THE PANAMA CANAL EXISTIN SAME GOAL, DIFFERENT SCA

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The existing Panama Canal locks were designed and built one hundred years ago. Today, due to increasing demand and vessel size, new locks are being constructed to work in parallel with the current locks. Although they share the same purpose, passing ships between the Atlantic and Pacific Ocean, a lot has changed since the existing locks were built. The new and old locks are not only different in size, but also their design and construction differ according to the developments in the fields of material science, construction methods, hydraulic, structural and environmental engineering. This article presents a comparison of the principal characteristics of the existing and new locks, including their dimensions, components, design approach, operation and an overview of the environmental impact studies.

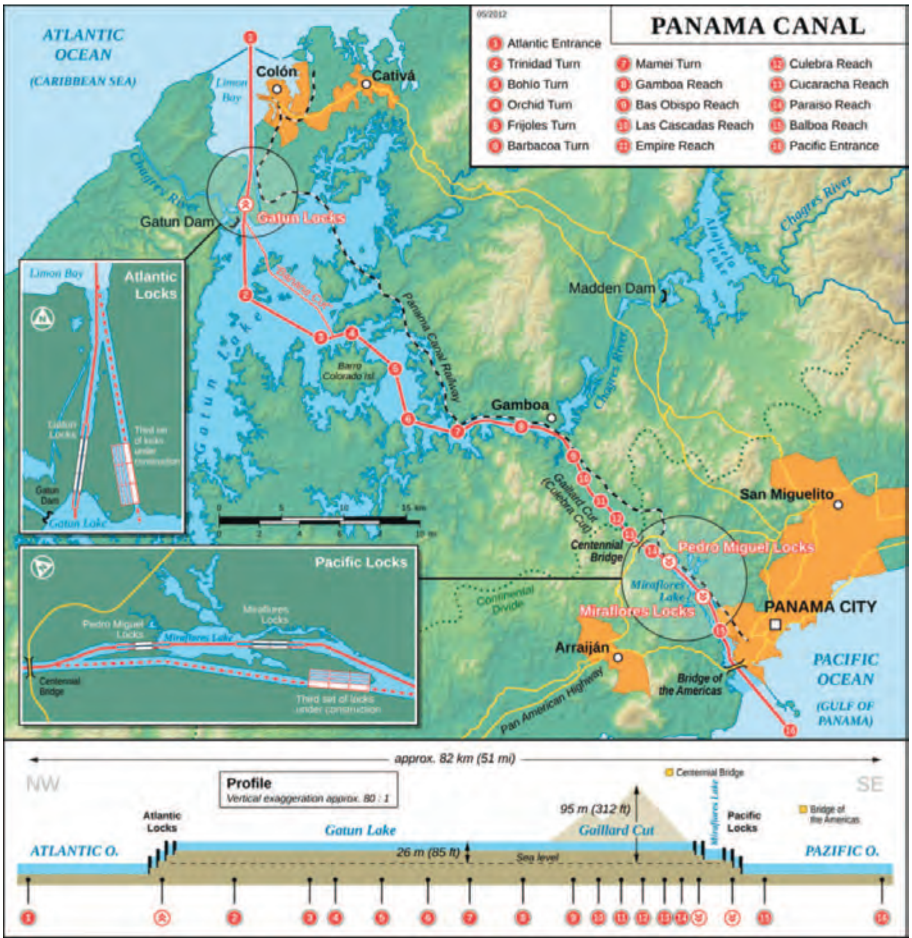

Figure 1: Panama Canal aereal view

The Panama Canal is a lock system that raises a ship up 85 feet to the average elevation of the Gatun Lake and then lowers it again to sea level. It has a total of six steps; three up and three down divided into three set of locks. After approximately 90 years of non-stop service, the existing locks became too small for the Post-Panamax vessels, which number of units started increasing at that time. This is when the need for a new, wider and larger set of locks arose. The design and bid processes for the new set of locks began in 2006 and construction started in September 3rd, 2007. Today, the project is approximately 65% advanced and it is expected to start operations in June 2015.

The expansion project includes the construction of new locks, excavation of new approach channels for these new locks, widening and deepening of the existing navigation channel (to allow a two-way traffic and allow ships with bigger drafts to pass through, respectively), raising the maximum operating level of Gatun Lake, and the construction of a number of earth dams. Figure 1 shows the path of the navigation channel, the location of the existing locks and a render of the proposed site of the new locks.

Components

The existing structure consists of three sets of locks with two lanes each; Miraflores Locks, with two steps; Pedro Miguel Locks, with one

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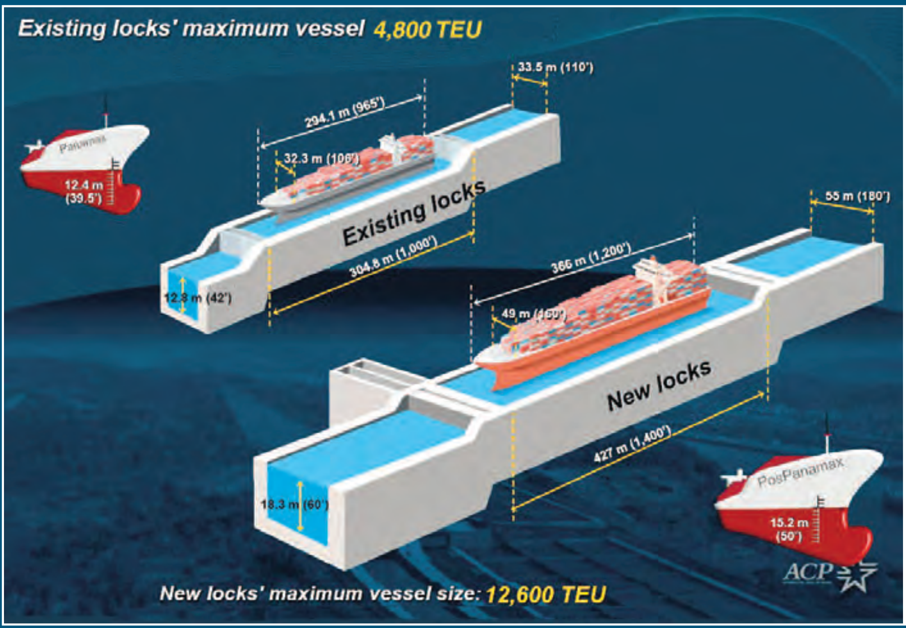


Figure 2: Dimensions of existing and new locks

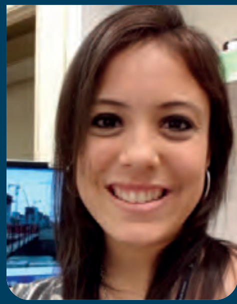
step and Gatun Locks, with three steps. It was decided to build two lanes to have redundancy when maintenance or repair took place and to provide transport in both directions at the same time. Each chamber is 33.5 m wide and 320 m long. The existing sets of locks are mainly composed by main culverts, auxiliary culverts, portholes, gates and valves.

The new set of locks, however, will consist of two sets of locks, one lane in the Pacific side and one lane in the Atlantic side, with three chambers each. The new chambers will be 426.7 m long, 54.9 m wide, and up to 18.3 m deep. The new set of locks is essentially composed by main and secondary culverts, central connections, portholes, water saving basins (WSB), trifurcations, and flow dividers from WSB to secondary culverts, gates and valves.

Concrete. The new and old locks differ in the use of reinforced concrete. The existing locks were built using mass concrete with no rebar. By the time the old locks were finished (1914) the methodology for reinforced concrete was being developed and tested. Even the formulation for the Portland cement was a theme of research and discussion at that time. The standard formula for Portland cement was not established by the US Bureau of Standards and the American Society for testing materials until 1917. Four and a half millions of cubic yards of concrete were used.

The new locks are being constructed with reinforced concrete classified in two types: structural concrete and structural marine concrete. The structural marine concrete contains fly ash admixtures to make the concrete cover impermeable to prevent corrosion of the reinforcement by chlorides. In the construction of the new locks 192000 tons of steel are being used.

Walls. The main walls of the existing locks have a concrete gravity section that ranges in thickness from 14.9 m at the base to 3 m at the top and are 24 m high. On the other hand, the walls of the new locks are of reinforced concrete, with a variable width. The walls are 22.5 m thick at the bottom and up to the entire height of the culverts, then the section is abruptly reduced to a width of 8 m, from which it gradually reduces to a width of 2 m at the top of the wall.



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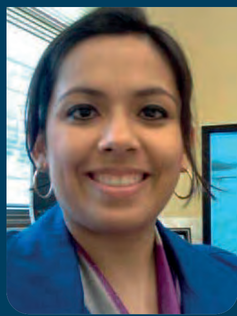

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Culverts. The existing set of locks has main culverts and lateral culverts. There are three main culverts; one central culvert shared between the two lanes, and two side culverts, one for each lane (Figure 3a). The main culvert in the center wall has a horseshoe shape - flat floor and round roof - with a diameter ranging from 5.5 m to 6.7 m, while the main culverts in the side walls have a circular shape with a diameter of 5.5 m. The lateral culverts are located below the chamber floor, having an elliptical cross section, with a maximum height of 1.98 m and a maximum width of 2.44 m.
The new sets of locks have main and secondary rectangular culverts. The main culverts are 8.30 m by 6.50 m while the secondary culverts are 6.50 m by 6.50 m.

Portholes. The portholes in the existing set of locks are circular, with a diameter of 1.2 m, and are located in the chamber floor; in contrast with the rectangular portholes in the new locks, located in the chamber walls, and having a section of 2 m by 2 m.

Gates. The existing locks use massive steel miter gates. The biggest ones reach up to 25 m high, 19.5 m wide and 2.13 m thick in Miraflores locks, next to the Pacific Ocean, where the largest tidal range takes place. The existing gates consist of two leaves that close to a “V” shape with the point upstream, which allows the force of the water to push the ends of the gates together. For maintenance, these gates are removed using big barge mounted cranes and transported to a workshop to be overhauled. The existing lock chambers have intermediate gates, except for the lower Miraflores lock. These gates divide the lock chamber into two shorter ones for smaller vessels and their original purpose was to save water during the dry season, however, this is unlikely to be used in the present due to the current size of ships. A better technology was developed for the new structure. The new locks being built will use rolling gates which will open sideways, sliding perpendicular to the path of ships. These will allow maintenance in situ, without the need to take the gates out to a workshop garage and without interrupting transit, saving money and time. The new gates will also be larger than the actual ones, reaching up to 32.9 m high, 57.6 m wide and 10 m thick. Intermediate gates were not included in the design of the new locks.

Water Saving Basins. Another aspect on which the new set of locks will differ from the existing ones, is that each set of locks will go with nine water saving basins (three per chamber). These gravity-fed basins will be 70 m wide, 426.7 m long and 5.5 m deep, approximately, and will allow reutilizing 60% of the water used in every transit. Thus, the new locks will use 7% less water per transit than the existing locks, even when they are much bigger. This, plus the facts that the maximum water level of the Gatun Lake will be raised 0.46 m and that the navigation channel will be deepened 1.5 m, will permit the expanded canal to function without the need of new reservoirs. Figure 2 shows a cross sectional view of the water saving basins.

Locomotives. One more feature on which the new structure differs from the existing canal is that the existing locks use electric locomotives all along the center and side walls of the canal. Even though forward motion inside the locks is provided by the vessels’ own engines, locomotives work as a safety feature and help keep the vessel in the right position, avoiding accidents or collisions. The new structure, however, is designed to use tugs to keep the vessels in the right place.

Operation

During a lockage, water will flow by gravity through culverts and into the chamber in the existing and new set of locks. The flow in the culverts is regulated using a set of valves, which have an extra set for redundancy.
In both sets of locks the filling and emptying (F/E) process occurs in three different paths: lake to lock, lock to lock, or lock to ocean. In addition, due to the existence of the WSBs in the new set of locks another path occurs: WSB to lock. The existing and new locks’ F/E system mainly differ in the distribution and complexity of its hydraulic components.
In the current infrastructure, main culverts are situated along the side and center walls of the locks. The main culverts are connected to lateral culverts located below the chamber floor utilized to transport water from the main culverts into the chambers to raise the water on them or vice versa. Specifically, eleven lateral culverts

Figure 1: Cross sectional view of existing and new culverts

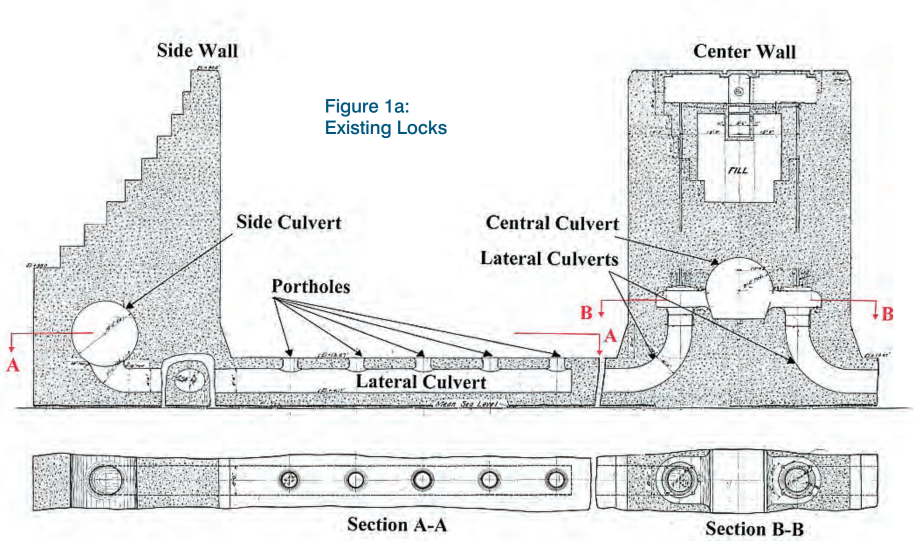
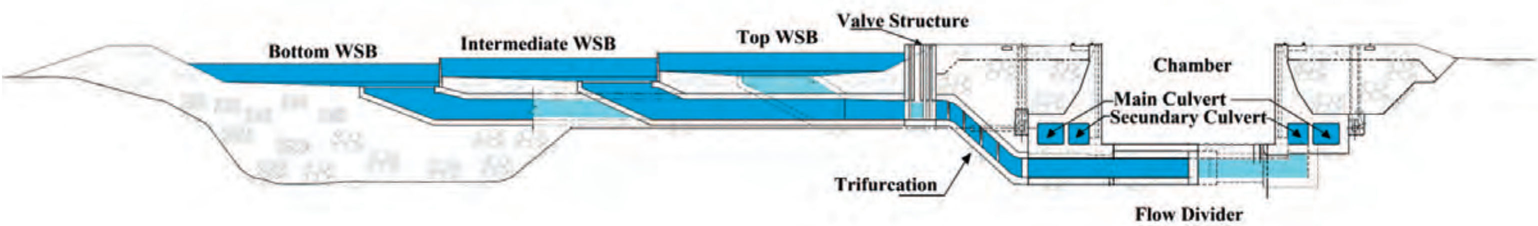


Figure 1b: New Locks



connect the side culverts to the chamber, while ten lateral culverts connect the central culvert to the chamber. In the roof of each lateral culvert there are five portholes, having a total of 105 portholes in each chamber. Water flows from the lateral culvert through the portholes and to the chamber. Each chamber is filled and emptied in a procedure that takes around eight minutes, if the side and central culverts are used. In the whole process, water is moved by gravity and is controlled by huge valves in the culverts. Figure 3a shows a cross-sectional view of the current locks' culverts and floor openings.

The new locks, however, will work with two main and two secondary culverts, all of them rectangular-shaped, to ease its construction (Figure 3b). These will then be connected to 40 rectangular-shaped holes located in the bottom part of the side walls of each chamber, through which the water in the chambers will raise and drain. This culvert configuration will ensure homogenous filling and emptying of the chambers, thus helping in the safety of the operations. The filling and emptying time results were presented in CICP et al (2010) and resulted similar to the values calculated at the tender stage, that is, without WSB ten minutes, and using WSB seventeen minutes.

Every time a ship passes through, the existing Canal uses 55 millions of gallons of water, approximately. Since the new locks will be larger, even more water will be needed to pass ships through, around 63 millions of gallons. Nevertheless, as explained earlier, the water saving basins will allow reutilizing 60% of water per lockage, therefore, the amount of water released to the sea is reduced by 7%.

Design approach

The existing set of locks was designed using an approximate analytic approach. It had to comply with an acceptable filling and emptying time of 15 minutes (using only one culvert), not producing disturbances in the locks or approach channels. Economy influenced the final dimensions and distribution of the components. For example, it was decided that the culvert located in the central wall was going to operate in both sides of the lock chamber, since constructing an additional culvert would result in considerable higher costs. After finishing the construction of the set of locks, filling and emptying tests were conducted to verify the performance and equalization time of the locks. The tests showed that using the two main culverts (side and central), water distribution was good and also safer and faster (equalizing

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in around 8 minutes) than using only the side wall culvert. Initially, it was intended to use mainly the side culvert, and the central culvert was only an auxiliary culvert that operated to accelerate the last few feet of flow. The tests also showed that the salinity slightly affected the filling and emptying times and the water distribution in the chambers, mainly in the lower locks next to the oceans.

A numerical and physical modeling approach was used for the new set of locks. Detailed hydraulic studies were presented by the contractor, including the numerical modeling of the filling and emptying system and a physical model of the locks. The results complied with the design requirements: maximum flow velocity of 8 m/s, and for hawser forces a maximum longitudinal and transversal surface slope of 0.14‰ and 0.10‰, respectively. Regarding the numerical models, a one-dimensional model was used to estimate the filling and emptying

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times and flow velocities. Each component of the new set of locks was individually analyzed to estimate and optimize local head losses using three-dimensional models. Hawser forces were verified using a two-dimensional model of the chambers. The physical model was used to verify and validate the design and the results of the numerical models. A more detailed paper explaining this system is presented by Calvo (2013).

Water Demand and Environmental Impact

At the time the Panama Canal was built there was little concern about the water resources and the environmental impact of such a project. A major river (Chagres) was dammed, the biggest manmade lake (Gatun) was built, entire villages were displaced, and tops of mountains became islands as the water level rose.

The construction of the Panama Canal had a great impact not only on the environment but also in the way the towns and cities around it developed. The Canal Zone area primarily created for protection and water supply for the canal, became also a wildlife protection area. However, this zone impacted the way Panama City developed as an elongated city near the coast.

The expanded canal will need more water to function. This fact arose some worries on how Panama would manage to get more of this vital resource without causing permanent damage to the environment. During the design process of the Panama Canal expansion project, a comprehensive environmental impact assessment was carried out to make sure that the project did not have unfavorable effects on the environment. During the construction of the new locks an environmental monitoring and control program is in effect to monitor environmental quality, conduct wildlife rescue and enforce mitigation and compensation activities; for example, the reforestation of the Panama Canal watershed. This would help protect the dry-season flows and sequestrate carbon releases, however, it would not necessarily increase water supply. To address this issue, a water supply program was proposed which purpose was to maximize the water capacity of Gatun and Alhajuela Lakes and to use water efficiently so that no communities were affected and no new reservoirs were necessary. This led to the use of the WSB, the deepening of the navigation channel, and the rise of the Gatun Lake; aspects that significantly reduced the impact in water demand.

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