PLANNING, DESIGN AND SUCCESSFULLY EXECUTING 4M M3 OF DREDGING AND DRY EXCAVATION TO EXPAND PSA PANAMA'S CONTAINER TERMINAL

By

David Taylor, MICE CEng[1]; Jan Neckebroeck[2] and Dominic de Prins[3]

ABSTRACT

Of all the obstacles in the construction of the Panama Canal over a 100 years ago, it was the complex, varied geology that possibly provided the biggest challenge, being the primary cause for the failure of the French Canal Company to construct the channel. When planning a new construction project involving removal of more than 4m m3 of material for expansion of PSA's container terminal at the Pacific Entrance of the Canal, obtaining information and how to structure the project was of prime importance.

In this paper the authors will explain the development of the project through the various stages, from concept design to successful execution, showing how knowledge and understanding of the site developed and how this changing information was used in the design, tendering and wording of the construction contract.

The solution adopted by the contractor, using a combination of dry excavation, together with backhoe, trailer and cutter-suction dredgers, was developed based on detailed experience gained from working in similar conditions nearby in Panama.

1.0 DESCRIPTION OF THE TERMINAL

1.1 Overview

PSA Panama International Terminal (PPIT) is located at the Pacific entrance to the Panama Canal on the west bank (the opposite side to Panama City). Figure 1 shows the location. The terminal operates under a concession with the Panamanian government, via the Maritime Authority (AMP). The initial concession was granted in 2008.

Planning, design, and construction of the terminal took place over a three-year period with the first cargo handled in 2011. The design was based on a single Panamax berth of 330-meter length, three quay cranes, and an operating area of 14 hectares, including container yard, gate, maintenance workshop, and administrative and customs buildings.

Figure 2 shows the operating Phase 1 terminal, with a large container vessel on the berth and well-utilized container storage yard. The administration building, gate complex, and equipment workshop are in the right-hand corner and clearance has started for the Phase 2 construction area.

[1] Head of Civil Engineering Latin America, PSA, david.taylor@globalpsa.com
[2] Regional Manager, Jan de Nul, jan.neckebroeck@jandenul.com
[3] Project Manager, Jan de Nul, dominic.deprins@jandenul.com

Figure 1: Location of PSA Panama International Terminal

Figure 2: Completed PPIT Phase 1 Terminal

1.2 Phase 1 Construction

Construction of the quay deck was carried out partially in the dry, with the rock slope at the rear of the quay wall being constructed in a bunded area. Figure 3 shows the initial excavation of the slope at the rear of the quay deck, together with a later photo showing the ongoing quay deck construction, including piling operations, placing of the grillage of concrete beams to tie the piles together. Figure 4 shows further construction photos during the piling and quay deck construction.

The construction was awarded to a JV of Colombian Contractors as a single contract, including dredging, quay, yard, electrical, utilities and buildings.

Figure 3: Phase 1 Quay Deck Construction

Figure 4: Phase 1 Quay Deck Construction

During the Phase 1 quay deck construction and dredging, an unforeseen outcrop of basalt was encountered, which caused significant delays and costs to the overall project, as well as altering the construction and dredging methodologies.

2.0 EXPANSION OF THE TERMINAL

In the period from the planning and negotiation of the concession in the mid-2000s, there have been many significant changes in the shipping world. There has been a dramatic increase in the size of container vessels (see Figure 5), the opening of the expanded Panama Canal, and major consolidation of container shipping lines and alliances (see Figure 6).

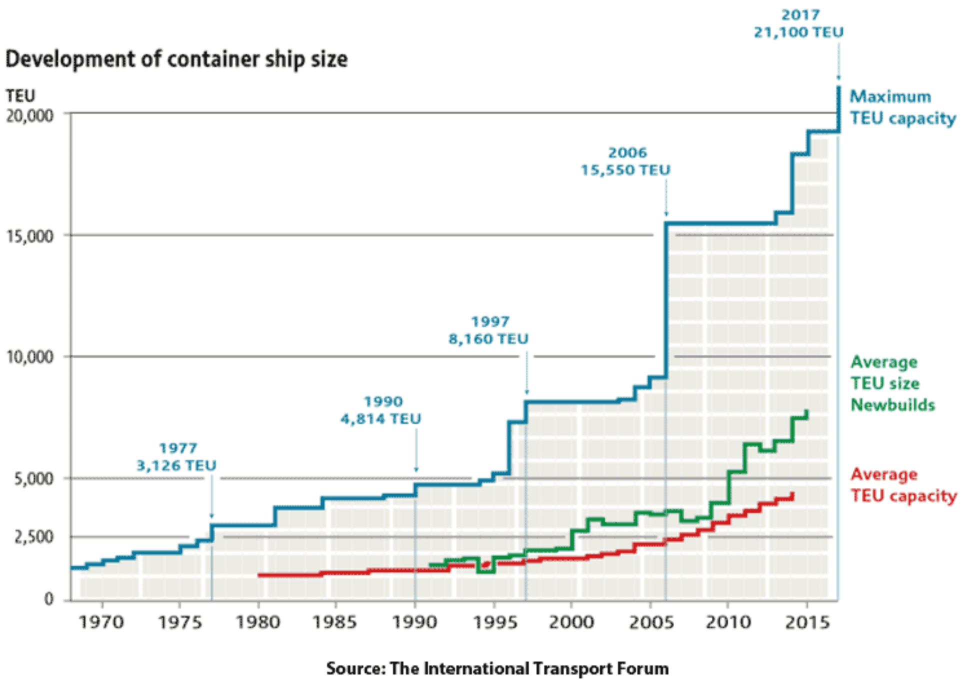

Figure 5: Evolution of Container Vessels Sizes

The dimensions of the locks in the original Panama Canal restricted vessel dimensions such that the maximum capacity of container vessels was approximately 3,500 TEUs (twenty-foot equivalent units – the standard measure of container volumes and capacities, with 1 TEU being a single ISO 20-foot-long container).

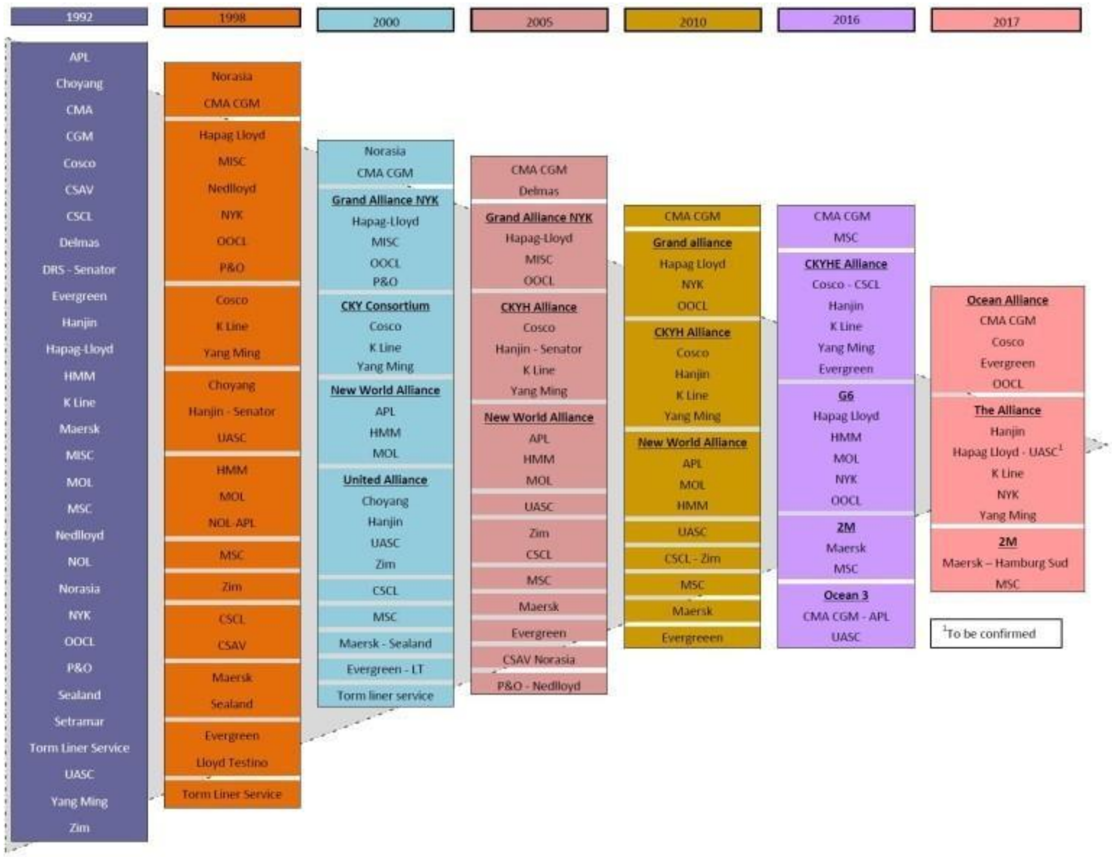

Figure 6: Consolidation of Container Shipping Lines and Alliances

Source – Ricardo J. Sanchez (UN-ECLAC)

The enlargement of the canal, which was completed in 2016, now enables vessels of up to 13,500 TEUs to transit the canal, greatly changing the economics of container vessel operations. In combination with this, there has been a huge increase in ship sizes, and the quantity of these large ships, as shipping lines have sought to reduce the shipping costs per container. The injection of capital needed for these new build campaigns and the need for revenues and capacity has resulted in dramatic consolidation of individual shipping lines and shipping line alliances to the point where there are now only three global alliances. Figure 6 illustrates this rapid consolidation starting from the mid 1990's to the present day.

3.0 DESIGN AND PLANNING

3.1 Preliminary Design and planning

The first stage in planning the expansion was to carry out vessel navigation studies to determine the optimum alignment of the new berth with respect to the Panama Canal. This was carried out locally using the SIDMAR navigation simulation center in Panama and with Panama Canal pilots.

Once the berth alignment was established, then it was possible to design the terminal layout to suit the operational goals, including vessel sizes, terminal capacity, etc. thus enabling preliminary engineering design to be carried out and the scope of the site investigation works to be defined.

3.2 Site Investigation

3.2.2 Introduction

As noted in the introduction, the ground conditions in the area of the Canal are challenging due to previous volcanic activity that has left basalt intrusions and metamorphic zones, combined with more recent alluvial and sedimentary materials.

A common perception with regard to the construction of the original Canal was that the French didn't have the correct equipment, having not anticipated that there would be rock excavation. As might be expected, the reality was a great deal more complex. In places the igneous rocks are extremely hard (UCS strengths of 100mpa are not atypical) and very well cemented with 100% RQD in borehole recovery. However, there is also huge variation in rock types and strengths over very small distances – within a 50m space the rock can vary from 100mps to 5mpa, and RQD from 100% to 0%. In addition, the tertiary sedimentary rocks which are encountered along the route of the Canal are not stable and many landslide have occurred resulting in huge movements of material – the Cucaracha Slide is perhaps the most well know. A slide of more than 10M m3 of material from this slide closed the Canal for 9 months after opening in 1915, and regular movements have continued (landslides closed the Canal on 26 occasions between 1914 and 1986).

Given the above, considerable effort was put into carrying out a thorough data collection program, within the financial restraints of a project that was still in the feasibility stage.

3.2.3 Site Investigation Program

A very preliminary set of boreholes was conducted in 2012, but little useful data was able to be collected. Following definition of the berth alignment and preliminary terminal layout, a seismic survey was carried out along the line of the quay deck and the area to be dredged. The fact that the berth line was set back from the canal allowed this to be executed quickly and cost effectively as it was a land based campaign.

Figure 7 shows a longitudinal profile from the seismic survey, with the variation in hard rock (the magenta colors) being easily identifiable.

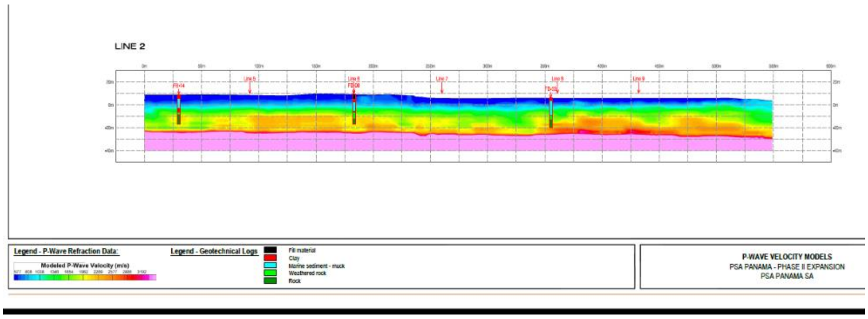

Figure 7: Longitudinal Profile from the Seismic Survey

Based on the results of the seismic survey, a scope of work was drawn up for a borehole and testing program. Following a competitive tender process, Fugro were awarded the contract, including around 20 boreholes (all land based) a CPT program to collect information on the soft sediments overlying the main site and full set of laboratory tests.

Figure 8 shows a borehole being drilled at the south end of the site and a photo of a core box of mainly basalt with almost a full core recovery indicating the material to have little or no faults of fissures.

Verification of the seismic and CPT's was carried out by conducting boreholes in the same location as some CPT's.

Figure 8: Borehole Drilling and Typical Core Box

Different laboratory tests were specified for the different materials – e.g. consolidation tests in the soft compressible materials, rock strength tests for the basalt and other hard materials.

3.2.3 Site Investigation Results

As has been indicated in the text, the results showed a changeable geology over the site, but with some basic patterns emerging.

Along the berth line there was an outcrop of hard basalt, with the top of it being somewhere around elevation +2m (relative to Chart Datum – MLWS) but that spread longitudinally around 200m and towards the dredged area by about 50m. At the south end of the site the rock elevation was around -18m and generally softer, being La Boca Formation (a sedimentary formation of weak mudstones, siltstones and limestones). At the north end there was a sheet of basalt at around -10m to -13m in a triangular shape with highly fractured limestone from the La Boca Formation.

The rock layers are overlain by Pacific Muck, a soft unconsolidated alluvial material containing a mixture of sands, silts and clays. This varied from 2 or 3m in places to over 10m in the north.

The Pacific Muck was in turn overlain by fill placed during the initial construction of the US Naval Base in the 1930's and dredged materials deposited since.

4.0 TENDERING PROCESS

4.1 Early Contractor Involvement

Given the known challenges with the ground conditions, an early involvement of potential contractors was sought to give as much time as possible for them to absorb the information about the site with the obvious aim of avoiding unrealistic tender prices. This was both in the sense of too high and too low.

A prequalification process was carried out, with the 2 main capabilities evaluated being hard rock dredging capabilities and experience working in these materials in Panama. It was important for PSA to have a dredging contractor who was used to working with the Panama Canal Authority and the rules and regulations pertaining to works in the Channel.

Boskalis, Dredging International, Jan de Nul and Van Oord prequalified. After signing a non-disclosure agreement with PSA, all available site was shared with the contractors and comment sought on the scope of the SI campaign being undertaken with Fugro. Contractors were also given the opportunity to witness the boreholes and laboratory tests, so being able to see first-hand the condition of the materials.

4.2 Tender Process

The tender documents were prepared using FIDIC Red Book (Engineer's Design) Conditions of Contract under the Laws of England and Wales. The design and tender documents were prepared by URS (now AECOM). Tendering was on a competitive basis, with price and program being the main focus.

An important decision in preparing the documents was to make the tender remeasurable. This was to avoid contractors including sums against the risk that the quantities of the different types of materials were different to those expected. Based on the available soil data (the Fugro SI was still ongoing) URS calculated quantities for 3 different stratum – Stratum 1: soft materials, Stratum 2: clay and weathered rock and Stratum 3: hard rock.

Another point of much discussion was the potential for of carrying out much of the dredging as dry excavation and the potential benefits it might bring with regard to certainty of materials encountered and control of costs. However, there was also a concern over the viability of the methodology and timing. Since it was not completed clear there would be a clear advantage of dry excavation over conventional methods, it was decided to allow either option to be proposed by the contractors.

3 tenders were received, with interview held with the best ranked 2 tenderers. Finally Jan de Nul were selected as preferred bidder and negotiations conducted with them. In joint venture with the maritime construction arm of Saipem (now Eiffage) Jan de Nul were also preferred bidder for the quay deck, based on an alternative design submitted by them and which was based on construction in the dry.

Through the negotiation process it was possible to change the contract to be executed on a lump sum basis. This was achieved through a combination of defining and apportioning risks to each party as appropriate and as acceptable to each party.

5.0 CONSTRUCTION PROCESS

5.1 Planned methodology

JDN opted to excavate a building pit first, in which then the quay could be built in dry conditions. In this way, the remaining land constituted a natural dike next to the Panama Canal, Once they quay was completed, the pit was flooded and the dike was removed by dredging. Such dry building pit offered a cost reduction in both the civil works and excavation works. It's also much easier to monitor the works as it's possible to just walk through the site for a visual inspection rather than when doing the works underwater. All excavated material, be it in dry or dredge, was transported over approximately 20km to an authorized off-shore disposal area.

The opted methodology divided the works in three main construction activities – Activity 1: pre-treatment of hard material in both dry excavation and dredging area, Activity 2: dry excavation and off-shore disposal of material but leaving a retention bund for the Panama Canal and Activity 3: Dredging and off-shore disposal of the remaining dike up to the design level of -16.3m MLWS. In between the dry excavation works and the dredging works, once the main piling works and corresponding excavation and rockworks in between the piles were finished, the flooding of the pit was to be carefully designed and planned.

5.2 Drilling and blasting program

Based on the site investigation results. pre-treatment of the hard material was required both in the foreseen dry excavation area with drilling and blasting of La Boca formation and basalt, and in the foreseen dredging area with drilling and blasting of only basalt as La Boca formation was expected to be dredgeable with the foreseen equipment.

Normal practice would have been to first remove the soft overburden before commencing drilling and blasting operations, reducing the amount of linear meters to be drilled. However, this was not possible for several reasons – the first reason: the overall construction schedule to meet the Contractual Milestones required drilling and blasting program to commence as soon as possible. Dry excavation depended on the installation of a temporary loading facility for loading into barges. If drilling and blasting were only to start after removal of soft overburden, this activity would become critical and increase overall execution time. The second reason was the interface with the quay piling works: a minimum distance of 100m was established between any blasting activity and the closest (finished or unfinished) piles to avoid damage. The drilling and blasting program was thus pushed forward to always guarantee this distance. The third reason and last was the design of the temporary retaining bund which had to remain intact; overburden could not be removed in this area anyhow.

During drilling works, an unforeseen basalt outcrop was identified outside the foreseen area and within the footprint of the temporary dike. Pre-treatment of this basalt area was handled separately as early blasting could lead to stability and permeability issues with the dike. The drilling of this area was done in the last weeks in dry on terraces before flooding of the excavation pit; blasting was done after partial flooding to avoid a sudden collapse of the dike due to blasting vibrations.

5.3 Excavation of the pit

All excavated material, be it in dry or dredged, was to be transported to and disposed at an authorized off-shore disposal area at approximately 20km from the site. In order to do so, a temporary loading facility was designed and constructed, consisting of a flat top barge fitted with four mooring pile collards and hinges for connecting loading ramps (see Figure 9). The collards ensured proper securing of the pontoon to four temporary concrete mooring piles that were casted up to rock layer. This floating jetty was a solid solution for coping with the high tidal differences at the Pacific side (5m) and the large layer of Pacific Muck that made other alternatives less favorable (e.g. sheet piles). The floating jetty was connected by means of three loading ramps to the shore and equipped with fenders on sea side for mooring a self-propelled split-hopper barge with a hopper volume of 3.700m^3. Two large excavators in a fixed elevated position would load the material that was brought to the jetty by means of articulated dumpers into the hopper barge.

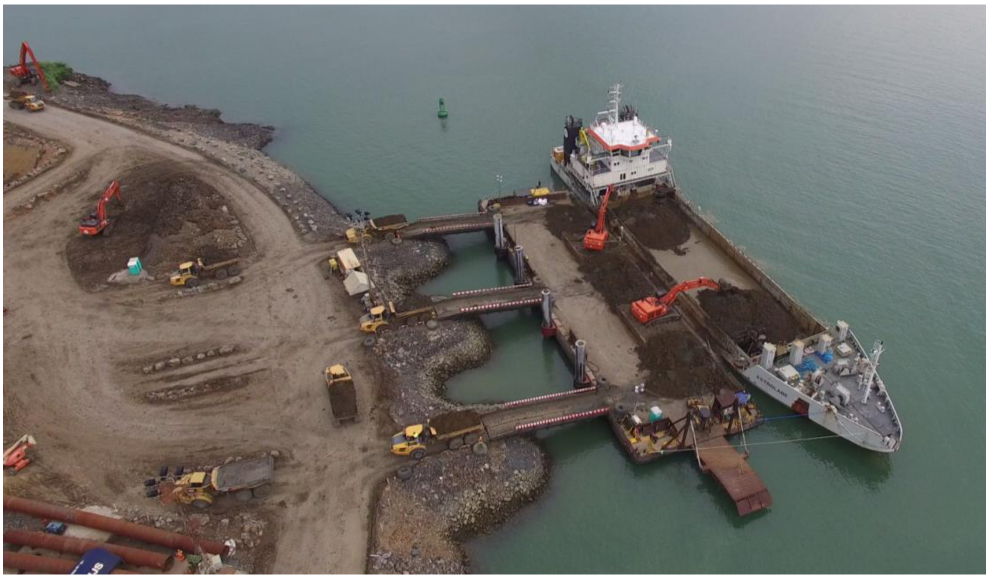

Figure 9: Temporary loading facility for off-shore disposal

Each row of piles required a working platform at a different elevation and so the excavation of the pit (see Figure 10) was done in different phases and in close coordination with the piling works. Close to the first row of piles, dry excavation was done up to final design to avoid future dredging very close to the quay structure.

Figure 10: Dry excavation works

An access ramp was maintained at all times haul material to the temporary loading jetty. The biggest challenge was excavation and hauling of Pacific Muck in rainy weather conditions. As an optimization, when reaching below residual soil, weathered and blasted rock was recycled on site as general fill.

During the excavation works, the condition of the temporary dike was monitored periodically using inclinometers and drone footage to verify soil condition assumptions made when designing the dike and to detect anomalies such as erosion (piping) of a sand layer around 0m MLWS level.

The last activity before start of the dredging works was the flooding of the dry excavation pit once excavation, piling and rock works in the main section of the quay were finished. The flooding process was designed to be slow and controlled at the beginning and to faster once blasting of the unforeseen basalt outcrop underneath the dike was finished (see Figures 11 and 12)

Figure 11: Controlled start of flooding

Figure 12: Final flooding stage

5.4 Dredging to remove bund and complete depths

For the dredging of the dike and remaining material above final design level of -16.3m MLWS, a very complete dredging spread was mobilized consisting of a backhoe dredge with split-hopper barges, a cutter suction dredge and a two trailing suction hopper dredges. See Figure 14 for view of equipment deployed.

The backhoe dredge was used for removal of the soft upper layer of the dike (see Figure 13), for dredging in between the piles at the northern and the southern closing section of the dike and for dredging a trench in front of the first pile row wherever this was not done during dry excavation phase.

The cutter suction dredge was used for dredging of the La Boca formation and basalt layer to reach to design depth. Taking into account sailing distance and the expected variability of soil conditions, two large trailing suction hopper dredgers were used as barges with the cutter suction dredge for transport and disposal of the dredged material to the authorized off-shore disposal area. The loading of these hopper dredgers was done via floating line connected the hoppers bow connection. The large hopper capacity guarantied high efficiency of the cutter suction dredge independent of the type of material that was being dredged.

Apart from its use as barge with the cutter suction dredge, one of the two hoppers was used for general clean-up of the dredge area before its taking over and for maintenance dredging of Phase I berth pocket and basin.

Figure 13: Dredging of loose upper layer with backhoe dredge

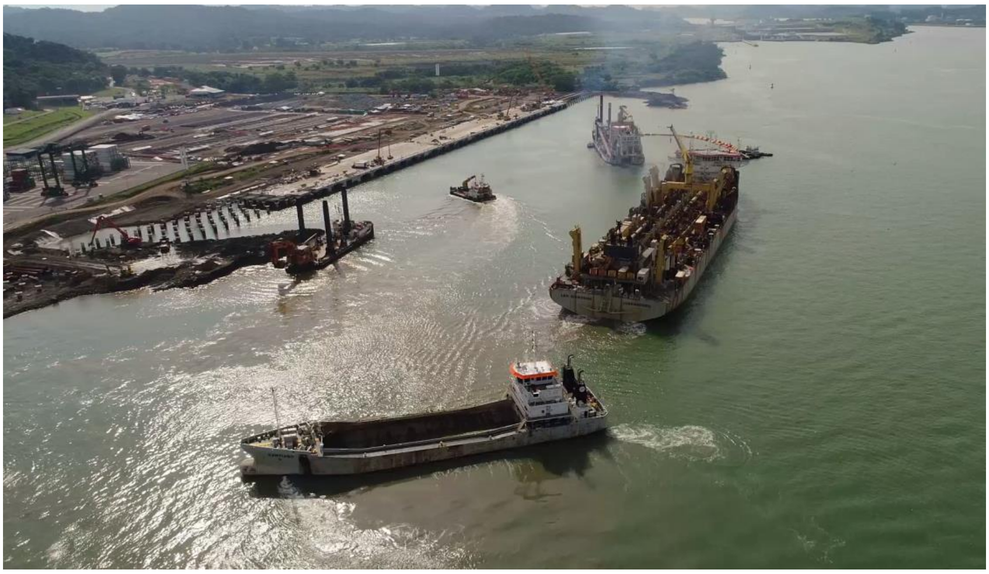

Figure 14: Complete dredging spread at work

5.5 Accommodation of crane deliveries

As the start of dredging works was governed by the date of the flooding, which in turn was based around the critical milestone of the delivery of the first set of cranes. This was approximately one month after flooding and required a berth pocket for tide independent berthing and enough depth for the crane delivery vessel to reach this berth pocket. In order to reach this milestone, a section of 300m was selected in close coordination with the quay construction team and this section was dredged first with the backhoe dredge.

For the delivery itself and the commissioning of the cranes, dredging of the remaining scope was planned in such a way to minimize interference.

5.5 Variation in materials versus expected at time of tender

Although in terms of area less hard material was found than expected (which generated a saving on the drilling and blasting works), the hard material that was present turned out to be averagely harder than expected. This generated an extra cost for the dredging works mostly as a result of excessive consumption of soil wearing parts, requiring additional mobilization of spare parts and consumables and intensive repairs during and after the works. Thanks to the high efficiency of the dredging spread, JDN was able to maintain dredge productions within the scheduled execution time.

Additionally, an unforeseen outcrop of basalt was found under the central section of the temporary dike. This area was blasted after partial flooding of the excavation pit to ensure dredgeability.

5.6 Equipment solutions to accommodate variability of materials

The variability of materials that would be encountered was taken into account when selecting the equipment for this job. During dry excavation on one hand, the deployment of articulated dump trucks, the design of the loading facility for off-shore disposal and the type of barge guaranteed high production rates even in rainy conditions and with wet, soft material as the Pacific Muck.

For the pre-treatment of the rock, systems were foreseen for drilling with casing through soft overburden as well as drilling without casing straight from rock level.

On the other hand during dredging works, the selection of the powerful cutter suction dredger 'Niccolo Machiavelli' is with 7,000 kW of cutter power part of the world's most powerful cutter dredgers and was able to dredge the hard blasted and unblasted rock. The hopper barges made sure enough loading capacity was available and hence minimized downtime while changing barges or waiting for barges, not depending on the type of material encountered. On shore, a 24/7 welding workshop was deployed for continuous repairs to cutter heads after being worn or damaged by the hard material. Dredge planning was made in such a way that the backhoe dredge was working on-site until the end of the project, for the removal of some remaining big boulders that would have been tossed around by the cutter dredger.

6.0 COMPLETION

The execution of the dredging and excavation contract for PPIT was accomplished successfully and expeditiously. Final outturn price was less than 5% above the agreed contract amount. The only unforeseen event that occurred was a delay to the quay contract caused in connection with permitting for the concrete batch plant, which in turn impacted the start date of the dredging works. Otherwise the additional amounts were either due to increases in scope or other variations. Given what is known about the challenging soil conditions, this is a very significant achievement and a validation of the selected tender and contact methodology, as well as the execution of the works by the contractor.