly in rock bottoms (Basalt and La Boca at the Pacific side, Gatun rock at the Atlantic side), a number of possibilities of lock wall type are excluded.
As loading conditions are rather severe, and the requirement to have a very performing E/F system (with large culvert dimensions), the choice of a gravity type lock wall has not been difficult to make.
Of course it is clear that even the gravity type lock wall may lead to a lot of different alternatives which have to be investigated and optimized during further studies.

In this conceptual design, the lock wall dimensions have been chosen primarily in order to minimize excavation. A solution without using steel reinforcement (mass concrete gravity wall type), or a solution with RCC (roller compacted concrete) has not been considered anymore in this actual study as experience has shown that the application of reinforcement has become common practice in modern quay and lock wall construction methods, which also lead to more economical structures. However, during further and detailed design it is recommended to investigate if such a solution could be envisaged for the Panama locks. This is even more actual since the prices of steel reinforcement have been doubled over the last 18 months.

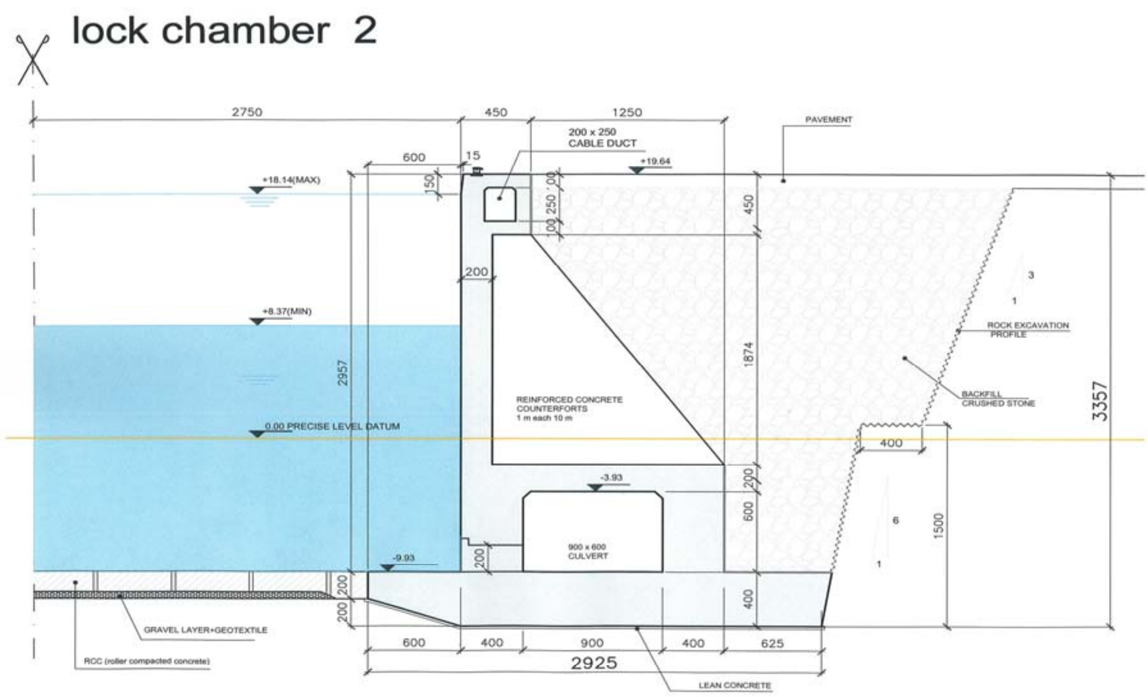
One major change in design criteria is most certainly the higher peak ground acceleration (PGA "a"-value), which was raised by ACP from 0.21g to 0.40g (Pacific) and 0.41g (Atlantic).
At the other hand, the removal of the locomotive tracks and the reduction in freeboard (1.5m instead of 3.0m) are favorable for the dimensioning of the lock wall structure. The new conditions together with the normal loading conditions and the local rock conditions have resulted in following typical cross sections for the lock walls.



Pacific side – typical cross section lock wall in Basalt



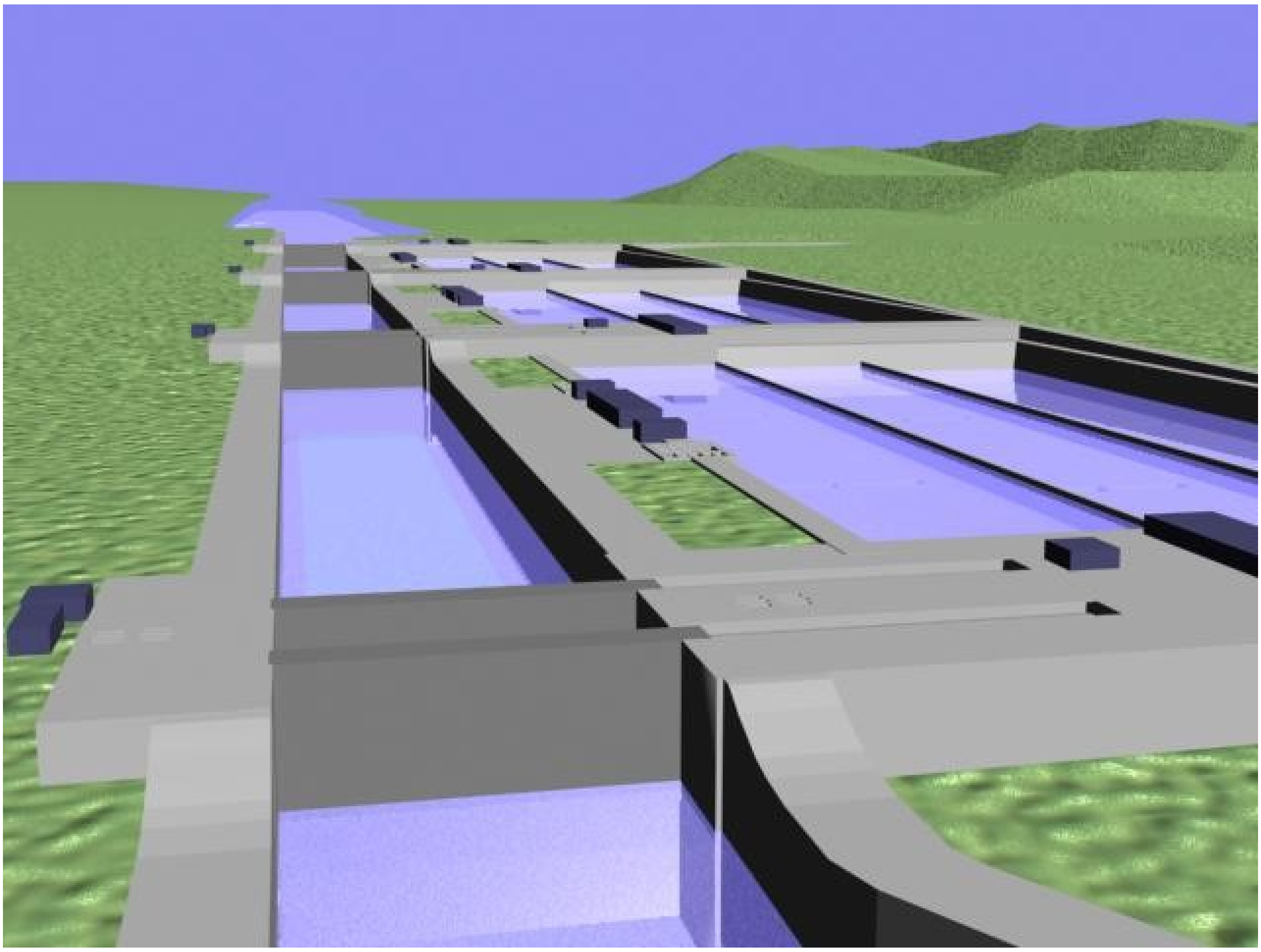
Pacific side – typical cross section lock wall in La Boca



Atlantic side – typical cross section lock wall in Gatun rock

c. Filling and emptying system – Water Saving Basins

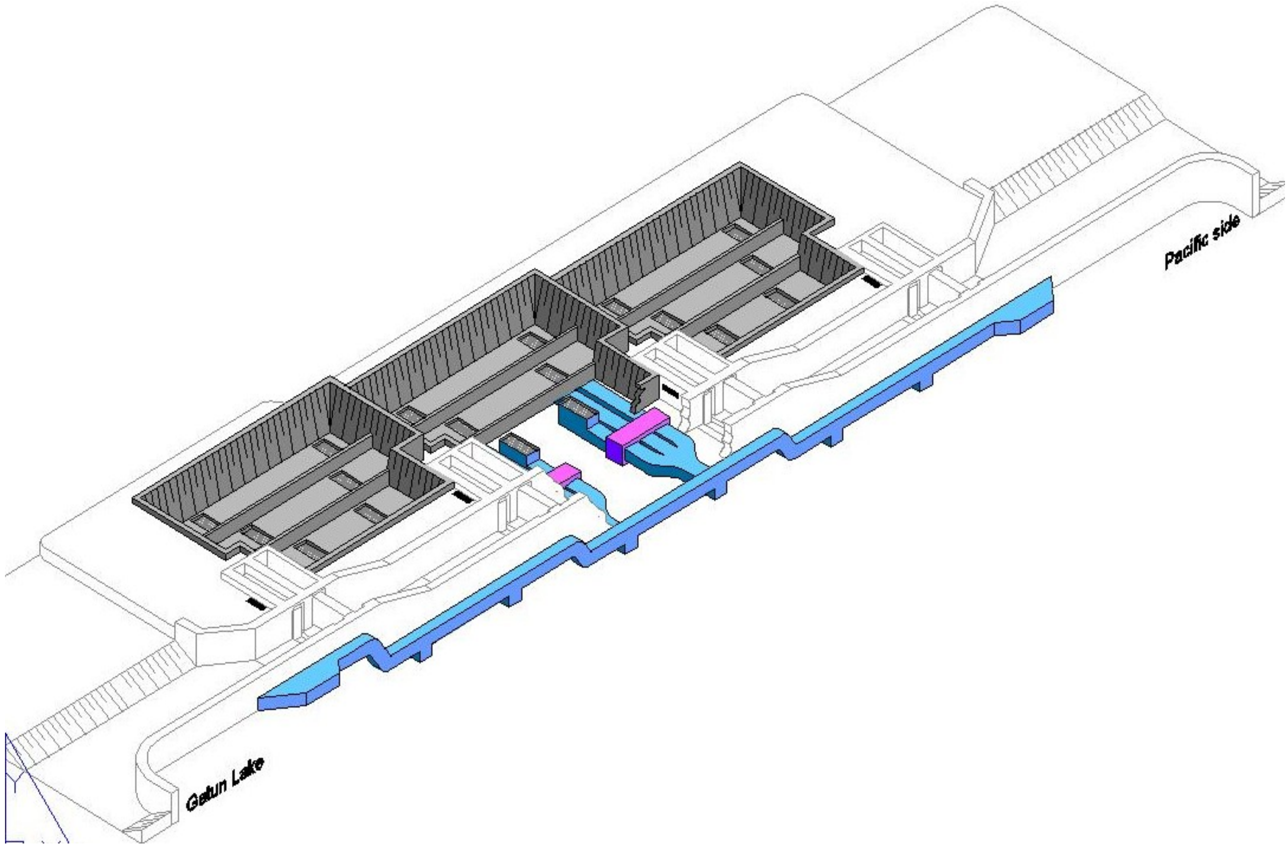
The ACP has retained a triple lift lock system with 3x3 side by side water saving basins for this actualization/harmonization study, as shown on following picture:



View on the triple lift lock system with 3x3 water saving basins

The hydraulic system originates from the 2002/2003 conceptual design and consists of longitudinal side wall culverts with ports, and water saving basins linked to these side wall culverts by means of conduits.
This system is composed of following main hydraulic elements:

- continuous culverts at both sides of the locks are integrated in the lock wall structure (dimensions Width x Height = 9m x 6m);
- both longitudinal culverts are linked with the lock chamber through the side walls by means of ports (2m x 2m), equally divided over the chamber length central part, in order to obtain as much as possible a well balanced filling and emptying;
- water saving basins (3 parallel basins for each lock chamber situated at one side of the lock) are linked to the culverts by two conduits per WSB. For each culvert (total of 12 conduits per chamber with a section of W x H = 4m x 5m at the Atlantic side and W x H = 4.5m x 6m at the Pacific side).



Layout of the E/F system – only one culvert shown

Attention has to be drawn to the fact that the system has been selected as being integrated in the lock walls, which is much more cost-efficient and maintenance free than a system with openings in the lock bottom floor (such as in the existing locks). The ports in the side walls can be closed by means of bulk head slots, and this way it is no longer necessary to retain the dry lock chamber condition. This allows a more economic design of several lock structure elements (lock gates and lock walls).

One of the most important conditions for the design of the hydraulic system are the hawser forces exerted on the ship during filling/emptying of the lock chambers.
Hawser forces are mainly induced by an unbalanced filling/emptying of the lock chamber. In this case of a side wall E/F system with 20 ports each side discharging not always at the same rate and time, water movement in the chambers occurs and consequently exerts forces on the ship. As the ship is tightened up by means of a positioning system, the hawser forces are limited to the capacity of this system, which could in the actual case be the tugboat system or simply a fixed mooring against one of the lock walls.
In this phase of conceptual design, without having the possibilities of measuring forces on a physical scale model, the hawser forces analysis has been performed by means of the combination of two hydraulic models. The first one being the Flowmaster software which calculates the discharge – time series through the ports, and a second one (2D/3D Delft) which calculates the movement in the lock chamber as a consequence of the uneven port discharges.
Several scenarios have been analyzed, and further optimization has been done in order to demonstrate that the hawser forces can be kept at a level which corresponds with the hawser forces criteria depending on the positioning system.

In general it has been concluded that the E/F system as proposed, with integrated water saving basins, is a technical-economical advantageous solution for the new Post-Panamax locks. It needs further optimization in a next study phase by means of more detailed numerical modeling, and finally it will have to be validated on a physical scale model.
Attention has been drawn to the fact that the same system, without using the water saving basins and if required to be working at the same capacity (number of ship transits per day), would need to be modified. However it is the consultant's recommendation that water saving basins need to be installed, operating the locks without water saving basins will then be considered as a special operating mode which allows increasing the valve opening times and rates.

d. Lock Gates.

Lock gate selection and analysis for the triple lift lock configuration has led to the application of the "Rolling gate" type. This choice has been justified by means of a multi criteria analysis, performed during the original 2002 conceptual design, to evaluate the miter gates and the rolling gates. The rolling gate type is the only existing lock gate type for this size of Post Panamax locks, and has been successfully used in Europe, especially in Belgium where the locks of Berendrecht, Zandvliet in Antwerp and Vandamme in Zeebruges are the largest in the world.

Picture of a rolling gate in its recess in the P. Vandamme lock in Zeebruges – Belgium

Furthermore, the rolling gate type has some particular advantages that are of utmost importance for the new locks that will be demand driven. One main advantage is certainly that the gate is moved horizontally in the transversal direction of the lock, into a lock gate recess chamber, which can be easily dewatered, and as such represents an ideal maintenance place and position. As there are two lock gates and lock gate chambers on each lock head, it is practically impossible that the traffic should be interrupted due to failure of a lock gate. Moreover, a lock gate can be floated and can be towed away as a vessel (for example if replacement is required, or when using the gate as a bulkhead to dewater the lock chambers).
The rolling gates have been designed for the normal operating conditions, as the dry lock chamber condition will not be retained as a basic requirement. Although, the outer gates have been designed to withstand the total water head that occurs during the dry lock chamber situation.
The lock gate structure has been analyzed using 2D/3D-structural engineering software and according to the expert's experience with rolling gates in Belgium. This analysis allowed to determine and verify the general dimensions of the different gates, the dimensions of the steel truss structure, and consequently it was possible to make a fairly accurate estimation of the weight of the steel structure.
Other auxiliaries, such as wheel barrow wagons, supports, etc, have been assessed according to the experience with the Berendrecht and Van Cauwelaert locks in Antwerp, which were also designed by the CPP-experts.
The main differences as compared to the original design (2002) are the reduced lock width (55m instead of 61m) and led to a further reduction of the lock gate size and weight. At the other hand, the new seismic design criteria have been taken into account.
It was also investigated if the lock gates, both on Pacific as on Atlantic side, could be standardized. This was indeed possible:

- the upper gates are identical for both Pacific and Atlantic (Gatun Lake side)
- the intermediate gates would only slightly differ in height and can thus be given the same overall dimensions (although it is the consultants opinion that this advantage should not be overestimated as there is a main consequence for the top levels of the lock heads, which will have to be adapted artificially)
- the downstream gates are different (due to the high tidal variation at the Pacific side)

Following table shows the main dimensions and weights of the different lock rolling gates:

GATE	**PA1 AT1**	**PA2-PA3 AT2-AT3**	**PA4**	**AT4**
Width (outside plating)	**7 m**	**10 m**	**11 m**	**10 m**
Spacing between vertical frames	**3.18 m**	**3.18 m**	**3.18 m**	**3.18 m**
Weight per lateral area (height x length)	**1340 kg/m²**	**1480 kg/m²**	**1500 kg/m²**	**1450 kg/m²**
Weight of gate structure	**1550 tons**	**2550 tons**	**2700 tons**	**2450 tons**

e. Culvert and conduit gates.

Similar to the selection procedure for the lock gates, a multi criteria analysis has been carried out to select the most convenient valve type for lock culverts and conduits. The most suitable valve was found to be the vertical fixed wheel type moved by means of a vertical hydraulic cylinder.

This is the same type of valve and operating system that is used at the Berendrecht lock, and has proved to be very reliable.

Nowadays vertical-lift valves of that type are preferred for big locks because they are cheaper to build and do not require the large space that is necessary for other valves as reverse tainter type for example.

In order to guarantee a maximum of reliability, the valves on the culverts are made redundant (two parallel valves per culvert, each operating on half of the culvert section. Each valve has a rectangular section of 4.5m wide x 6m high at the Pacific side as well as on the Atlantic side.

The valves on the conduits (in between the water saving basins and the lock chamber culverts) are not made redundant as such, but there are always two conduits for one WSB, which in fact gives the same redundancy as for the culverts. The valves on the culverts are 4.5m wide x 6m high at the Pacific locks and 4m wide x 5m high at the Atlantic side.

The valves have been designed for maximum operating and maintenance conditions, can easily be set in dry conditions using bulkheads at both sides of the valves, and can be reached through vertical shafts on both sides.

There are no noticeable changes required in this actualization of the former conceptual design, except for the changes in size of the gates.

f. Operating Machinery

Control system

The control system shall be efficient, safe and reliable and will require a minimum of staffing. The proposition for the control system of the 3-rd lane of locks of Panama is a distributed control system with several PLC’s and a redundant optical fibre network connecting all the devices. Operator workstations shall be installed in the central control room and shall allow the control of all the installation. This is a very open system that allows future PLC's extensions by the simple connection of new devices on the network. But for reasons of redundancy and proximity during exceptional or maintenance operations, a local control near the concerned equipment shall be supplied.

Gate operating machinery

Each rolling gate is moved by steel cables connected at anchorage points by compensating beams on both sides of the gate and wound around the cable drums of a winch. The two cable drums are driven by variable speed motors through gear boxes.

That type of machinery has been successfully used on the biggest existing lock gates (Berendrecht, Zandvliet, Zeebruges,..).

The two main AC motors are duplicating the drive in the event of failure of one motor. Moreover, a small emergency motor can be used to move the gate at reduced speed if the two main motors are not available.

Valves operating machinery

The culvert and conduit valves are operated by hydraulic cylinders. The pressure oil to open a valve is provided by separate hydraulic power units. The valves can be closed by gravity.

Each valve can be locally operated during maintenance from a control board located next to the hydraulic power unit.

The hydraulic cylinder solution is widely used and the technique has improved a lot especially by increasing the size and operating pressure. ACP has in particular a good experience through the replacement of existing operating mechanism of miter gates by hydraulic cylinders.

In general, there are no noticeable changes required in this actualization of the former conceptual design, except for the slight reduction of required power, which is not very significant when compared to the total investment cost of the Electro-mechanical equipment.

g. Lighting

Based on the experience of ACP, a lighting system is proposed that solves the main problems of the existing system. The most important problems of existing locks lighting are first of all the lack of visibility at the extreme ends of the lock chamber and in the lock chamber between ship and walls. The lights on high mast produce a glare that interferes with the pilot’s visibility, in addition, they are subject to corrosion and maintenance problems.

The lock chambers and gates will be illuminated by use of small 150W floodlights turned down in lighted vertical recesses in order to solve the problem of lack of visibility of the water level in the locks chamber and the space between the ship and the chamber walls. It will also provide to the pilot a clear cut reference.

It is clear that the high masts solution giving actually satisfaction to operating people does not need to be replaced by anything else. It was tried to facilitate the maintenance of the lighting fixtures by use of a ladder and platform combined with safety harness. To reduce the interference of high mast lighting with the pilot’s visibility and to reduce light pollution, the use of asymmetric lamps and deflectors are recommended. Corrosion effects can be reduced by improving the quality of material and tightness level.

The number of masts has been based on a illumination level of 100 lux (instead of 86 lux at Gatun) remaining almost constant all over the working area.

Due to the reduction in length of the entrance walls, the number of light poles has been reduced accordingly.

h. Electrical Power and Power Requirements

The main difference with the 2002 original conceptual design is the removal of the power transformers dedicated to the locomotives.

i. Entrance walls.

Entrance walls are the transitional part between the narrow (55m) lock entrance and the wider access channel or lake (in the case of the Atlantic locks at Gatun Lake side). They have been reduced in length due to the fact that the locomotive operated positioning system has been replaced by tugboats. Nevertheless entrance walls are required and will be used according to general international design guidelines to facilitate the entrance maneuver of the vessels, and in case of emergency to safely moor the ship.

j. Operating Structures

In general, the layout of the operating structures has not changed in this actualization/harmonization study when compared to the original conceptual design of 2002.

l. Construction Plan and Schedule

The construction plan and schedule of the 2002 conceptual design of the triple lift lock structure with water saving basins has been revised and updated in function of the new quantities, both for the Pacific and the Atlantic sides.
With these new quantities the Pacific locks execution time is reduced to 5 years, while the Atlantic side locks would require 6 years for construction as the excavation volumes are quite larger.

m. Cost Estimation

The scope of work for the actualization/harmonization does not include the cost estimation because ACP uses her own estimation method which differs from the CPP methodology. The scope of work only requires to prepare the quantities for both projects.

Nevertheless, as it is no real effort to estimate the construction cost at the same unit prices as the original conceptual design, and as it is the only way to evaluate the relative cost reduction linked to the size reduction of the lock, the cost estimation has been added to the report.
It should be mentioned that no indexation has been added to the unit prices of 2002, neither has it be taken into account that the steel prices have practically been doubled since then.

The result of this comparison are as follows:

- - Original triple lift lock with 3x3 WSB (2002) :	978,419,427.00USD
- - Pacific Actualization:	794,125,115.00USD
- - Atlantic Harmonization:	827,000,000.00USD

Conclusions and Recommendations.

The actualization study has allowed to adapt the original conceptual design of the Pacific triple lift lock structure with 3x3 water saving basins to the new design criteria. At the same time it was possible to further optimize the hydraulic E/F system in function of the hawser forces criteria.
Mainly due to reduced excavation and smaller lock width and reduced entrance wall length, a cost saving of +/- 19% has been realized.
The same concept design has been used for the harmonization study of the Atlantic locks. The main difference with the Pacific being the small tidal variation at the Atlantic Ocean, the large excavation volumes especially for the water saving basins, and the different rock base characteristics.

As at this moment it is being investigated if a system with 3x2 water saving basins would be beneficial (technical-economical), a possible solution to reduce the excavation volumes would be to retain such solution for the Atlantic side.

A next design phase before proceeding with tendering will require following scope of work:

- further optimization of the E/F system and related hawser forces analysis, by means of numerical modeling;
- physical model testing, with validation of the system;
- preparation of a reference design documentation (technical specifications, performance criteria, drawings, quantities survey and detailed cost estimation, planning of construction works), allowing to proceed with a tender procedure.

However it is necessary that ACP decides on the type of lock system to be retained, as well as on the positioning system that is going to be implemented in the Post Panamax locks.
The mitigation measures to be taken against or to prevent salt water intrusion into the canal have not yet been taken into account in lock design, but should be during further studies.

Some other tests and measurements still need to be carried out:

- detailed topographic and bathymetric measurements;
- additional soil investigation (field and laboratory);

May 2005.