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IMPACTS OF EVOLVING SHIPPING AND VESSEL CHARACTERISTICS ON BERTH MAINTENANCE DREDGING

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ABSTRACT

Changes in vessel and shipping characteristics over the last several years have been a major driver of changing requirements for berth maintenance dredging operations at the Port of Portland.

Noticeable changes in vessel characteristics of ships calling at the Port's terminals over time are not limited to deeper, longer and wider vessels, but also include other aspects such as shape of the hull, increased horsepower and use of bowthrusters.

At many existing terminals, simply dredging deeper in order to accommodate deeper vessels is not an option due to structural issues, environmental constraints, permitting challenges, high cost, and long lead times. As a result, berth maintenance dredging projects are needed more frequently, handle smaller sediment volumes, and require a higher degree of accuracy.

Changes in shipping logistics and terminal operations have also resulted in significant changes in the way berth maintenance dredging must be performed. Factors such as increased charter rates, customer-driven schedules, and berth occupancy often impact planning and scheduling of maintenance dredging work. Changes to the patterns of deposition and scour are driving changes in maintenance requirements and methods.

Resulting complications and cost increases have in turn become factors in the development of different approaches and methods to monitor and maintain water depths at the Port's berths. All aspects of the product delivery process have been affected, from survey through design and contract management of maintenance projects. In some extreme cases, these factors have changed the way projects were contracted and risks allocated.

This presentation provides an overview of how the different changes in maritime shipping have impacted maintenance dredging at the Port of Portland, and the initiatives taken to address berth maintenance safely and efficiently. These patterns as experienced and observed at the Port of Portland's bulk and container terminals, as well as the lessons learned from them, are likely to apply to other facilities throughout the nation as well.

Keywords: Draft, Portland, bowthrusters, tombolo.

INTRODUCTION

Portland is a river port located at the confluence of the Columbia and Willamette Rivers. The Portland Harbor receives approximately 900-1000 vessel calls per year, and roughly 25 million metric tons (27.5 million tons) of waterborne trade moves over the docks. Portland's facilities are widely diverse, including liquid bulk, dry bulk, break bulk, ro-ro, automobile and container terminals. Both deep draft and shallow draft vessels are accommodated, and the current 12.2 + 1.5 meters (40+5 feet) channel is being deepened to 13.1 + 1.5 meters (43+5 feet).

The Columbia and Willamette are the fourth and fifteenth largest North American rivers by annual discharge volume. Both rivers carry significant amounts of suspended sediment and bedload, and Portland Harbor is subject to regular siltation. In Portland, as at many seaports throughout the country, maintenance dredging at marine cargo terminals is an annual requirement essential to the continuity of the maritime enterprise.

Dredging means and methods have had to adapt to meet changing environmental, operational, and regulatory requirements. This paper explores the adaptations made in Portland as a result of changes in the operational characteristics of the vessels serving the terminal and the related terminal operations. Environmental and regulatory matters are also significant as to their effect on dredging, but have been well documented elsewhere (CEDA/IADC 2001) and are not the focus of this paper.

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BASELINE SITUATION

Without waxing too prosaic about the past, it could be said that maintenance dredging in Portland during the 1980s and 1990s was rather simpler than it is today. During those decades, there appeared to be adequate time to undertake a given project and accomplish the design goals; terminal operations were only moderately impacted; and projects, once identified, were carried out without creating vessel draft constraints; but these are certainly not today's conditions. What, besides environmental and regulatory matters, has changed?

Several maritime industry trends, independent of environmental issues, have made it more difficult to carry out a dredging project in Portland now than in the past. For the purpose of this discussion, the authors have split these between physical changes in the vessels calling the port, and operational changes in the way the vessels are handled while at berth.

PHYSICAL CHANGES

Vessel Drafts Increasing

The most obvious trend in the industry is the increasing draft of vessels needing to be served at berths. The size of ships has increased faster than the majority of the industry expected (US DOT, Office of Intermodalism (1998)), and, more importantly, the physical draft of the fleet calling Portland's terminals has increased much more quickly than the typical ability of the Port to deepen terminal berths.

In the best of cases, long lead times are required to design and implement deepening projects. Frequently, and in more difficult cases, docks and berthing areas may not be easily modified due to structural, geotechnical, or other physical limitations. As the vessel draft increases at a berth with fixed design depth, the infill capacity for routine sedimentation decreases, leading to the need for more frequent (and less productive) dredging to maintain the advertised depth.

As an example, soda ash has been exported at Terminal 4 in Portland since the mid 1980's. In 1991, the average load for the 100+ vessels calling the terminal was roughly 20,400 metric tons and the average size was 27,878 DWT. Load size grew by 20-25% during the 1990s, and the size of ship has steadily increased as well, to an average of 34,805 DWT for the most recent 12 month period.

With the increase in ship size, loaded draft has also increased (both as a result of deeper loading as well as larger vessels stopping at several ports to load multiple cargos). Numerous structural constraints limited deepening the berth, and as a result, infill capacity has been reduced. Dredging projects have increased in frequency from once every three or four years to every year to maintain the same operational capability.

This same pattern has been in effect at our container, breakbulk and all dry bulk terminals. Drafts of vessels are increasing faster than our ability to modify berths, leading to an increase in frequency of dredging events.

Shape of Ships is Evolving

As newer ships come on line, we have witnessed an apparent drive by vessel designers to maximize the loading capability within a particular class of vessels- to fill out the available volume. This trend can be seen in the following chart, which shows the growth in vessel size within the Panamax and Handy-max bulk carrier categories over time.

This chart (Figure 1) clearly shows that for both Handymax and Panamax class vessels that call the Columbia River Ports, the more recently the vessel was built, the larger is its dead-weight tonnage. This maximization of dead weight tonnage within the Panamax or Handymax 'envelope' is achieved, in part, by reducing the turn of the bilge, making vessels "boxier".

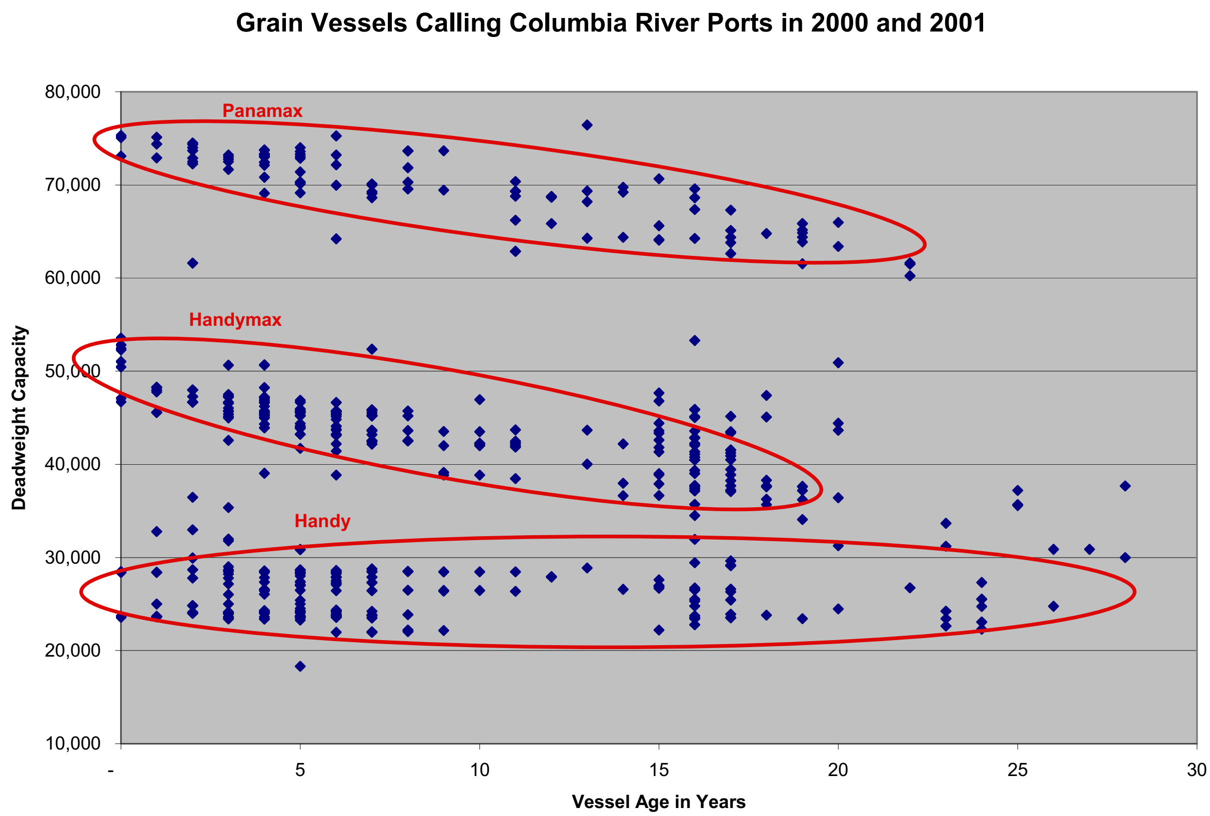

Figure 1. Vessel age of bulk carriers calling the Columbia River, 2000-2001.

As a result of the change in hull shape, sediment buildup at the fender line margin of the dock may become a more critical maintenance issue than it was before, even for ships loaded to the same effective draft.

As one example, we have had to resort to factoring in the turn of the bilge at one highly active bulk facility in order to maximize loads, just because some small humps above advertised depth were identified within the area where the turn of the bilge allows a slightly shallower depth.

Figure 2 shows more specifically for all Panamax class vessels built between 1980 and 2000 (here defined as having a width between 32 and 32.5 meters as well as having a length between 224.5 and 225 meters), the gradual increase of dead weight tonnage within those specific maximum dimensions. The overall increase of 19% in DWT as shown in this graph is attributed to a simultaneous increase of only 9% in maximum draft, indicating that more than half of that increase is due to vessels becoming boxier within their set envelope.

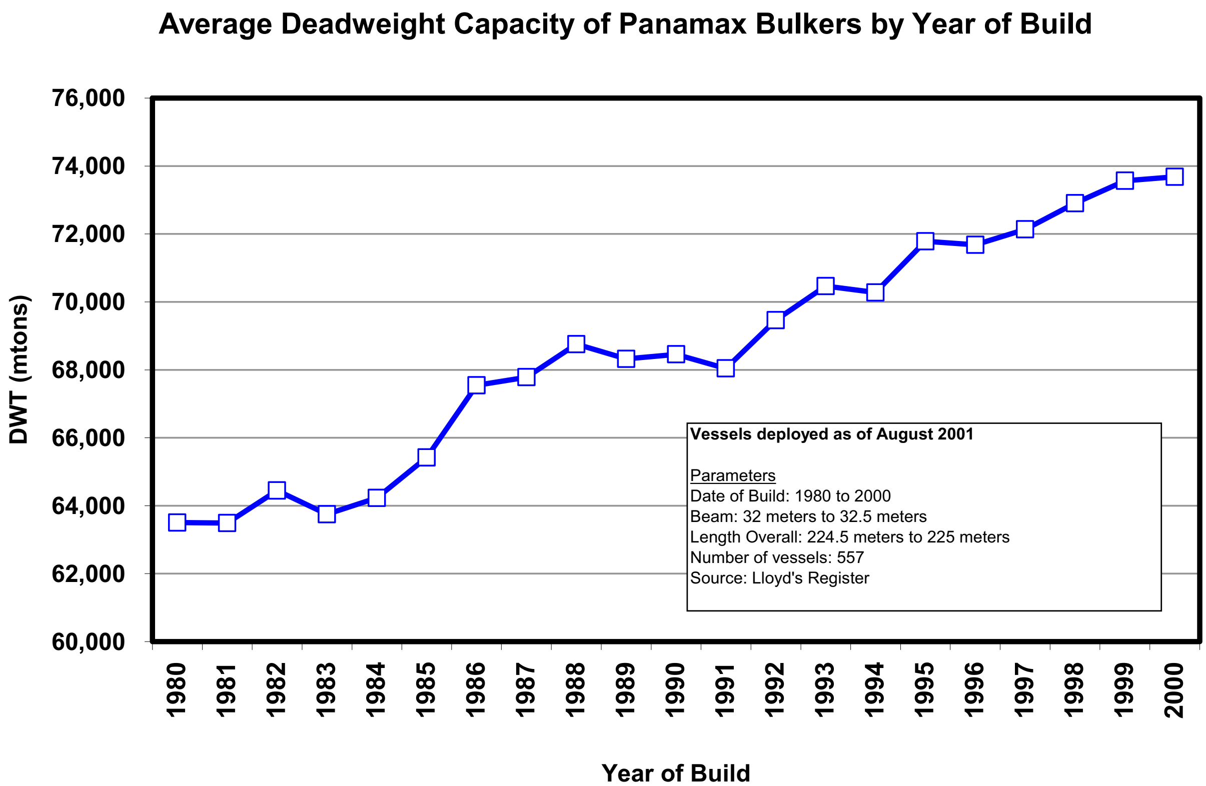

Figure 2. Development over time (1980-2000) of Panamax bulk carrier dead weight tonnage.

The Port's soda ash export facility at Terminal 4 has a pile-supported dock with a slope that runs underneath that dock and extends out approximately 4.6 meters (15 feet) in front of the fender line before reaching advertised depth of 12.2 meters (40 feet). Many older pile-supported facilities have similar set-back requirements that did not pose a constraint to loading until vessels became both deeper and "boxier". At a 3 meter (10 feet) radius turn of the bilge, the 3:1 slope from 10.7 meters (35 feet) at the fender line to 12.2 meters (40 feet) berth is hardly a constraint, but a 1.8 meters (6 feet) turn of the bilge creates an almost 0.76 meter (2.5 foot) limitation. (Although anecdotal evidence clearly indicates this trend, we could not generate any numeric data specific to the turn of the bilge to illustrate the exact order of this trend.)

As stated above, the impact to maintenance dredging is the need to dredge more precisely, with greater frequency, and was, ultimately in the case of our most constrained terminal, an incentive to remove the toe slope by installing a structural sheetpile wall to hold back the under-pier slope, and to dredge out the toe.

Bowthruster Power and Use Increasing

In Portland, we have experienced significant bowthruster scour from container vessels calling our facilities, a phenomenon that is mentioned but not yet widely publicized in the literature. However, we believe that, for certain docks, vessel patterns, and substrate characteristics, bowthruster scour is an increasing issue, and is not just limited to container vessels. Bowthruster force on container vessels has grown significantly as the size of ships has increased; for instance, the power of a typical bowthruster of the older, smaller vessels calling at Portland's Terminal 6 was around 750 kW, while currently installed power of a bowthruster on a typical vessel can be as much as 2000 kW.

Of course, underlying cause of this increase is the increase in size of the vessels themselves, as the design bowthruster power is directly related to the lateral cross sectional area of the vessel below water (with thrust in pounds of force being roughly twice the size of that lateral cross sectional area of the vessel below water).

To illustrate the extent of this aspect, an increased vessel length of 30%, combined with an increase in draft of 15%, results in an increased lateral cross section of the vessel of 50%, while an increased length of 50% in combination with 20% more draft would result in almost doubling the required bowthruster power.

It is not just the installed power of bowthrusters that has increased dramatically. The duration of use of the thruster during mooring and demooring operations has also increased. A longer vessel with less under-keel clearance requires a disproportional longer time to be moved off the dock because of hydraulic forces and the vessel's increased virtual mass.

At our container facility, the use of bowthrusters by fully laden vessels, particularly at low water periods, has created not only unwelcome holes at our sheetpile bulkhead wall, but also the adjacent deposition of sand and silt, which has become a constraint on berth depth. This scour activity has led to high spots, rather than shoals within the berthing area, that need to be addressed through maintenance dredging. These vessel-related high spots can develop faster than routine annual sedimentation, and require more frequent intervention by the Port.

The impact of sediment redistribution resulting from vessels can be clearly identified in a recent bathymetry survey at Port of Portland's Terminal 6 (Figure 3).

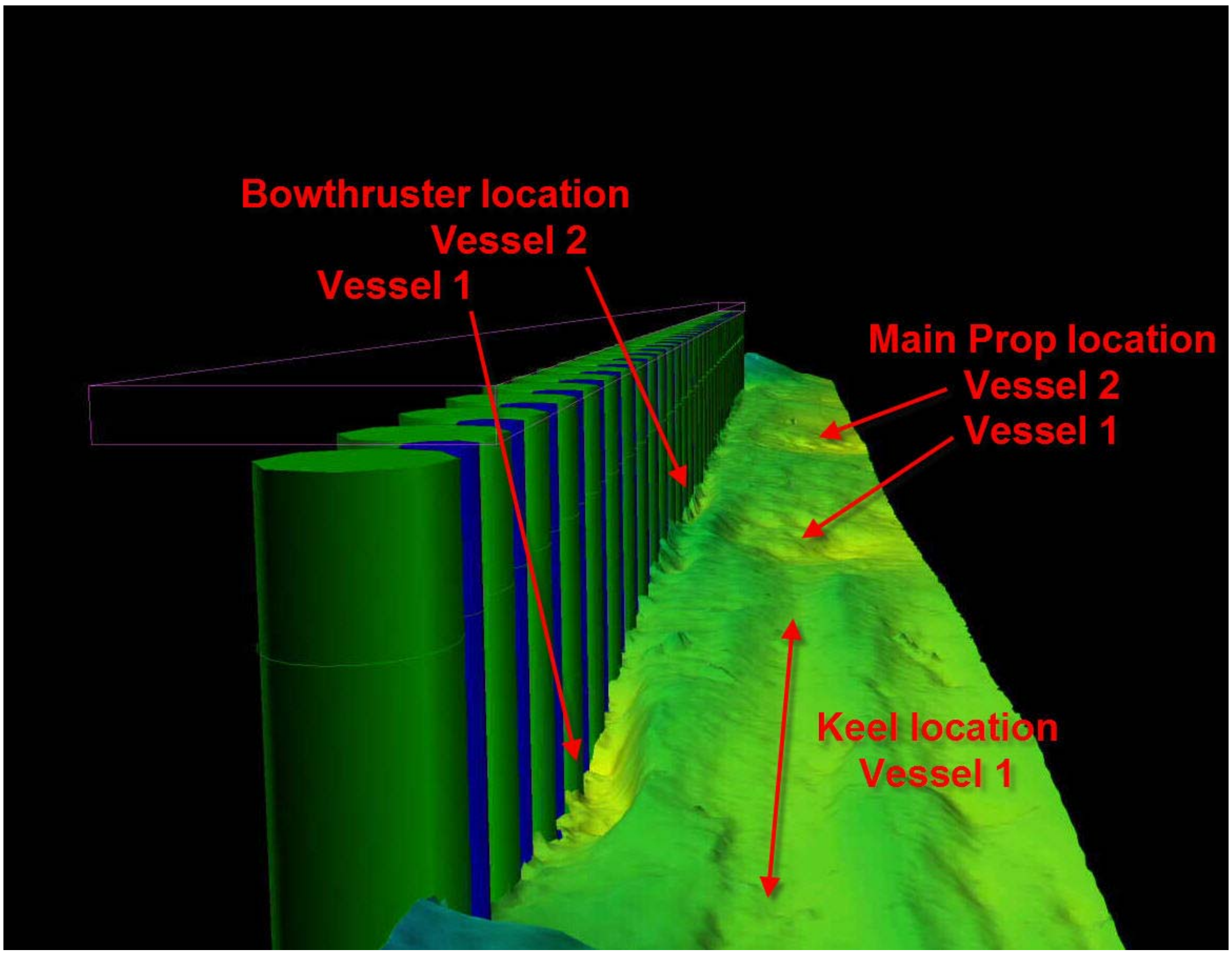

Figure 3. Bathymetry survey of Terminal 6, showing the imprints of container vessel activity.

While at first glance it might look much like the typical bathymetric survey information depicting a seemingly irregular pattern of bottom elevations, factoring in information about the prevalent use of the berth provides clear clues to what's happening as far as marine operations at the berths. The visible pattern of sediment scour and deposition is unmistakably evidence of the typical mooring locations and procedures of container vessels at this 865 meters (2830 feet) long continuous dock structure.

Greater Barge Dimensions Causing Increased Tombolo Effects

The frequent presence of large vessels at berths can lead to increased dredging needs by creating conditions in which the sedimentation rate at such berth increases. We have previously discovered and described the formation of tombolos at Portland terminals (Kcrma, et al. 2002) as a result of near-shore barge activity.

A tombolo is a bar or spit that connects a near-shore island to the mainland, most often found in coastal environments. However, in Portland, we have seen evidence that the high occupancy rates of certain berths with barges and vessels proximate to the shore essentially act as near-shore islands, reducing the vessel and wind wakes that are present on the river in the area between the barge or vessel and the shore. The resulting wave shadow forms the ideal condition for the creation of tombolos by locally reducing sediment transport capacity along the shore and encouraging deposition of suspended sediments in the berthing area. Figure 4 depicts an aerial view of a tombolo formed by barge activity at Portland's Terminal 5.

Figure 4. Typical tombolo at a grain elevator berth in Portland.

The tombolo effect may have been strengthened as standard wheat barges on the Columbia River have increased in all dimensions over the last decades. Most prevalent now are the 3,180 metric ton (3,500 ton) capacity barges measuring 83 meters (272 feet) long by 12.8 meters (42 feet) wide, by 4.1 meters (13.5 feet) deep. In 2000, the river's largest grain barges were put into service, with a capacity of 3,815 metric tons (4,200 tons), and were both longer at 91 meters (298 feet) as well as deeper at 4.9 meters (16 feet). The impact of the larger barges is that the conditions that encourage deposition are intensified in proportion to the length of time the barge sits at dock to be loaded or unloaded, and the size of the wave shadow it casts. All of these factors have taken effect at the Port of Portland's grain facility, thus impacting the dredging needs.

OPERATIONAL CHANGES

Berth Occupancy Rates Higher

Berth occupancy has increased at all of the Port of Portland's active marine cargo facilities. This is a result of the high cost of dock construction & dock modification (relative to other components of the terminal and port infrastructure) and the concentration of more throughput per length of dock due to efficiency improvements.

In several cases, it is the size of the vessel loads and the vessel itself that have driven additional time at dock. This trend has been documented on the largest container vessels in the trans-pacific trade, and is also true regarding the bulk trades in Portland. Efficiency improvements have been made in the volume transferred across the dock, but they are not commensurate with the growth in cargo volume per call.

Consequently, as more vessels have called at each dock and as occupancy has risen, it has become progressively more difficult to maintain the flexibility to schedule all necessary berth maintenance without interfering with the essential business activity. To accommodate these changes, dredging projects have had to become more flexible, accommodating, effective, and creative.

Vessel Time Becoming More Valuable

Vessel time has become increasingly valuable across all lines of maritime business. Figure 5 shows increases in the time charter cost per TEU for mid-sized container ships over the last seven years. The cost per day for bulk vessels has increased in a similar fashion.

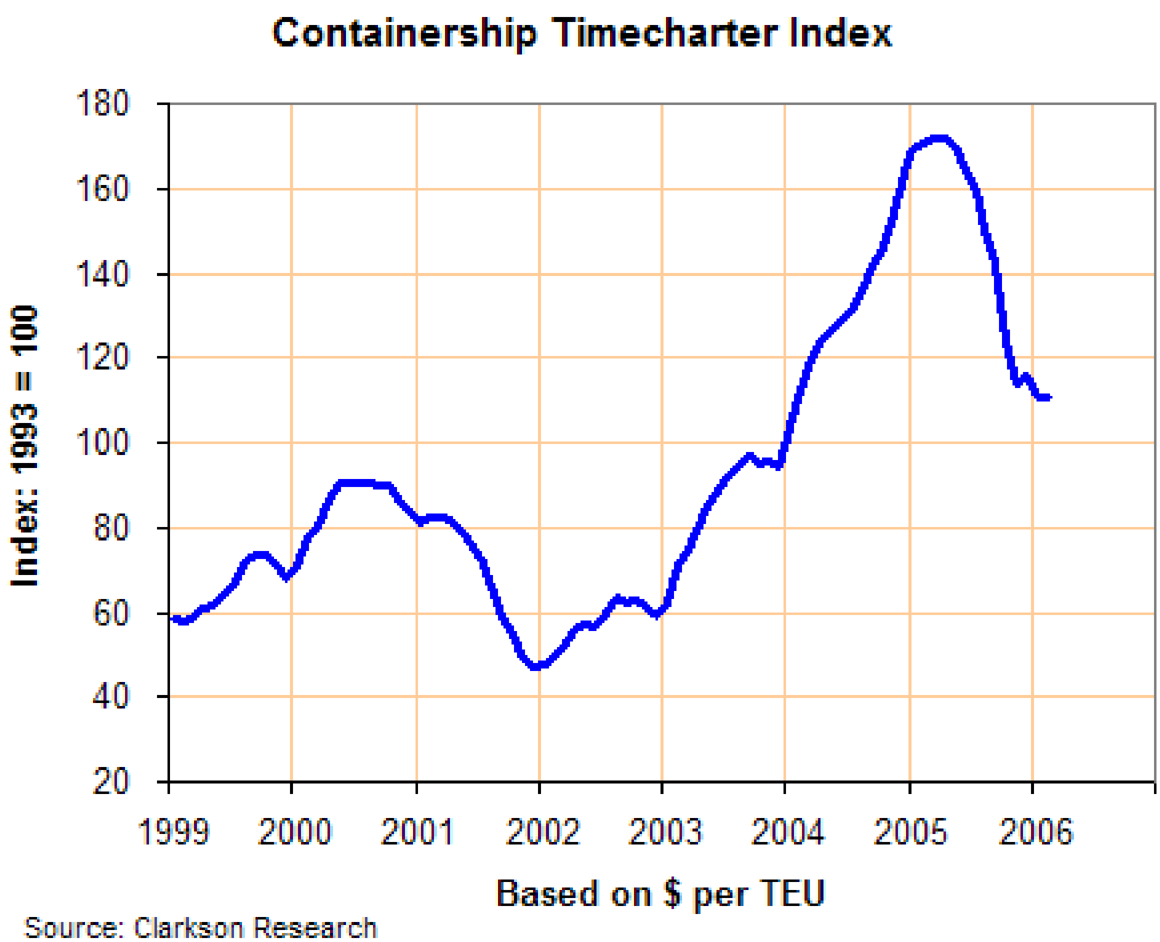

Figure 5. Charter cost per TEU for mid-sized container ships.

There are multiple reasons for the increases, including demand outstripping supply; fuel price increases; and competition for berth space. Just-in-time delivery logistics have also added to the opportunity cost of vessel delays. As a result, providing uninterrupted berth availability as needed by terminal operations has become an even more significant operational requirement than in the past. The impact of this trend is to require better schedules, performance, reliability, and certainty on the part of berth maintenance projects.

IMPACTS ON DREDGING APPROACH

As a result of these changes in vessel and shipping characteristics described above, the approach to maintenance dredging at the Port of Portland has undergone certain changes as well. Some of these responses have been very gradual and hardly noticeable as resulting from the changes in vessel and shipping characteristics, while in some other cases, a very specific and identifiable action was taken related to described changes.

Especially for the more gradual changes, it can be hard to distinguish between changes that are specifically and solely responses to the described factors, versus changes that were also in part driven by other influences occurring during the same time frame. In fact, it seems realistic to say that most changes apparently attributable to vessel or shipping characteristics were driven by other factors as well.

Maintenance Dredging Changes Outlined

Some of the changes that were made were general and applied to the maintenance dredging program as a whole, while some other changes were applied on a specific project level.

Changes made to the approach and program of maintenance dredging at the Port of Portland are discussed below, and are separated into the following categories:

- Coordination between terminal tenant and dredging contractor
- Changes to lease contract language with tenants
- Development of alternatives to maintenance dredging
- Re-design of dredge prisms
- Modification of infill depths in permits
- Obstruction removal
- Increased focus on quality of the final product
- Dredging closer to the dock
- Dealing with effects of bowthruster scour

Coordination between Terminal Tenant and Dredging Contractor

For the typical tenant, the preferred situation is that berth is available to the tenant at all times and that maintenance activities such as dredging are allowed only at times during which no tenant activity is taking place at the dock.

From the perspective of the dredging contract and contractor, it's typically preferable to retain all operational flexibility, allowing leeway in setting a schedule that takes into consideration other jobs, labor availability, weather or river conditions, etc.

With vessel schedules becoming tighter and occupancy rates for some berths being extremely high, both sides cannot be fully accommodated. To avoid situations where unreasonable demands are made of the contractor to be available and ready to work during the whole in-water work window, even though actual berth availability within that timeframe may be sparse and unpredictable, the Port coordinates very specifically with the tenant about timing of dredging and contract language.

The Port recognizes that serving both the interests of the contractor and the tenant are of importance to the Port, its performance and its financial bottom line. In balancing the needs of contractor and tenant, the Port works to minimize the overall cost of disruptions to both operations and maintenance activities, regardless of which party would initially appear to incur the cost.

On a project-specific basis, before the dredging contract is even put together, the Port estimates how many days of dredging will be needed and checks with the tenant to determine whether or not there are specific business advantages to performing the dredging at a specific period within the in-water work window. In some cases, seasonality of the business or other maintenance activities at the facility will indicate the preferred timing.

The Port also checks with the tenant and the contractor community to determine whether the preferred dredging schedule will be one longer continuous period of berth availability, or a combination of several shorter periods interspersed with dates during which the berth is made available to the tenant, and the contractor can take care of activities like barge offloading. Berth availability to the contractor is then specified in the contract as, for example, "*a minimum of three 4-day periods between July 15 and August 30, with a minimum of three days in between*".

The Port further promises the contractor that it will provide at least 48 hour notice of the start date of each of those four-day dredging periods. If the contractor needs additional dredging days beyond those specified, they will be made available only in accordance with the tenant's operational needs. This way, both the contractor and tenant know what to expect and can plan accordingly, thereby minimizing any costs due to disruption on their account.

In this sense, timing of maintenance dredging has now been adjusted to, and in some ways even has become part of, the logistic chain of tenants' operations. The Port takes an active role in coordinating this interaction and optimizing the overall result.

Changes to Lease Contract Language with Tenants

Related to the change described above, and as opportunities arise, the Port has modified the lease contract language with some of its tenants to include a provision indicating that, with sufficient notice, the Port can claim berth availability up to a certain number of days a year to schedule any needed maintenance work.

Of course, the Port and tenants can still coordinate any additional maintenance work as well; however, the expectation is that any such additional maintenance will be scheduled around tenants' operations.

Because of this, the Port is able to include some guarantees as to berth availability in its dredging contracts, while the tenants are aware of maintenance demands well in advance, enabling them to plan and schedule around the dates on which the berth will be unavailable for their operations.

Development of Alternatives to Maintenance Dredging

Because of the trend in maintenance dredging projects to be performed with higher frequency and at a lower volume, the cost of maintenance dredging has increased significantly, not just on a per volume unit basis, but also as a total cost to operations at a terminal.

As a result, the Port of Portland started an initiative to identify and develop an alternative method to more efficiently and cost-effectively deal with small volume shoaling at the Port's berths. After looking into several alternatives, the Port selected the method "Underwater Grading" (by others also referred to as *high-spot knock down*, *sweeping* or *beam dragging*) that is specifically fit for situations with small volume shoaling at its berths.

Major advantages of this Underwater Grading method, developed by the Port of Portland as an alternative berth maintenance technique, are not only the significant reduction of cost but also a reduction of complexity of project preparation, a very quick response time, and a very high degree of operational flexibility. Quicker response time and higher operational flexibility directly tie in to the demands imposed by changed shipping logistics.

A more specific and detailed description of the Port of Portland's Underwater Grading can be found in a paper entitled "Underwater Grading, A New Method For Berth Maintenance at Port of Portland" (Hermans et al. 2006) in these same proceedings.

Re-design of Dredge Prisms

As another response to described changes, the Port of Portland has reviewed and modified its dredge prisms. The dredge prisms – the descriptions of the areas to be maintained at a certain depth for vessel access to those berths – were made more specific to the actual dimensions of the ships that use those berths.

Assessing or establishing a certain dredging need is no longer based on just a certain volume of sediments above a defined grade within the dredge prism, and a horizontal alignment of the dredge prism that is rather general in nature. Instead, the aspect of depth in a certain location within the dredge prism and the way in which the vessels move in and out of the berthing area are now both taken into account on a more site-specific basis.

Modification of Infill Depths in Permits

In new permit applications during the last few years, the Port has requested an additional depth of one foot below the required depth to specifically account for infill capacity (advanced maintenance dredging) as well as a two feet margin for dredging accuracy. Now that more and more vessels load to their maximum drafts, it is no longer acceptable to just count on (or hope for) river stage to be high enough whenever a deep vessel needs to use the berth, or to begin scheduling a maintenance dredging project only after the required depth is already found to be compromised at a certain berth.

Obstruction removal

Another result of margins becoming tighter is that nowadays, in its evaluation of the annual hydrographic condition surveys, the Port specifically looks for any obstructions that might be present in the berthing area. Even if submerged logs or other large debris are identified as being within the berthing area but below the required depth, the Port usually opts to perform a diver-assisted removal operation of the debris, because with only small margins to spare, a minor change in its location or positioning could easily result in a draft restriction or hazard to navigation. This practice is largely facilitated by improvements in survey equipment capabilities that have occurred over the last decade. Use of multibeam equipment has made it now possible to identify obstructions and have a diver locate and/or remove those, where in many cases a single beam survey would not have been able to identify such obstructions.

Increased Focus on Quality of the Final Product

Because planning of maintenance dredging activities at its berths has become more rigorous, the Port also puts more effort in providing conditions to follow that stricter schedule. As an example, post-dredging surveys are now typically scheduled on the very same day or the day after the contractor finishes work, instead of within the week.

Additionally, with the contract language defining available work periods for the contractor, as described in a previous section, there is obviously also an incentive for the contractor to ensure that the work is completed as planned within those work periods. The contractor relies upon proven methods such as progress survey checks, overdepth allowance, etc., to increase the emphasis on timely completion.

Also, a maintenance dredging project is now virtually always concluded with a final post-dredge survey, even if that means it must involve a second or occasionally third post-dredge survey. With depths being more critical, having the exact final depth recorded on the drawing becomes more critical too. This replaces the practice of just marking on a post-dredge survey that that last little hump is now gone because it was removed as the final action in the dredging project, based upon and subsequent to the post-dredge survey.

Dredging Closer to the Dock

With the shapes of vessel hulls becoming boxier, and vessels more frequently loading to maximum capacity or depth, there has been an increased emphasis on dredging to the full depth directly adjacent to the dock.

In the case of the Port's Terminal 4 soda ash export loading facility operated by Kinder Morgan, this did not fit with the existing design of the berth. The berth was originally designed in 1962 for 10.7 meters (35 feet) depth, but was deepened to become a 12.2 meters (40 feet) berth soon after completion in 1969. This was accomplished by dredging the entire berthing area, except the 4.6 meters (15 feet) closest to the dock, to the depth of 12.2 meters (40 feet), leaving those first 4.6 meters (15 feet) sloping from -10.7 meters (-35 feet) to -12.2 meters (-40 feet) because of concerns for the stability of the dock structure and the slope underneath.

In this particular case, as illustrated by Figure 6, an underwater sheet pile wall was needed to protect the dock structure and hold back the slope underneath in order to dredge beyond the -10.7 meters (-35 feet) depth. This sheet pile wall was required to accommodate future berth clean up dredging, anticipated for 2008, but because the current tenant's operations generated an immediate use for more depth in 2004/2005, the Port decided to install the sheet pile wall in 2004 in order to optimize berth functionality by offering the tenant a true full 12.2 meters (40-feet) berth. Following installation of the sheet pile wall, the toe of this slope was removed in 2005.

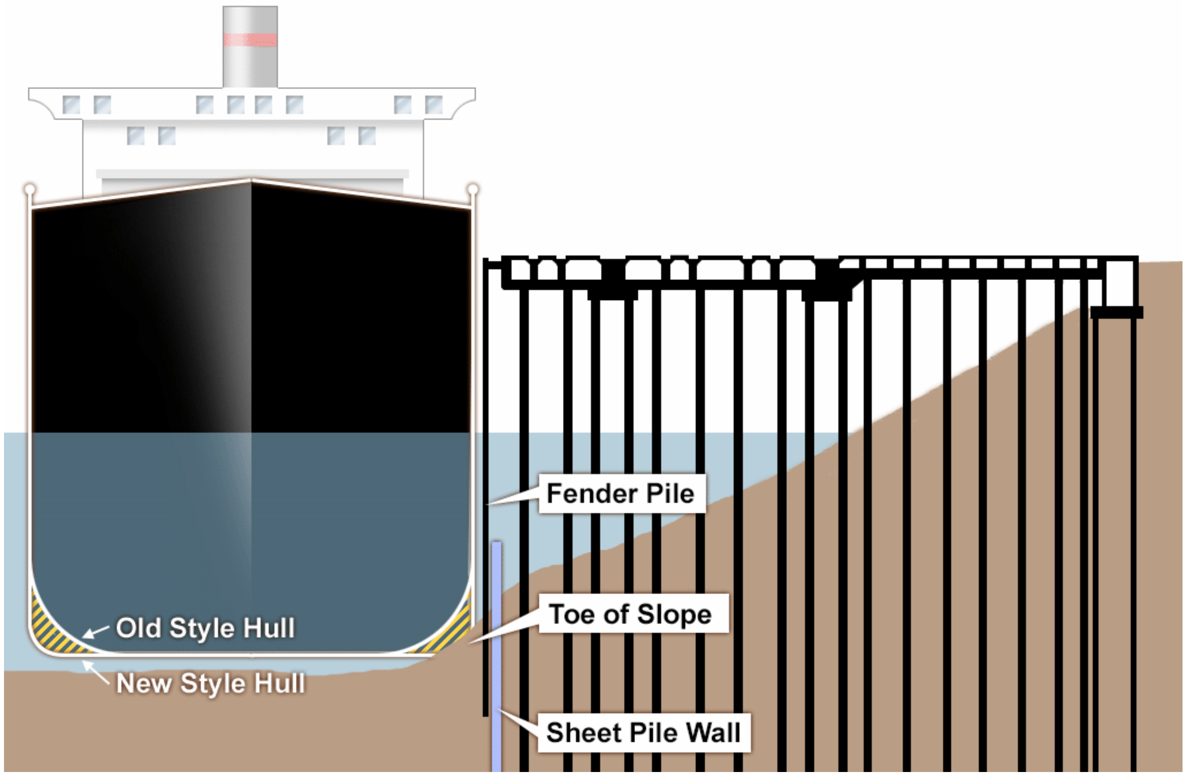

Figure 6. Underwater sheetpile wall at Terminal 4 accommodates boxier hull types.

The increased importance of accomplishing the full depth all the way up to the dock has also been evident at other terminals. This need poses additional technical challenges, both in situations with solid wall berthing structures, and in front of pile-supported open dock structures.

For solid berth structures, the main objectives are to get the bucket placed right up to the dock also in order to remove the sediments right up to the dock. For open pile-supported structures, the major challenges are the build-up of sediments under the dock and the inability to effectively dredge there. Removal of sediments in front of the dock will usually lead to sloughing. If sloughing occurs after dredging is completed, the newly accomplished depth in front of the berth will be compromised or reduced again. Purposely setting off such sloughing to occur during the dredging project, by over-dredging in front of the berth, is often neither feasible nor acceptable because of concerns for the slope stability under the dock.

For both types of structures, the presence of fender piles in front of the dock structure makes it difficult to remove sediments in that area. Not only do the existing functional fender piles act as obstacles, but so do the large number of pile stubs and broken fender piles that have been left in place. Some of the specific problems related to these fender piles are interference with bucket placement; sediment being held back behind piles; and difficulty in obtaining accurate and definitive survey data about the actual sediment depth.

Dealing with Effects of Bowthruster Scour

Bowthruster-induced scour at the Port's container terminal, Terminal 6, as described in the previous section of this paper, resulted in two related issues with sediments. Not only was the depth of some scour holes and their proximity to the dock a serious concern for dock stability, it also appeared that those same sediments blown out from the area directly adjacent to the dock were deposited nearby within the berthing area, causing depth-limiting high spots that triggered the need for maintenance dredging.

This aspect of unwanted redistribution of sediments within the berthing area was taken into account in the evaluation of scour protection alternatives, but the alternative that was ultimately selected does not address this specific aspect. The Port selected a solution involving installation of deep sheet piles in front of the existing berth structure in locations that are most subject to bowthruster scour, thereby protecting the berth structures but also enabling some redistribution of sediments.

It is anticipated that, although some high spots may be created initially when scour holes reappear, the new sheet piles will allow some equilibrium situation to be established so that this will not be a continuous source of sedimentation or high spots. It is also hoped that, if any minor high spots were to occur as a result of bowthruster scour, the Port could respond by using the underwater grading method described earlier (Hermans et al. 2006) to redistribute any sediments from the high spot back into the holes within the berthing area.

CONCLUSION

Independent of environmental regulatory factors, the changes in vessel design, operating practices, maritime shipping and terminal operations impact the characteristics of berth maintenance needs. Consequently, the means and methods for accomplishing necessary maintenance dredging have had to be adjusted to meet the requirements of the more dynamic and constrained operating environment.

At the Port of Portland, we have learned that we need to pay closer attention to detail and to margins in order to carry out a successful project that meets customer requirements. Effective maintenance has required more specification and contract definition to assure proper coordination and performance. We have also found that the majority of the operating problems exist in areas often ignored in the past: those margins right next to the face of the berth or in the approaches to the berth.

In response to the increased pressures of high occupancy and interruption cost, we have had to move to appointment systems for scheduled maintenance and monitoring, and to develop means and methods that allow maintenance equipment to move in and out faster, between vessel calls, and with easier mobilization.

We've had to develop better information on berth conditions, tolerances, and coordination with survey to assure timely performance and to optimize activities.

This paper has identified steps we have taken at the Port of Portland to change berth maintenance practices in response to the evolution of the maritime industry. We believe that recognition and analysis of these trends will allow ports to anticipate changes, make needed improvements in a timely manner, and where necessary, adapt their means & methods to address evolving needs at older facilities in continued operation.

Most of these changes result in an increase in cost to the facility owner, but they are justified by their contribution to the efficient utilization of the Port's investment in docks and infrastructure.

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