Project Next Generation

Dredging Methodology and Disposal Alternatives

Prepared for

Port Otago Ltd

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Thanks also to the crews of the *New Era* and *Vulcan* who in addition to keeping a custodian's eye over the beautiful Otago Harbour, spend the majority of their days plying their trade and keeping the Harbour and Port open for business.

Lincoln Coe, General Manager Infrastructure, was responsible for the initiation and completion of the resource consent application for Project Next Generation. His knowledge of the Harbour is surpassed only by his love of ships. His support, research, assessment and analysis of the art of dredging has been instrumental in the completion of this report.

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Executive Summary

This report presents options and assessments of dredging plant likely to be utilised in the proposed widening and deepening of the navigable shipping channel in Otago Harbour. The widening and deepening is the key component of the Next Generation project and entails a total dredging volume of approximately 7.1 million cubic metres made up of rock (1%), sand (62%), silt (33%) and clay (4%) from the seafloor within the Lower Otago Harbour and then disposal at sea of unwanted material.

If a capital dredging campaign was to be instigated a medium sized Trailing Suction Hopper Dredger (TSHD) is the preferred and most likely dredger for the channel silts and sands. TSHD's can work in unfavourable weather and sea conditions but are also sufficiently flexible to readily change to the best areas for dredging during adverse conditions. Due to its flexibility and manoeuvrability a TSHD has minimal effect on other shipping and has the ability to effectively transport material outside of the dredged area for disposal. This dredger has a high rate of production and therefore minimises the time when dredging effects occur.

TSHDs are used worldwide for the dredging of harbour channels and are the most technologically advanced dredgers available due to the considerable research, investigation and practice undertaken over many projects. The advancement in technology has been led by the desire to maximise the retention of sediment within the vessel hopper while reducing turbidity generation when overflowing. Overflow valves, often called "Environmental Valves" or "Green Valves", discharge through the bottom of the vessel and have been developed to reduce entrained air and consequential turbidity.

Three locations of rock outcrop will most likely require the use of a barge mounted backhoe dredger (BHD) with sufficient leverage to excavate fractured rock and to minimise the need for blasting. The rock is weathered or moderately weathered in the upper levels but hard in the lower levels which will likely require blasting.

The material to be dredged from the inside of Harington Bend and the swinging basin widening is predominantly sand but the difficulty in using a medium size TSHD is that the upper dredging level is close to chart datum providing insufficient depth for a TSHD to operate. The existing seabed level down to 9m below chart datum is suitable for a smaller grab dredge or backhoe excavators loading into barges followed by a small TSHD such as the *New Era*.

Once excavated, it is proposed the majority of the capital dredging material is transported to, and disposed of, in an area off the Otago Peninsula in a water depth of approximately 27m. The centre of the selected site is located approximately 6.3km off the Otago Harbour Landfall Beacon. Bottom dumping over the disposal site from both TSHD and barges, by splitting the hopper or opening doors, is the acceptable method for the disposal of the uncontaminated material from the Otago harbour channels. The existing maintenance dredging disposal sites

at Heyward Point and Shelley Beach will continue to be used for maintenance dredging material up to its existing annual limit.

Allowing for a number of key assumptions including 24 / 7 operation of the dredge and no downtime allowance, the total dredging duration is expected to be in the region of 6 months if completed as a large capital dredging project. An option to complete the work as an extension of the current maintenance dredging regime or with a smaller mid-size contract dredge will extend the duration of the total dredging works relative to the size difference.

Management and mitigation of environmental, social, cultural and economic effects will be controlled by the development and implementation of a dredging management plan, the Dredging Environmental Management Plan (DEMP).

1. Introduction

1.1 Background

This report is one of a number of reports addressing growth of Port Otago Limited (POL) operations at Port Chalmers Container Terminal (PCCT). One aspect of this progression is developing the capability to service large container ships of 6000 to 8000 TEU (twenty-foot equivalent units) in Otago Harbour. These ships have 50% more capacity and are longer and wider than existing ships that come to the harbour which will require modification to the harbour channel to enable safe passage. POL proposes deepening the approaches to Port Chalmers and the berth area by dredging the channel to a minimum of 15 metres below chart datum to allow the safe passage of these vessels.

This report aims to address the options and methodologies available to carry out the channel deepening and widening in accordance with international best practice while addressing environmental, social, cultural and economic considerations.

1.2 The Proposal

A full description of the design process undertaken to determine the proposed channel alignment is presented by POL (2010) in the Channel Design Report and summarised below.

The principal consideration in determining the final channel design was to minimise the dredging volume without compromising vessel safety, ensure that the port remained within acceptable limits of vessel accessibility in terms of tidal windows and that the overall result was commercially viable.

The initial review under the PIANC and IAPH Guidelines[1] indicated that the radii of Harington Bend and Deborah Bends should be increased considerably. The effect of this was a significant increase in dredging volume and its consequential environmental and economic impact. An alternative was to widen the existing channel alignment and demonstrate the radii was suitable with thorough testing of the ship manoeuvrability using full mission ship simulation modelling. This approach resulted in some minor constraints to the larger ship accessibility however minimised the volume of dredged material.

The realignment of the existing channel to avoid dredging of excessive rock volumes at Rocky Point, Acheron Head and Pulling Point was examined. The increase in additional dredging volume negated any benefit gained from engaging a different method of dredging from the main channel works to excavate the rock or to blast the stronger lower levels of rock.

The depth of the channel has been determined based on maintaining vessel safety and an acceptable window of accessibility. The Otago Harbour tidal range and reasonable commercial limits on wind, wave and channel currents, with the effectiveness of tugs and improved navigational aids minimised the depth while providing a balanced design.

[1] International Navigation Association and International Association of Ports and Harbors. Approach Channels, A Guide for Design, June 1997.

As a result of the channel design process it is proposed the minimum depth of the main shipping channel between the Fairway Beacon and Port Chalmers will be increased from the current 13.0m below chart datum to a minimum of 15.0m below CD. The entrance channel will be deepened from an existing minimum depth of 14.5 to a proposed depth of 17.5m from the Fairway Beacon to the mole to account for ocean swell conditions encountered in this area. Figure 1.1 shows the proposed final bathymetry for the harbour channel..

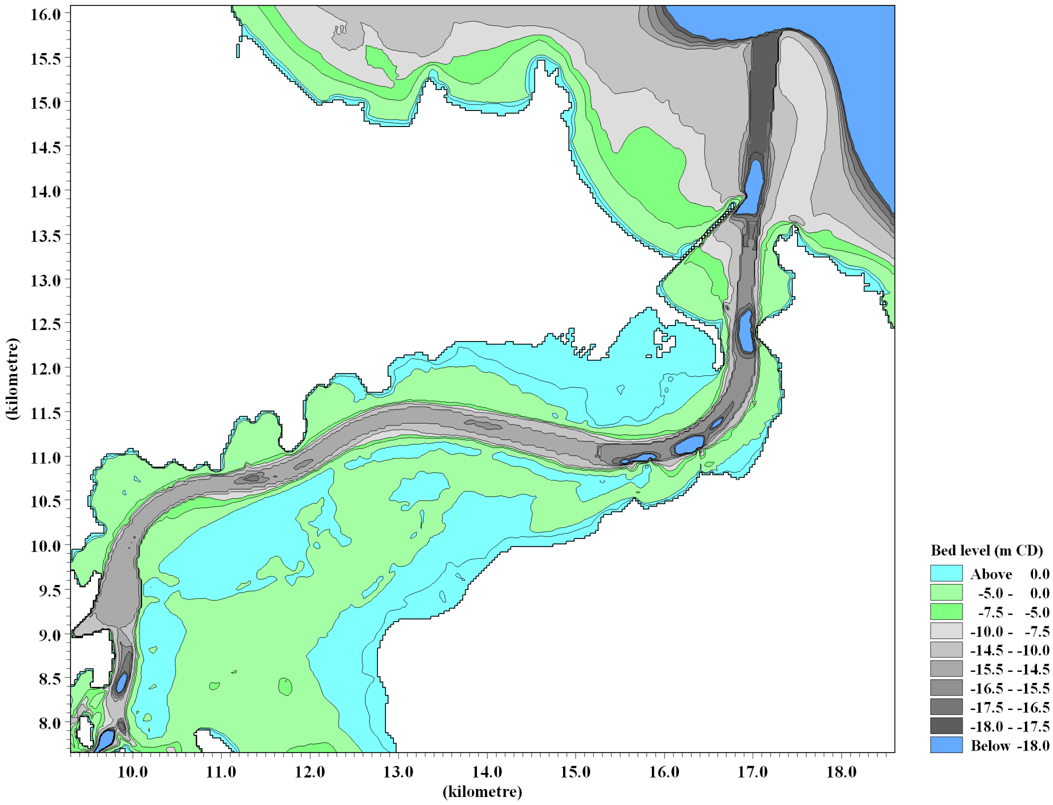


Figure 1.1 Proposed Bathymetry of Lower Otago Harbour

(Source: Figure 3.8, Bell et al. 2009)

To realise the harbour bathymetry shown in Figure 1.1 the extent of excavation required within the channel is shown in Figure 1.2 . In addition to the shipping channel being deepened the channel margins require widening at the main bends (Harington Bend and Taylors Bend) and the area of the swinging basin at Port Chalmers needs to be increased to enable safe turning of the longer vessels.

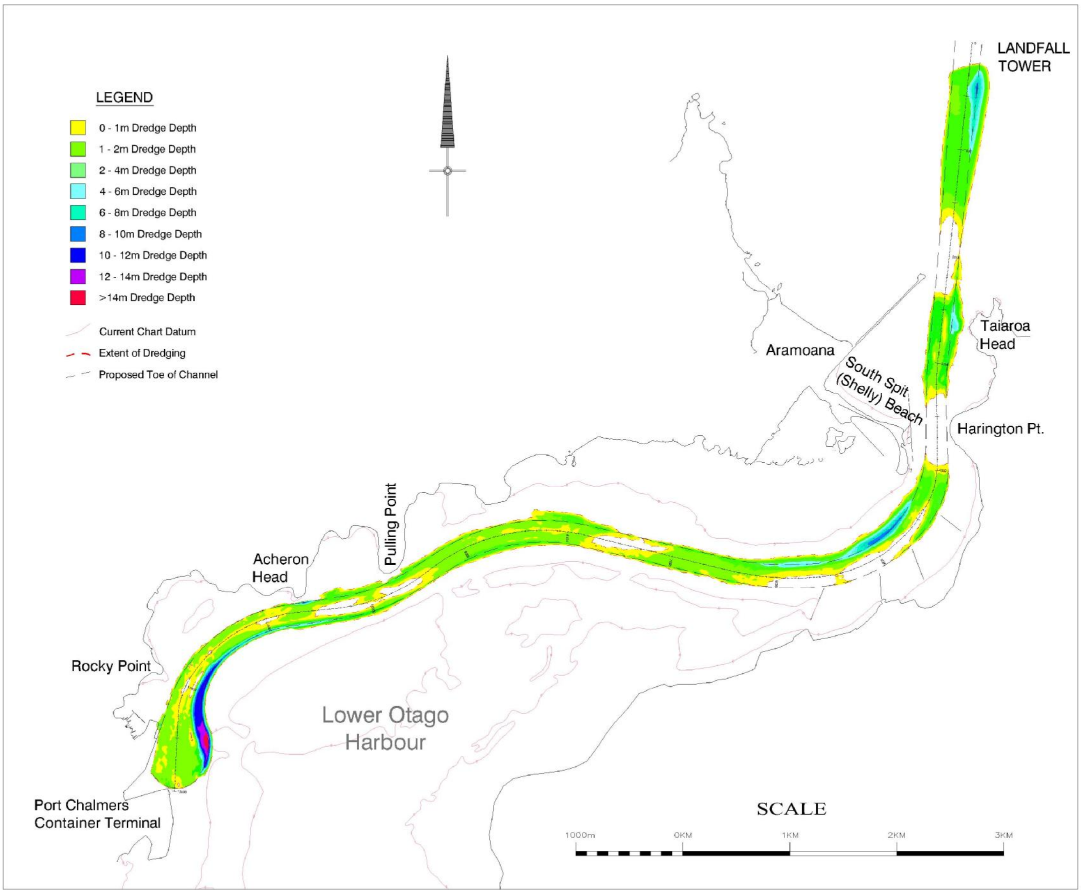


Figure 1.2 Proposed depths of dredging within the Lower Harbour

(Source: Port Otago drawing No. 11112)

The colour banding shows the depth of material requiring excavation from the existing bathymetry to achieve the final channel profile. Figure 1.2 also clearly shows the areas of the channel that are already deeper than that proposed due to the natural harbour processes. With the exception of a small area of less than approximately 8,000m² on the eastern side of the swinging basin, all dredging is below the intertidal zone, which is 0.0m below chart datum. The total volume estimated to be removed from the harbour channels is approximately 7.1 million cubic metres (M m³).

Once excavated, it is proposed the majority of the dredged material is transported to, and disposed of, in an area off the Otago Peninsula in a water depth of approximately 27m. Figure 1.3 shows the approximate location of the area to be used as an offshore dredged material disposal site, known as site A0. The centre of selected site is located approximately 6.3km off the Landfall Beacon (Background image source: Google Earth, 2009).

It is proposed rock with no beneficial project use will be placed in the existing Heyward Point maintenance dredging disposal site.

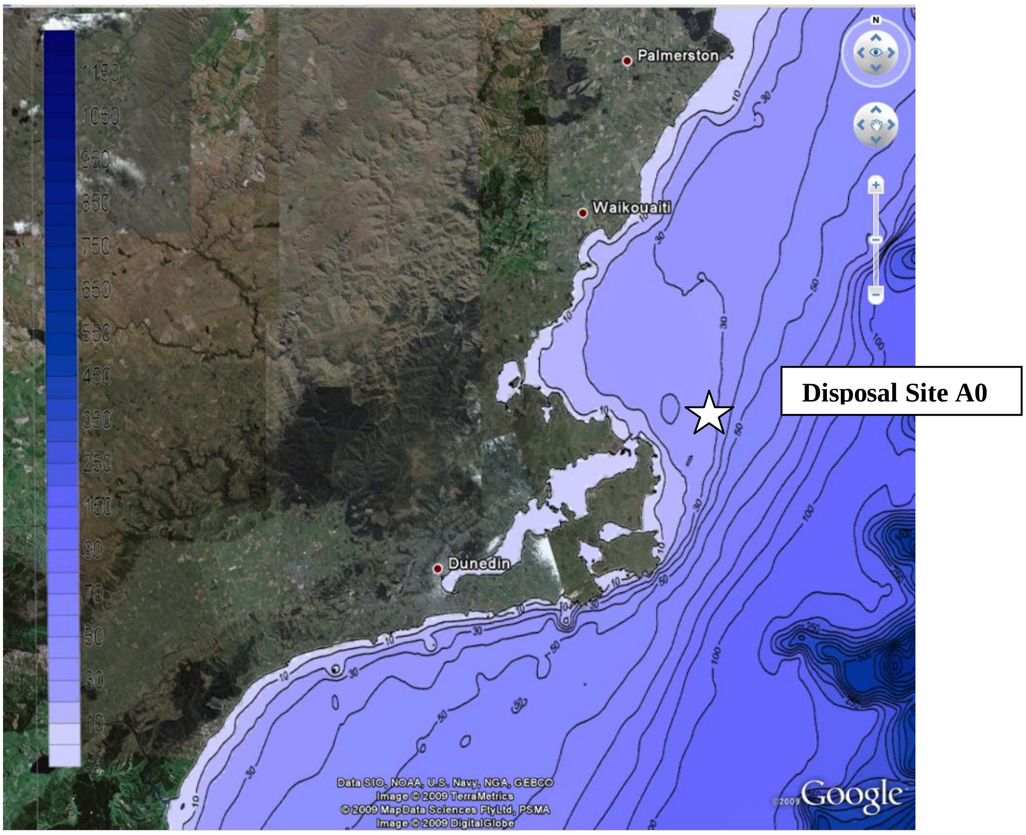


Figure 1.3 Proposed dredge disposal site A0.

2. Best Practice – Dredging Methodology

2.1 Best Practice

"A best practice is a technique or methodology that, through experience and research, has proven to reliably lead to a desired result"

Adopting best practice is the notion of applying the best available and proven method to achieve the project objectives that include minimising environmental effects. This includes minimising the impacts of dredging and the effects caused by the disposal of dredged material while optimising the beneficial use of dredged material and economical considerations.

There are environmental, social, cultural and economic factors to consider. The main environmental factor is related principally to turbidity from both the dredging operation and the disposal of material. The social aspects include the project duration, turbidity potentially disturbing recreational fishing, disposal affecting recreation activities, construction noise and dredging influencing boating safety. The economic factors include the project cost, interference with commercial shipping operations and impact on commercial fishing and aquaculture.

Channel design, dredging technology, dredging strategy and dredged material management are discussed based on the notion of adopting best practise.

2.2 Historical Development Dredging

As illustrated in the "*Next Generation – Channel Development Short History of Otago Harbour Development and Dredging History*" RM Davis [2], Otago Harbour has been the subject of a number of capital dredging campaigns in addition to an ongoing maintenance dredging regime over the past 130 years.

Over decades the maintenance dredging has been carried out within the Lower Otago Harbour by Port Otago Ltd, and its predecessors. A vast volume of institutional knowledge and intellectual property has been retained within Port Otago. This knowledge is a valuable resource utilised throughout the design process and development of the dredging methodology, particularly during the preliminary phases.

[2] RM Davis, July 2009: Next Generation – Channel Development Short History of Otago Harbour Development and Dredging History

3. Dredging Areas and Materials

3.1 Dredge Claims

The Lower Harbour has been dredged by Port Otago and it's predecessors for many years, refer, RM Davis [3], 2009.

Maintenance dredging of the Lower Harbour has split the harbour into separate "claims" to track the areas and volumes removed as part of the maintenance dredging programme of the channel. These same claim descriptions have been used during the design process and are shown below in Figure 3.1.

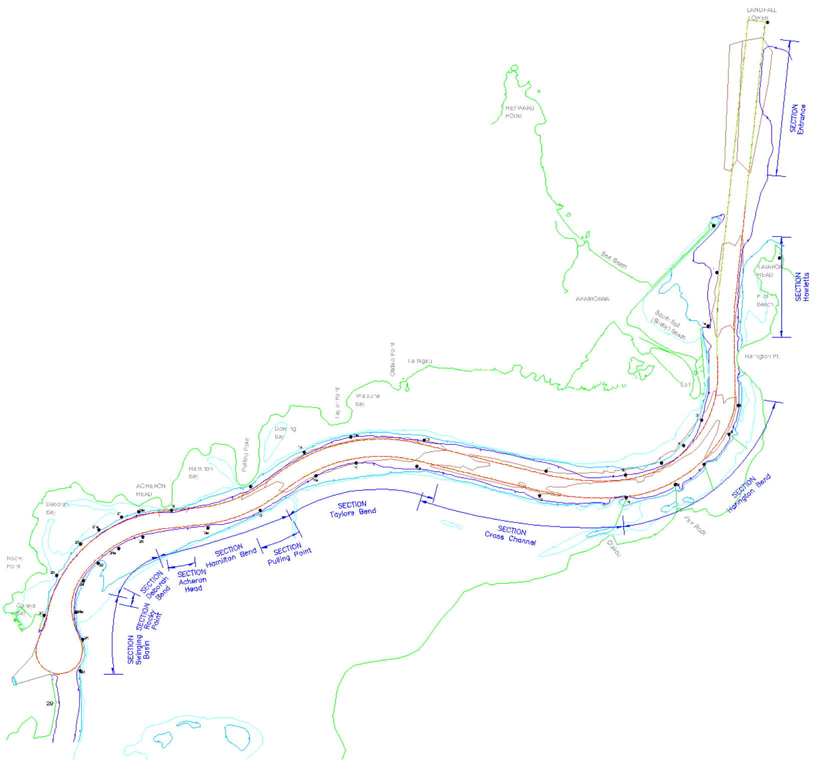


Figure 3.1 Lower Otago Harbour Dredge claims

(Source: Port Otago drawing No. 11011)

3.2 Geotechnical Investigations

One of the key elements determining plant selection, and therefore the dredging methodology, is the requirement to establish the extent and location of subsurface materials to be excavated. The material breakdown provides one tool to settle on the preferred selection of plant, dredging methodology and to calculate the likely duration of the works.

[3] RM Davis, July 2009: Next Generation – Channel Development Short History of Otago Harbour Development and Dredging History

[4] PIANC Report of Working Group 23, 2000: Site Investigation requirements for dredging works

In accordance with PIANC Guidelines [4] ground investigation for this project was completed in five distinct phases:

1. Desktop study;
2. Preliminary field investigation;
3. Detailed field investigation;
4. Laboratory testing;
5. Analysis and reporting.

Investigations were carried out in this order, however, this report shall summarise the final three phases. The subsurface field investigations consisted of drilling and logging (rotary core drilling and vibrocoring) at 43 locations within the existing channel from Port Chalmers to past Taiaroa Head under the guidance of Opus International Consultants Limited (Opus) during April 2008. The locations of the investigations are shown on drawing 11011 attached in Appendix A. The full presentation of these investigations is contained in the Opus report "*Factual Report of Geotechnical Investigations - Port Otago – Project Next Generation*", August 2008 [5].

Laboratory testing, including soil and rock mechanical testing, was carried out on the samples extracted from the boreholes. Testing included;

- Particle Size Analysis
- Atterberg Limits
- Water Content
- Unconfined Compressive Strength
- Shear Vane
- Solid Density

A series of chemical laboratory tests were also carried out on some samples to determine the presence or absence of a range of potentially harmful materials that may have been deposited in the harbour sediment or occurring naturally. Samples were analysed for:

- Heavy Metals and Metalloids - As, Cd, Cr, Cu, Ni, Pb, Zn
- Organic Compounds – PCB, PAH, TPH
- Inorganic Compounds – CN, TN

Summary reporting on material composition and testing results were provided in the factual report. In addition to the factual report an interpretative report, "*Geotechnical Advice "Next Generation" Project – Interpretation of Geotechnical Data and Quantity Survey*", July 2009 [6] was commissioned to determine material splits within each claim on a percentage basis.

[4] PIANC Report of Working Group 23, 2000: Site Investigation requirements for dredging works
[5] Opus International Consultants Limited: Factual Report of Geotechnical Investigations, August 2008
[6] Opus International Consultants Limited: Geotechnical Advice "Next Generation" Project – Interpretation of Geotechnical Data and Quantity Survey, July 2009

3.3 Geotechnical Investigation Results

On completion of the factual report the following overview of materials within the Lower Otago Harbour was provided.

Section Name	Geological Description of Material
Swinging Basin	Grey, sandy SILT and fine SAND. Silt is soft to very soft and nonplastic. Sand is loosely packed
Deborah Bend with Rocky Point	SILT in the southern part close to Carey's Bay and silty CLAY closer to Acheron Head. Sediments soft to very soft and plastic where clay present. Completely to moderately weathered basalt in borehole 3 along the north side of the existing channel.
Hamilton Bend with Acheron Head and Pulling Point	Clayey SILT with some sand, soft to very soft, non-plastic to slightly plastic. Silty CLAY, soft to very soft and plastic close to Acheron Head. Completely to moderately weathered basalt in boreholes 4 at Acheron Head. Basalt cobbles at Pulling Point
Taylors (sic) Bend	Clayey SILT at Dowling Bay end of section and sandy SILT at Waipuna Bay, soft to very Soft, plastic where clay content high.
Cross Channel	Clayey SILT, soft to very soft, slightly plastic sand content increasing toward eastern end of section.
Harington Bend	Fine SAND near Otakou changing to clayey SILT near Harrington Point and the Spit.
Howletts	Fine SAND with some Silt near the eastern side around Pilot Beach
Entrance	Fine SAND

Table 1 Overview of Geological Description of Materials

Source: Opus International [5]

The above overview was then used as a basis for completing an interpretative breakdown of the materials within each claim to ultimately determine the material volume split.

Port Otago Ltd undertook an internal assessment of the location and percentage of materials, and also engaged Opus International to complete an independent interpretation. The Opus International interpretation is reported here and is used throughout the project, it should be noted that both assessments were very similar in their findings.

No.	Claim	Rock (%)	Sand (%)	Silt (%)	Clay (%)
1	Entrance (Port)	0%	100%	0%	0%
	Entrance (Stbd)	0%	100%	0%	0%
2	Howletts Point	0%	94%	6%	0%
3	Harington Bend	0%	68%	32%	0%
4	Cross Channel	0%	65%	35%	0%
5	Taylors Bend	0%	18%	80%	2%
6	Pulling Point	0%	28%	72%	0%
7	Hamilton Bay	0%	7%	33%	60%
8	Acheron Head	43%	48%	7%	2%
9	Deborah (Port)	0%	29%	71%	0%
	Deborah (Stbd)	0%	30%	24%	46%
10	Rocky Point	32%	24%	42%	2%
11	Basin (Port)	0%	73%	27%	0%
	Basin (Stbd)	0%	2%	98%	0%

Table 2 Geological Unit Percentage Split

Source: Opus International [5] above

3.4 Claim Materials and Quantities

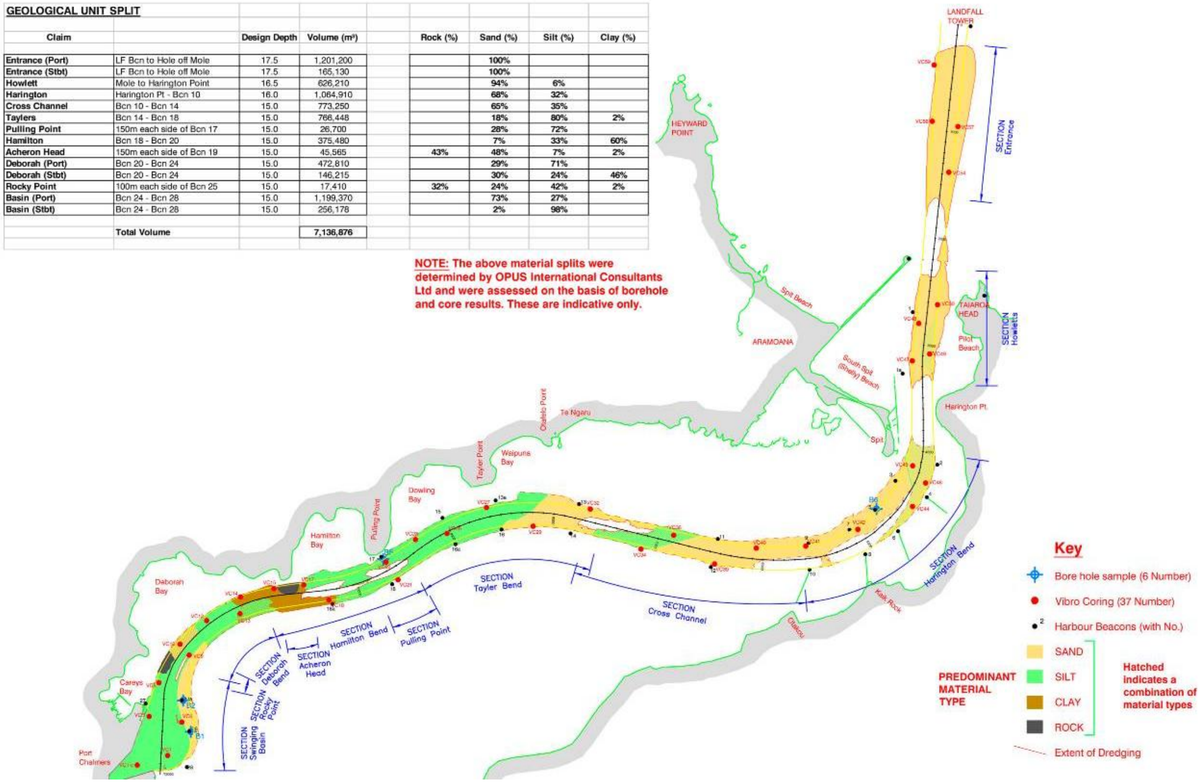
On completion of the channel design process the volumes within each claim were calculated by Hunter Hydrographic Services using a direct comparison between the existing bathymetry and the proposed bathymetry. The percentage material splits contained within were then referenced against the total claim volume to assess the material breakdown shown in Table 3.

No.	Claim	Rock (m^3)	Sand (m^3)	Silt (m^3)	Clay (m^3)	Total (m^3)
1	Entrance	0	1,366,330	0	0	1,366,330
2	Howletts Point	0	588,637	37,573	0	626,210
3	Harington Bend	0	724,139	340,771	0	1,064,910
4	Cross Channel	0	502,613	270,638	0	773,251
5	Taylors Bend	0	137,961	613,158	15,329	766,448
6	Pulling Point	0	7,476	19,224	0	26,700
7	Hamilton Bay	0	26,284	123,908	225,288	375,480
8	Acheron Head	19,593	21,871	3,190	911	45,565
9	Deborah	0	180,979	370,787	67,259	619,025
10	Rocky Point	5,571	4,178	7,312	348	17,409
11	Basin	0	880,664	574,884	0	1,455,548
	Sub-total	**25,164**	**4,441,132**	**2,361,445**	**293,806**	**7,121,547**
	%age of Total	*1%*	*62%*	*33%*	*4%*	*100%*

Table 3 Material Volume Split (Assessed)

As Table 3 shows, the majority of this material has been identified as fine sand (62%) with large volumes in the Entrance claim, the Harington claim and on the Port side of the swinging basin. The area to be dredged on the eastern side of the Swinging Basin commences at, or near, chart datum. This area contains approximately 711,000m³ of fine sand to be dredged.

Figure 3.2 below shows the predominant material locations for the channel by claim.



GEOLOGICAL UNIT SPLIT

Claim		Design Depth	Volume (m³)	Rock (%)	Sand (%)	Silt (%)	Clay (%)
Entrance (Port)	LF Bcn to Hole off Mole	17.5	1,201,200		100%		
Entrance (Stbt)	LF Bcn to Hole off Mole	17.5	165,130		100%		
Howlett	Mole to Harington Point	16.5	626,210		94%	6%	
Harington	Harington Pt - Bcn 10	16.0	1,064,910		68%	32%	
Cross Channel	Bcn 10 - Bcn 14	15.0	773,250		65%	35%	
Taylers	Bcn 14 - Bcn 18	15.0	766,448		18%	80%	2%
Pulling Point	150m each side of Bcn 17	15.0	26,700		28%	72%	
Hamilton	Bcn 18 - Bcn 20	15.0	375,480		7%	33%	60%
Acheron Head	150m each side of Bcn 19	15.0	45,565	43%	48%	7%	2%
Deborah (Port)	Bcn 20 - Bcn 24	15.0	472,810		29%	71%	
Deborah (Stbt)	Bcn 20 - Bcn 24	15.0	146,215		30%	24%	46%
Rocky Point	100m each side of Bcn 25	15.0	17,410	32%	24%	42%	2%
Basin (Port)	Bcn 24 - Bcn 28	15.0	1,199,370		73%	27%	
Basin (Stbt)	Bcn 24 - Bcn 28	15.0	256,178		2%	98%	
	Total Volume		7,136,876				

Figure 3.2 Predominant dredge material locations in Harbour Channels

Source: Port Otago drawing No. 11024

3.5 Chemical Test Results

The laboratory tests carried out to detect the presence, or perceived absence, of potentially harmful chemicals concluded that none of the parameters analysed exceeded the guideline values, see Opus, August 2008 [5].

This indicates the material to be dredged can be classed as clean with no contaminants and is therefore suitable for disposal without prior treatment or capping.

4. Dredge Material Disposal

4.1 Introduction

The last step in the dredging process is the disposal of dredged material in a location away from the harbour channels in the most beneficial or least obstructive location. Internationally, most unwanted uncontaminated spoil is disposed of at sea whether into designated disposal grounds, into seabed depressions or to form islands (Bray *et al*, 1997)[7].

Once placed in the dredge or barge hoppers, the material can also be considered as a resource with possible beneficial uses such as construction material, aggregate, in creation of wildlife habitats, in the construction of shore protection features, for nourishment of beaches, or creating land for commercial or community use through reclamation or landfill.

The determining factors for disposal in consideration include:

- The type of material dredged - in this case predominately fine sand to clayey silt with small volumes of clay and rock,
- The type of dredger and transport system,
- The location of the dredging work - in this case the lower Otago Harbour Channel and Port Chalmers Swinging Basin,
- Whether the material contains contaminants such as heavy metals and other pollutants. Depending on test results, there may be three classes of dredged material: i) clean with no contaminants, ii) contains some inert contaminants, and iii) contains significant pollutants that should be removed for controlled disposal. The tests undertaken as part of the Geotechnical Investigations show the material as clean with no contamination,
- Other factors such as the volume of dredged sediment available, the demand for the material and the logistics of transport or storage of the material – in this case the volume of dredged sediment is approximately 7.1 million m^3, although there is a relatively small quantity of rock, assessed at 25,000 m^3,
- The net cost to dispose of the material.

The following sections present offshore marine disposal and potential alternative uses of dredged sediment considered by Port Otago Ltd. These include commercial use, reclamation, beach re-nourishment and disposal offshore.

4.2 Marine Disposal

4.2.1 Designated Offshore Disposal Site

Disposal in open water is the most commonly used international practice especially when there are large volumes of material to dispose of. Offshore disposal has been the method used by Port Otago Ltd, and its predecessors, to dispose of about 17.5 million m^3 of dredged material over the history of port channel development (reference R.M.Davis, 2009) [3]. The

[7] Dredging: A handbook for Engineers RN Bray, AD Bates, JM Land, 1997

total volume dredged is estimated to be approximately 33.65 million m³ with the bulk of the balance being used in reclamations.

The determination of an appropriate site for disposal is based on a number of factors, such as:

- Avoidance of nature conservation and other protected areas,
- Effect on fishing and aquaculture,
- Effect on recreation, sailing, surfing, boating,
- Avoidance of shipping routes,
- Affect on currents and waves,
- Likelihood of sediment being re-transported and causing effect on other areas such as beaches and estuaries,
- Distance from dredging work and consequential travelling costs.

With the above considerations in mind, an offshore study was commissioned (reference Bell et al, 2009[8]) with appropriate sites selected for further hydrodynamic modelling. On completion of the study a preferred disposal site, known as A0, was identified as shown on Figure 1.3. The proposed disposal site is 2km diameter and was selected following a detailed examination of effects. The site is approximately 6.3km northeast of Taiaroa Head.

4.2.2 Alternative Offshore Disposal Sites

Earlier scientific studies of alternative disposal sites were considered closer to Taiaroa Head. These sites were replaced with A0 once the initial findings of the offshore hydrodynamic modelling work were released, see Bell et al, 2009[9]. Determining the final location of A0 was an iterative process which considered the overall effects of the disposal site.

4.2.3 Other Disposal Sites

Several alternative disposal sites have been identified for the disposal of small quantities of material. For example surplus rock may be deposited on the Long Mac groyne north of the spit to assist with the retention of sand on South Spit Beach.

Also, as a result of the proposed deepening of the berth pockets at Port Chalmers by approximately 2m, it was necessary to evaluate the effects this deepening will have on the stability of the existing wharf structures, the Multipurpose Wharf and Container Wharf, particularly under earthquake load. This work (Robinson, 2010)[10], concluded that the placement of rock fill by extending the current rock slope protection and adding a rock buttress at the toe of the new slope will maintain or improve the current wharf stability. It is proposed dredging of rock will provide the material for this work.

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[8] Bell et al, 2009: Port of Otago Dredging Project: Harbour and Offshore Modelling
[9] Bell et al, 2009: Port of Otago Dredging Project: Harbour and Offshore Modelling
[10] Hadley & Robinson Ltd: Stability of Slopes Multipurpose and Container Wharves Port Chalmers, February 2010

4.3 Alternative Uses of Dredged Material

4.3.1 Concrete Aggregate

The total ready mixed concrete production in the Dunedin Region is approximately 40-50,000 m³ per annum, of which approximately 40% volume is sand. The sand used in ready mixed concrete is graded with the very fine dredged sand representing approximately 14% of the total sand requirement, amounting to approximately 2,500 m³ per annum. This is a very small fraction of the total quantity that will be dredged from the harbour, approximately 0.04%. Reference M. Connor - 27 Mar 08 [11].

4.3.2 Construction Fill and Road Aggregate

The total volume of aggregate (varying in size from rock down to crusher dust) currently used in the larger Dunedin Region is about 44,000 m³ per month.

Depending upon the quality of rock, the cost to unload the barge and the transport costs, local quarry companies may be interested in receiving some of the rock from the dredging work on the points although rigorous testing will be required to determine the end use. The cost of this testing and offloading would prove prohibitive and this option will not be considered further.

Recovery, unloading and transport costs would also make supply of sand or aggregate to areas outside the Dunedin Region prohibitive.

4.3.3 Sand Aggregate

Use of sand in the region included;

- Foundry Mounding Sand – less than 1,000 m³ per month or 10,000 m³ pa. This sand generally is supplied from Waldronville.
- Concrete Aggregate Sand – about 1-2,000 m³ pa. supplied from Tomahawk lagoon entrance.
- Building Concrete Slab Fill – less than 1,000 m³ pa.
- Road Aggregate – blended mix.

The sand for concrete and road aggregate needs to be well graded, not the even graded fine sand available from the dredging.

There is a commercial use for sand although the annual volume is small and required at regular intervals rather in a large volume over a short period of time. Hence, the use is more relevant to material sourced from maintenance dredging using Port Otago's dredge *New Era*, than to the material from the Next Generation capital dredging campaign works.

[11] M. Connor (27 Mar 08): Report on the suitability of sand extracted from dredging of the shipping channel for the manufacture of ready mixed concrete.

4.4 Reclamation

Over the history of dredging in Otago Harbour it has been approximated that almost 50% of material (16.15M m^3) from the Harbour has been used in reclamations, RM Davis [12]. The first reclamations were in Dunedin at Lake Logan / Pelichet Bay (now Logan Park) and the last being the Back Beach reclamation during the early 1990's.

Since then the New Zealand Coastal Policy Statement (NZCPS 1994), set out in Section 56 of the Resource Management Act 1991, identifies reclamation within the marine environment as undesirable. Reclamation of an area large enough to retain the volume of dredged material from the Next Generation Project would be classified as a restricted coastal activity. It is considered that filling an embayment within Otago Harbour for the sole purpose of placement of the dredged material would be environmentally unacceptable in the eyes of the wider community.

The environmental cost versus benefits to the community of filling the embayments or mudflat areas formed between the railway embankment and the road to the port has been examined. The benefits could include:

- The provision of playing fields or recreational for the adjacent communities,
- Enabling the road to the port to be straightened resulting in improved traffic safety as well as moving traffic a further distance from residential areas,
- The construction of additional transport lanes for cycles, buses or trucks.

The environmental effects could include:

- Loss of tidal and sub-tidal habitat.
- A small reduction in the tidal prism of the harbour.
- Requirement for extension of drainage channels across the embayment areas.

Additional costs include:

- Consenting and assessment of environmental effects for each reclamation site,
- The construction and purchase of specially built load-out berths and pumping systems to enable transfer of material from the dredge hopper to the reclamation areas.

Although never seriously considered, a calculation on the potential volume that could be accommodated within the existing embayments was undertaken. The volumes of material that could be accommodated in reclamation are summarised as follows and illustrated in Figure 4.1.

	Bay	Total Fill Required (m^3)
1	Burkes Bay	178,500
2	St Leonards	171,500
3	Blanket Bay	577,500
TOTAL		**927,500**

Table 4 Embayment Reclamation Volumes

[12] RM Davis, July 2009: Next Generation – Channel Development Short History of Otago Harbour Development and Dredging History

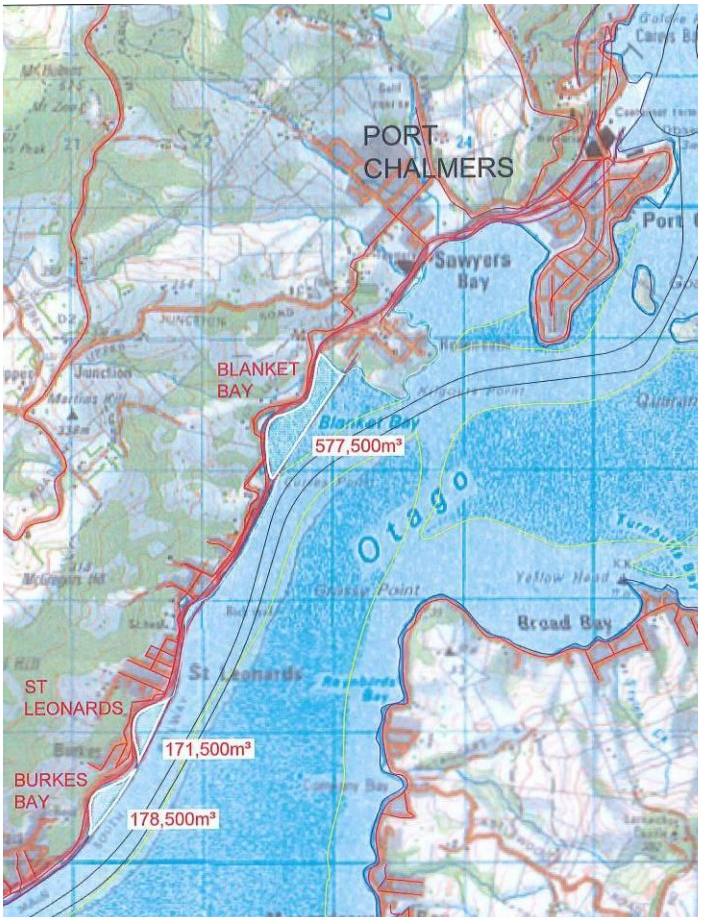


Figure 4.1 Embayment Fill Options - Upper Otago Harbour

This exercise shows that the total volume of material that could be accommodated within these areas is only 927,500 m³ or approximately 13% of the total volume of dredged material. Port Otago is unaware of any commercial, community or private plans for major reclamation works in the vicinity of Port Chalmers or along the margins of Otago Harbour that would benefit from receipt of significant portions of dredged sand material. There has been interest expressed for additional community land resources along the margin of the harbour in Carey's Bay and Deborah Bay, however, the immediate requirement for reclamation fill is limited.

Potential reclamation within Otago Harbour would not utilise a significant volume of the dredged material. Although reclamations, albeit small, may result in additional community resources, they would also result in associated environmental and economic costs. Reclamation is therefore not considered a viable option for Port Otago Ltd for the disposal of dredged material from the proposed capital dredging project.

4.5 Beach Re-nourishment

4.5.1 General

A number of sand beaches in the Dunedin area are subject to either long-term or short-term erosion of sediment volume. At present Port Otago Ltd places maintenance dredging material in the nearshore off Shelley Beach to offset losses of sediment from the narrow dune system of the South Spit.

Commencing in July 2007, Dunedin City Council used sand from Port Otago Ltd maintenance dredging to nourish Middle Beach after a prolonged period of storm wave induced erosion of the Ocean Beach foreshore and dune system. The Te Rauone Beach community, in conjunction with Port Otago and other agencies, are investigating the potential to nourish Te Rauone Beach as part of management of erosion of the foreshore and dunes and other small bays within Otago Harbour have also been replenished with sand in the past to restore and protect local recreational resources and some property.

Beach re-nourishment requires sand of an appropriate size, texture, colour and cleanliness to be effective and acceptable to the beach users. In assessing the potential use of the capital dredging material for beach re-nourishment in the Dunedin area, these factors have been considered and areas of suitable sand identified. In addition, the total volume required for possible beach re-nourishment projects has been estimated.

4.5.2 Ocean Beach Re-nourishment

Dredged sand from the harbour channels has proven to be satisfactory sand for beach re-nourishment of Ocean Beach (St Clair, Middle and St Kilda Beaches). According to the emergency response plan of the Dunedin City Council, the estimated volume required to mitigate the adverse effects of erosion could be approximately 100,000 m³ every 5 years.

The method used in 2007 is suited to the port’s current maintenance dredging operation. An excavator at a city wharf can extract 400 - 450 m³ of sand from the New Era hopper while the vessel is laid up over night. The sand can then trucked the 4 km distance across South Dunedin to Ocean Beach. In 2007 the sand was stored near the beach and placed as necessary along the foreshore and dunes. Approximately 1,000 to 2,000 m³ of sand was stockpiled at a time.

The dredge contracted to carry out the Next Generation capital dredging will be considerably larger than the *New Era*, and for economies of scale would work 24 hours per day 7 days per week. The physical size of any capital dredge would preclude unloading by excavator as is the current practice while any other specific method of unloading would delay the cycle times and greatly increase the cost of capital dredging.

As there is a limit to the amount of sand required at any one time for Ocean Beach, an area would be required to stockpile the material and the stockpile would require management to avoid wind blown sand and sediment runoff.

Hence, the supply of sand for the Ocean Beach re-nourishment work is more suited to the use of maintenance dredging from the *New Era* as has been undertaken in the past.

4.5.3 Shelley Beach (The South Spit)

The quantity of sand placed off Shelley Beach is resulting in gradual shoaling of the nearshore, maintenance of a small foredune and some growth of the dune system. The work to date is fulfilling the desired purpose of mitigating erosion that was prevalent during the 1980s and early 1990s. It is possible that additional sand would benefit the ‘health’ of the beach. It is also likely that if the nearshore is oversupplied with sand then sand will 'leak' out of the embayment and back into the harbour channel. This effect could be managed through construction of an artificial headland (for example), and enhanced management of retention of sand within the dune system (by fencing and planting). However the total amount of sand that could be accommodated at Shelley Beach is likely to be less than 100,000 m³ initially, with maintenance top-ups of 30,000 to 50,000 m³ per year.

Hence, the Port Otago Ltd maintenance dredging programme could again adequately meet these volumes and be more easily controlled due to the smaller loads and shallower draft.

4.5.4 Te Rauone Beach

The Te Rauone community is concerned about the erosion of the beach frontage at Te Rauone. Re-nourishment using dredged sand is a possible solution to erosion at the northern end of the beach, and concept design plans prepared by Port Otago indicate a maximum of 90,000 m³ of sand would be required. Further work would be required to hold the sand in place, and so re-nourishment would be a part of an integrated management programme including engineering work and dune fencing and planting.

Design and consultation work for the Te Rauone Beach community is currently being resourced by Port Otago as a separate exercise with limited input from the Dunedin City Council and Otago Regional Council. Current channel bathymetry shows that it would not be possible to deposit sand onto the beach directly from the dredge-hopper, as there is insufficient depth of water to manoeuvre the dredge inshore and open its bottom doors.

One practical solution would be to pump the sand onto the beach and then spread with a bulldozer once the sand settles out and the excess water drains. A temporary mooring for the dredger would be required in conjunction with either a pumping system to move the dredged material from the hopper or low point in the channel and along a pipeline to the beach site. These pump out operations are time consuming and relatively expensive.

Due to the relatively small volume of sand required, the cost and difficulty of using a large dredger to supply the sand, re-nourishment of Te Rauone Beach is more suitable for consideration associated with placement of maintenance dredging sand as a separate project.

4.6 Summary of Alternative Disposal Options

The main constraint for any beneficial practical use of the dredged material is the sheer volume of material, approximately 7.1 million m³. Most beneficial uses only require relatively small volumes of material regularly over extended periods. This requirement could be provided by Port Otago Ltd from its maintenance dredging programme if consent conditions allow.

5. Dredging Equipment

5.1 Overview of Dredging Options:

In general, the selection of dredging equipment for any one project is determined by the Contractor appointed to the work based on the current availability of plant and the economies. The following is list of available dredging equipment that could, in principle, be used to dredge areas of the Lower Harbour channel:

- Trailing Suction Hopper Dredger – TSHD
- Grab Dredger – GD
- Backhoe Dredger – BHD
- Bucket Ladder Dredger – BLD
- Suction Dredger - SD
- Cutter Suction Dredger – CSD
- Other Dredgers

There are a few other dredger types that will be mentioned but are not standard or common.

When selecting an appropriate type of equipment to be used the Contractor will examine the contract requirements and the material and layout of the dredging work. Aspects that will be considered are:

- Capability to effectively and economically dredge the respective material,
- The potential to minimise dredging tolerances to achieve the required depth,
- Capability to transport dredged material from the dredging area to the disposal locations,
- Flexibility to perform under prevailing weather and shipping conditions,
- Environmental aspects, in particular turbidity generation,
- Efficiency, in terms of project duration and cost.

Further, when examining the actual dredgers the contractor intends to use several aspects that will be considered such as:

- Ability to perform following current best practise,
- State of the art positioning systems,
- Monitoring of overflow and volume productivity systems,
- Closed buckets or grabs that reduce turbidity or “Green Valve” on TSHD overflows to reduce turbidity,
- Split hopper or door efficiency for discharge of vessel or barges,
- Balance between dredger productivity and size of barges.
- State of the Art dredge head, bucket or grab design for particular material being excavated,
- Dredge availability and mobilisation costs.

5.2 Trailing Suction Hopper Dredger

The Trailing Suction Hopper Dredger (TSHD) is the most technologically advanced and productive type of dredge. In general they are a self-propelled sea or harbour channel vessel, equipped with a hopper for holding the material that is sucked from the seabed through draghead(s) and pipe trailed alongside the vessel. Dragheads loosen the soil using water jetting and/or teeth to assist in breaking up the material allowing the material to be pumped up the pipeline and settled into the dredger's hopper. After completion of loading, possibly using overflow, the dredger sails to a disposal site where material is either discharged through the bottom of the vessel via doors or splitting the hopper or is pumped out in a controlled discharge for reclamation, beach nourishment or positioning of contaminated material. The TSHD is generally used for dredging sands and silts but also clays and soft rock in certain conditions.

Port Otago has operated a small TSHD, *New Era*, since 1985 for maintenance dredging, discharging the surplus water with a weir over the side.

Figure 5.1 Port Otago Ltd Trailing Suction Hopper Dredge *New Era*

Most medium size dredgers (6,000 – 10,000m³ hopper volume) discharge the surplus water through the bottom of the vessel and commonly have two trailing arms, one each side of the vessel.

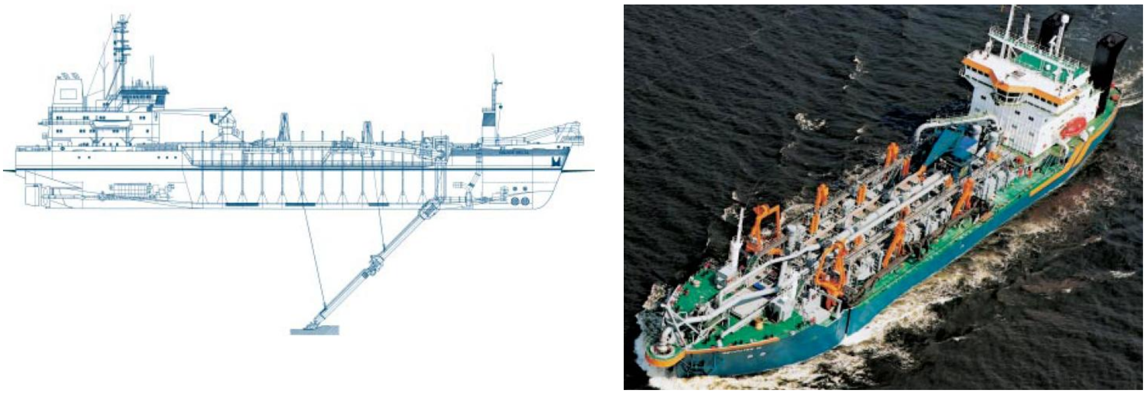


Figure 5.2 Van Oord Trailing Suction Hopper Dredgers

i. **Advantages:**

- Has the ability to dredge nearly all soils, particularly efficient in silts and sands,
- Generally technologically advanced equipment,
- Generates relatively low levels of turbidity during typical dredge operations,
- Most can work in adverse weather and sea conditions,
- Independent, flexible operation, easy to change location of dredging to suit weather or shipping,
- Manoeuvrable within the confines of the harbour channel,
- Minimal effect on shipping,
- Able to transport material relatively long distances,
- Relatively high rate of production (1,000 – 12,500 m^3/hr. depending on hopper size, soil and sailing distances.

ii. **Disadvantages:**

- Requires sufficient water depth in the dredging and disposal areas and on route between the two,
- Limited ability to dredge rock,
- Inability to work in confined areas,
- Variation in over-dredging depending on soil conditions, vessel size and weather conditions,
- Cohesive material can prove difficult to discharge from hopper,
- Suspension of silty dredging materials can generate high turbidity during the loading process if dredging beyond overflow.

iii. **Causes of Sediment Release:**

- Draghead disturbance at the seabed,
- Discharge of overflow water with silty material in suspension,
- Turbulence caused by dredger propeller scouring the seabed.

iv. **Management Options:**

- Optimise trailing velocity,
- Position of suction head and discharge pump with respect to each other to minimise sediment re-suspension,
- Correct trailing head for material to maximise soil content and minimise water content being sucked into the pipeline,
- Discharge water over weir, through a pipe to the bottom of the vessel rather than directly over the side,
- Install a “green valve” or “environmental valve” in the overflow pipe to minimise air entrainment of discharge water/sediment mix,
- Minimise overflow by operational techniques such as when in silty material the dredging may stop at overflow.

v. Commentary:

The TSHD is considered the most practical and likely dredger to be used for the majority of the project work. Alternative dredging will be required for rock (BHD) and for the upper level of the swinging basin widening (BHD or GD followed by small TSHD down to about 9m).

5.3 Grab Dredger

The Grab Dredger (GD) typically comprises a clamshell grab, wire suspended from a crane that is mounted on a pontoon or a vessel. Dredged material is normally loaded into barges moored alongside the pontoon that is either moored by anchors or hydraulically lowered legs (spuds).

i. Advantages:

- Can dredge by excavating a path forward when dredging shallow areas such as for widening the swinging basin,
- Suited for dredging confined areas and for a range of depths,
- Can dredge loose to moderately packed soils, such as clayey silts and loose rock,
- The grab size may be altered to suit the work load, 1 m^3 to 20 m^3,
- Port Otago owns a small GD (2.3m^3 grab), the *Vulcan*, which is very effective for small areas of work.

ii. Disadvantages:

- Unproductive dredging hard soils or rock,
- Limited in high wave or current conditions,
- Relatively low productivity (100 – 800 m^3/hour depending on grab size and material),
- Can produce comparatively high turbidity but can utilise special grabs,
- Needs to load barges and to move position periodically,
- Suitable access required for tugs and barges,
- Not easily moved out of shipping lanes.
- Greater dredging tolerance required.

iii. Causes of Sediment Release:

- Impact of grab on the seabed,
- Disturbance of the seabed when closing grab,
- Material spillage when hoisting grab,
- Spillage and overflow from barges,
- Washing of residual from grab when lowering.

iv. Management Options:

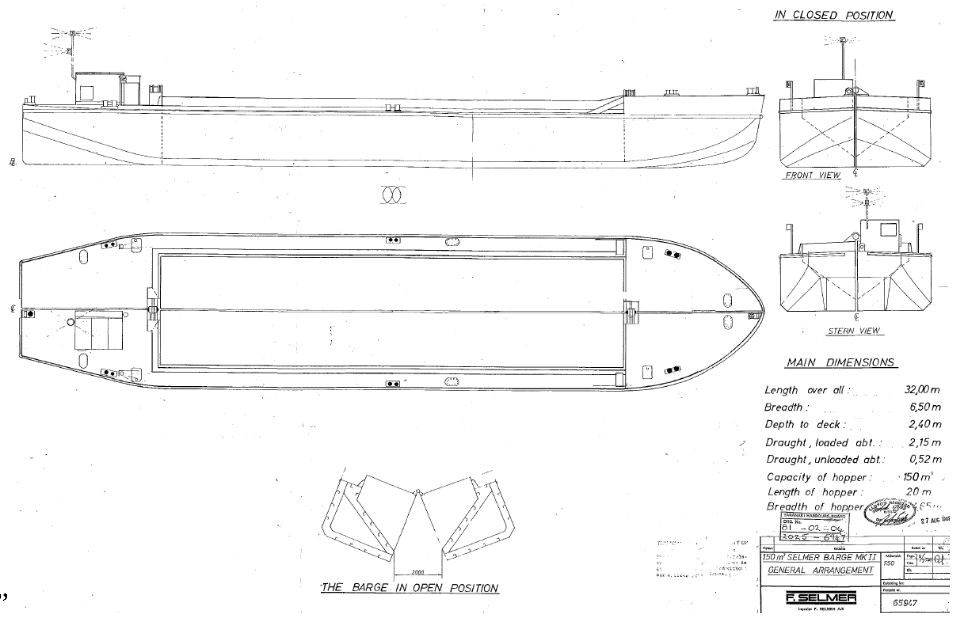
- Reduce spillage with water tight grabs,
- Use hydraulic grab on an arm rather than wire ropes,
- Using a silt screen around the work area although impractical in areas of high currents,
- Limit the swing of the grab over water,

- Avoid levelling seabed by swinging grab over the surface.

v. Commentary:

If a grab dredger were to be utilised it is likely that it would be confined to the top level of the swinging basin widening down to 5m below CD or for excavating soft to medium strength rock off the points. Due to the material likely to be encountered in these areas (sand and rock) the disadvantage referring to turbidity generation previously would be largely discounted. For this small amount of work an option is to use the port company's grab dredger, ***Vulcan***, and split hopper barge, details of which follow in Figure 5.3 and Figure 5.4.

Figure 5.3 Port Otago's Grab Dredger



"Vulcan"

Figure 5.4 Port Otago's 150m³ split hopper barge.

5.4 Backhoe Dredger

The Backhoe Dredger (BHD) is similar to a land-based excavator mounted at one end of a pontoon. For smaller work, a land-based excavator is often simply mounted on a barge. For good leverage, the pontoon is fixed in position by spuds (support legs) pushed into the seabed. The size of the excavator and of the bucket varies with the nature of the material to be dredged and the maximum dredging depth. The excavator loads into hopper barges that are towed to the disposal location.

i. Advantages:

- Large BHDs can excavate reasonably hard fractured rock avoiding the need to blast,
- Can dredge soil, especially cohesive soils, with little water added and hence load the barges efficiently without overflow,
- Can dredge effectively in confined areas,
- Can dredge by excavating a path forward when dredging shallow areas such as for widening the swinging basin,
- Position and excavation depth control is very accurate, reducing required over-depth to deliver accurate profiles,
- Can use bucket to level area after dredging,
- Suitable dredgers are available in New Zealand thereby minimising mobilisation costs.

ii. Disadvantages:

- Dredging depth is limited to the length of the excavator dipper arm,
- Relatively low productivity rates (200 – 800 m^3/hr depending on material and bucket size),
- Working on spuds cannot move easily out of shipping lanes,
- Can produce comparatively high turbidity in mud / silt materials, unless specific buckets are used which further reduce output.

iii. Causes of Sediment Release:

- Impact of bucket on the seabed,
- Disturbance of the seabed when digging with bucket,
- Material spillage when lifting bucket,
- Spillage and overflow from barges,
- Washing of residual from bucket when lowering.

iv. Management Options:

- Reduce spillage with water tight buckets,
- Skill of operator is important in reducing overflow,
- Using a silt screen around the work area although impractical in areas of high currents,
- Limit the swing of the bucket over water,
- Minimise levelling seabed by swinging bucket over the surface.

v. Commentary:

It is anticipated that a large BHD would be suitable for the excavation of the rock areas and thereby minimise the need to blast. It is anticipated that a BHD will not work in areas where there is a high percentage of silts thereby avoiding many of the effects and disadvantages discussed previously. This dredger may also be suitable for excavating sand at least for the top 5m of the Port Chalmers swinging basin but would need large barges in support to match productivity. The alternative is to use a smaller excavator over a longer period with smaller barges.

Photographs of typical large and small BHD follow:

Figure 5.5 Heron Construction Ltd – 230 tonne *Machiavelli* excavator

Figure 5.6 Small BHD and Barge Units

5.5 Bucket Ladder Dredger

The dredging action of the Bucket Ladder Dredger (BLD) is achieved by a continuous chain of buckets that scoop material from the seabed and release it into a barge moored alongside. The BLD moves systematically over the dredging area using mooring lines and winches. A variation to this is a Bucket Hopper Dredger that the port used in the early 1900s for both capital and maintenance dredging.

i. **Advantages:**

- Can dredge all types of loose to hard packed soils,
- Can dredge material with limited water which leads to efficient barge loading with minimal overflow,
- Is a continuous systematic dredging process,
- Can dredge by excavating a path forward when dredging shallow areas,
- Unaffected by boulders and debris,
- Relatively accurate depth control minimising over dredging tolerance.

ii. **Disadvantages:**

- Wide spread of anchors may disrupt navigation,
- Poor mobility,
- Not readily available,
- Not very workable in choppy conditions,
- Modest rate of production (200 – 1,000 m^3/hr depending on bucket size, soil and barges),
- Potential for generating high levels of turbidity particularly in fine material,
- Noisy above water,
- Time consuming to set up on anchors.

iii. **Causes of Sediment Release:**

- Disturbance of the seabed when digging with buckets,
- Material spillage when buckets are lifted through and out of the water,
- Leakage from discharge chutes,
- Spillage and overflow from barges,
- Washing of residual from buckets when lowering.

iv. **Management Options:**

- Reduce the degree of filling of buckets,
- Adjust the amount of slack bucket chain,
- Control rate of movement forward, bank height, rate of filling,
- Insert one way valves in the bottom of buckets,
- Avoid levelling seabed by swinging bucket over the surface.

v. **Commentary:**

A BLD is not a likely choice of dredger for any of the work with this project due to the relatively low productivity rate, interference with shipping and unavailability of such dredgers in the region. RM Davis[13] refers to the dredger *Otakou* used in the 1960's and 70's, this dredge did a vast amount of work in Otago Harbour and in comparing with other similar sized dredge (TSHD, GD or BHD) would have produced significantly greater turbidity for a similar productivity.

5.6 Suction Dredger

Suction Dredgers (SD) are suitable for sucking up relatively loose material and depositing it directly into barges or pumped straight to shore. The SD is stationary and held in position with mooring ropes or spuds. The barges need similar overflow design as for TSHDs and therefore mostly used to recover for use relatively clean sands and some gravels.

i. Advantages:

- High capacity sand delivery possible (500 – 2500 m^3/hr),
- Can dredge sand at greater depths, especially when an underwater pump is installed.

ii. Disadvantages:

- Can only dredge relatively loose material,
- Limited workability under medium wave conditions,
- Moored with studs and/or ropes,
- No accurate dredged profile can be achieved with variable overdredging,
- Barge overflows can create significant turbidity,
- Inflexible to change of location.

iii. Causes of Sediment Release:

- Excluding the effects of a moving draghead and propeller disturbance, the potential for losses are similar to those of a TSHD.

iv. Commentary:

A SD is not considered appropriate for the Otago project.

5.7 Cutter Suction Dredger

The Cutter Suction Dredger (CSD) cuts or breaks the seabed material by a powerful cutter mounted at the end of a suction pipe and the dislodged material is sucked into a pipeline by the means of a centrifugal pump. The material may be loaded onto barges or pumped ashore. CSD's have been used throughout New Zealand for numerous "cut to fill" projects creating channels alongside new reclamations.

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[13] RM Davis, July 2009: Next Generation – Channel Development Short History of Otago Harbour Development and Dredging History

Like the SD's, the CSD's are stationary and are held in position with mooring ropes or spuds. The barges need similar overflow design as for TSHD's and therefore mostly used to recover for use relatively clean sands, gravels as well as rock in some instances.

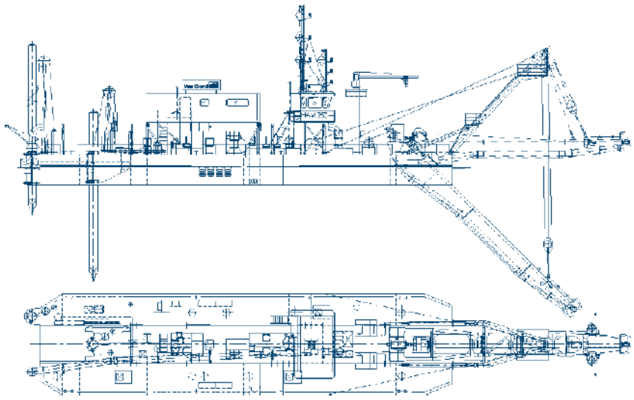


Figure 5.7 Cutter Suction Dredger

i. Advantages:

- Able to dredge a wide range of material, including rock such as at Rocky Point, Acheron Head and Pulling Point,
- Can convey the dredged material direct to an adjacent disposal or reclamation area, or onto a barge,
- Has the ability to dredge an accurate profile and hence minimise the volume of dredged material as a result of over-dredging,
- Can dredge by excavating a path forward when dredging shallow areas such as for widening the swinging basin,
- Relatively high rate of production (500 to 3,000 m^3/hr, depending on vessel size, barge hopper capacity, and soil type).

ii. Disadvantages:

- Limited workability under medium wave conditions,
- Moored with spuds and/or ropes, can form an obstruction to navigation and shipping,
- Barge overflows can create significant turbidity,
- Working in non-overflowing mode would require the maximum amount of barges plus tugs at considerable cost,
- Inflexible to change of location.

iii. Causes of Sediment Release:

- The rotation of the cutter causes centrifugal forces which "throw" material out of reach of the suction and adds to turbulence and re-suspension,
- Excavation can exceed the capacity of the pump resulting in excess material released into the current,
- Pumping into a barge need controls to prevent losses due to splashing and overflow,
- Pipeline leakage.

iv. **Management Options:**

- Optimise the cutter speed, swing rate and suction discharge,
- Moveable shields around the cutter head or suction head,
- Optimise the cutter head design for material being excavated.

v. **Commentary:**

The CSD is ideal when dredging into reclamation. However, reclamation is not an alternative considered acceptable for disposal of dredged material from this project. Refer to Section 4.4 for details on alternative disposal of dredged material.

A CSD may be considered appropriate for the excavation of rock if a suitable unit were readily available, however, for the volume of rock to be removed the cost of mobilising a CSD would be prohibitive.

5.8 Other Dredger Types

Numerous other dredgers and operations were noted as options or variations to the standard dredges referred to above. These include:

- Horizontal Profiling Grab
- Environmental Disc Bottom Cutter
- Dustpan Dredger
- Water Injection Dredging
- Auger Dredgers
- Dragline Dredging

These were not considered further due to these types of dredge being very specialist and generally located some distance from Port Chalmers. The result being that these dredger’s are not likely to be effective or cost efficient so have been disregarded from any assessment.

6. Initial Dredge Evaluation

Port Otago has undertaken a preliminary evaluation of the likely dredge equipment as listed in the commentary section of each dredge in Section 5 above. This assessment was based on a number of relative items including, but not limited to:

- Advantages and disadvantages listed,
- The likely material to be dredged based on geotechnical investigation and experience in the Harbour,
- Performance and capability of current Port Otago dredging equipment in terms of both productivity and environmental performance,
- Discussions with international dredging Contractors,
- Experience of Port Otago staff in relation to dredging in the Otago Harbour,
- Technological advances in dredging equipment.

The outcome of this deliberation has resulted in the likelihood that the deepening and widening of the channel may be carried out in a number of stages. This may involve an extension of the maintenance dredging programme carried out by the *New Era* followed by a dredging contractor utilising a medium sized (8,000 – 10,000m^3 hopper) TSHD to remove the balance of the material required to achieve the design channel profile.

A range of options comprising either a GD or a BHD supported by a small TSHD would be suitable for areas of soft rock and to dredge sand above the draft of the selected TSHD. It is anticipated that Port Otago's *Vulcan* and *New Era* would fulfil some of these roles.

It is also likely that there will be a requirement for a large BHD for the areas of hard rock on the Points.

7. Dredge Evaluation and Assessment

7.1 Introduction

The dredging programme will be undertaken through the initial use of a combination of Port Otago operated dredging plant such as the *New Era* and to a lesser extent the *Vulcan* in conjunction with the contracting in of larger plant as and when required to complete the bulk of work.

Contract dredging will be undertaken under performance based contract(s) and hence the detailed dredging methodology will be ultimately decided by the successful contractor. However, varying seabed materials and locations will require a variety of methodologies and plant as well as a range of disposal options. Soft non-cohesive materials such as clayey silts and sand, will be disposed of at the designated offshore disposal site while disposal of rock will depend on its alternative use that may be available at the time of dredging. This preliminary evaluation divides the dredging operation into three categories being:

i. Channel dredging comprising sands, silts and clays;
ii. Channel dredging where rock is encountered, and;
iii. Assessment of dredging techniques available for the swinging basin and berth pockets.

7.2 Assessment – Channel Dredging: Clay, silts & sands

7.2.1 General

The bulk of the dredging (95%) is of fine sands and non-cohesive clayey silts that are suitable for a trailing suction hopper dredger (TSHD) which will have a high production rate and efficient dredging cycle. The backhoe dredger (BHD) alternative, loading into barges, is practical for the widening of channels that have an existing surface near chart datum. Reference to the TSHD work follows and to the BHD activity within section 7.3.3.

7.2.2 Trailing Suction Hopper Dredger

The trailing suction hopper dredger (TSHD) pumps a water-sediment mixture (i.e. slurry) from the seabed to an onboard hopper via suction pipelines. The excavation is carried out by the dredger “vacuuming” a layer of seabed material through single or twin suction pipes trailing beside the vessel as it travels at about 2-3 knots over the dredging site. The material/water mix discharges into the dredger’s hopper and the heaver material such as the sands settle in the hopper. Once the coarse sediment settles to the bottom and the hopper fills with the water-sediment material the supernatant water is returned to the sea via an overflow weir. Since the residence time in the hopper is short, decreasing as the hopper fills, a component of the fine fraction of the sediment does not settle out and is released into the water with the overflow discharge.

Refer to figures 2 for the general layout of a typical TSHD.

The TSHD loads while moving and therefore does not require an anchorage system to position the vessel when dredging which can be an obstacle for passing ships.

The following sections describe the operation typical of a large contract TSHD. The proposal is for the dredging of sand, silt and clay to commence as an extension to the maintenance dredging operation carried out by the *New Era.* With a hopper capacity of 600m³, as opposed to that of a contract dredge of around 8,000m³, it must be noted that the *New Era* operation will be at a considerably reduced level of scale and intensity.

TSHD have capacities up to 31,136 m³, the "*Vox Maxima*", but the volume of work and the channel dimensions of the Lower Otago Harbour suit a mid-size TSHD, of 8,000 - 10,000 m³ hopper capacity.

Typical dredgers of this size include:

- *Cornelis Zanen* owned and operated by Boskalis,
- *Volvox Asia* owned and operated by Van Oord,
- *Volvox Iberia* owned and operated by Van Oord,
- *Alexander Von Humboldt* owned and operated by Jan De Nul.

		Cornelis Zanen	**Volvox Asia**	**Volvox Iberia**	**Alexander Von Humboldt**
Hopper Capacity	m³	8530	10834	6038	9000
Deadweight	mt	13430	17299	8159	14065
Length Overall	m	132.2	138.53	100.64	120.5
Dredging Draft	m	8.85	9.02	8.2	8.95
Dragheads	No.	2	2	1	2
Speed Loaded	Kn	13.5	15.3	13.8	14.0

Table 5 Typical trailing suction hopper dredges

7.2.3 Dredging Productivity

i. Loading:

The actual loading time will depend on the material being dredged. When dredging sands that readily settle into the hopper the loading will continue until the hopper is near full with the surplus water containing some silts still in suspension overflowing back into the sea. The loading will be terminated when the dredge productivity meter indicates it is unproductive to continue to overflow, this technology is a standard feature in a modern TSHD.

Dredging would be likely to cease at approximately 80% capacity in the case of a 10,834 m³ capacity dredger as efficiency starts to drop away. At a load rate of 90 m³/min, pumping will fill the hopper with 7,200 m³ in-situ load in some 80 minutes. The cut-off is assumed to minimise sediment overflow which increases in the latter stages of hopper filling.

When the material being dredged is predominantly silt, the dredging operations will likely to cease when the hopper reaches overflow as it is unproductive to continue past this point with the finer silts not readily settling out. The performance contract will also detail the limitations from the turbidity monitoring in the field that dredging must stay within. The silt volume retained on the vessel is about a third of the hopper capacity the reminder of the hopper volume being water. The load rate for silts is higher than for sands and is assessed at 158 m³/min for 20 minutes to overflow, filling the hopper with 3,160 m³ in-situ volume.

When dredging in areas that contain a mix of both sand and silt it is most likely that filling would cease at overflow level. The dredging contractor will work hard to minimise the occurrences of dredging mixed material as it will reduce productivity particularly in sand. The load rate is proportional to the sand/silt mix but the time to overflow remains at 20 minutes.

ii. Travelling and Turning Time:

The travelling time from the dredging site to the designated offshore disposal ground, Figure 7.1, varies with distance along the harbour channel. The cycle time has been calculated on an average speed of 10 knots within the harbour channel and 13.5 knots from the mole to the disposal ground. It is assumed the dredger will spend 5 minutes turning during each dredging cycle.

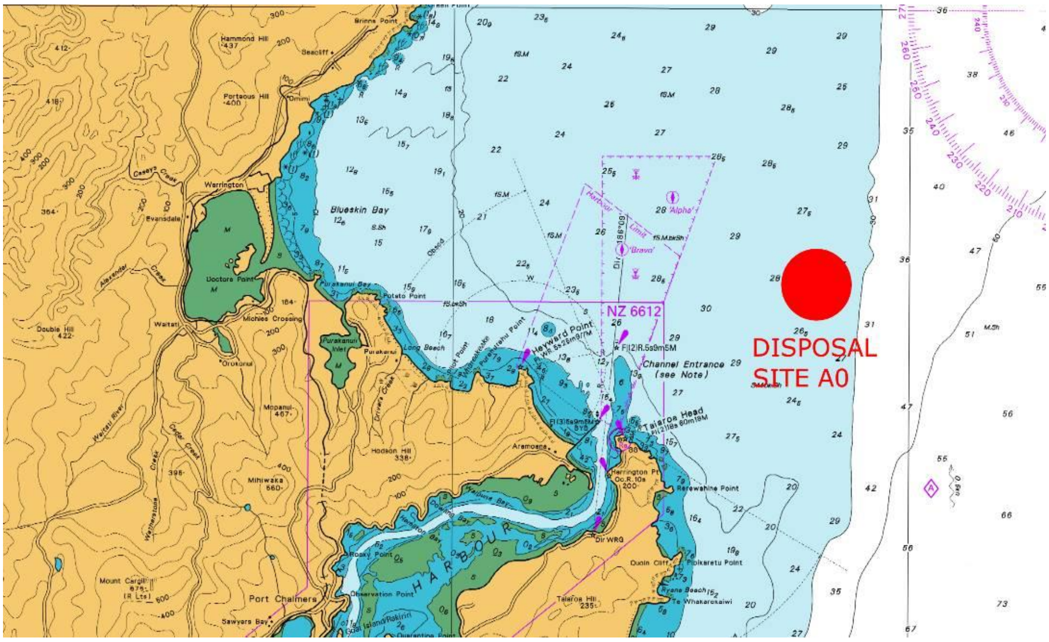


Figure 7.1 Proposed Disposal Site A0

(Source: Port Otago drawing No. 11142)

iii. Dumping:

Dumping sand or silt at the disposal site is assumed to take 10 minutes with the dredger either stationary or on a sweeping turn with bottom doors open. Dredging companies may use the forward movement of the vessel, or use water jets within the hopper as necessary, to help dislodge the load from the hopper sides. The bottom doors will be closed on the return trip subject to all the material being dumped from the hopper prior to leaving the disposal site.

7.2.4 Dredging Cycle Time and Productivity

Assuming use of the *Volvox Asia* and the above times for loading, travelling and discharge the dredging cycle times are following in Table 6 for sand and Table 7 for silt and clay:

SAND CYCLE	Volume Sand (m^3)	Load / Discharge Time (min)	Return Travel Time (min)	Total Cycle Time (min)	No. of Trips	No. of Days
Entrance	1,366,330	90	43	133	139	14.5
Howletts Point	588,637	90	54	144	19	6.8
Harington Bend	724,139	90	65	155	68	9.0
Cross Channel	502,613	90	79	169	84	6.8
Taylors Bend	137,961	90	92	182	58	2.0
Pulling Point	7,476	90	98	188	1	0.1
Hamilton Bay	26,284	90	103	193	3	0.4
Acheron Head	21,871	90	103	193	3	0.3
Deborah	180,979	90	110	200	16	2.2
Rocky Point	4,178	90	112	202	5	0.7
Basin	880,664	90	117	207	101	14.5
Sub-total	**4,441,132**				**512**	**57.4**

Table 6 TSHD Cycle times and productivity for Sand

SILT and CLAY CYCLE	Volume Silt and Clay (m³)	Load / Discharge Time (min)	Return Travel Time (min)	Total Cycle Time (min)	No. of Trips	No. of Days
Entrance	0	0				
Howletts Point	37,573	30	58	88	10	0.6
Harington Bend	340,771	30	69	99	90	6.2
Cross Channel	270,638	30	83	113	71	5.6
Taylors Bend	628,487	30	96	126	166	14.5
Pulling Point	19,224	30	102	132	5	0.5
Hamilton Bay	349,196	30	107	137	92	8.8
Acheron Head	4,101	30	107	137	1	0.1
Deborah	438,046	30	115	145	116	11.6
Rocky Point	7,660	30	116	146	2	0.2
Basin	574,884	30	121	151	151	15.9
Sub-total	**2,670,580**				**704**	**63.9**

Table 7 TSHD Cycle times and productivity for Silt and Clay

	Volume (m³)	No. of Trips	No. of Days
Sand	4,441,132	512	57.4
Silt and Clay	2,670,580	704	63.9
Total	**7,111,712**	**1216**	**121.3**

Table 8 Total TSHD Cycle times

It should be noted that the above cycle times are calculated based on the following assumptions:

- Hopper capacity is 10,834 m³,
- Load time of 80 minutes for sand and 20 minutes for silt and clay,
- Dredging operation is unrestricted for 24 hours per day, 7 days a week,
- No allowance made for vessel downtime including unsuitable weather conditions, equipment breakages, vessel maintenance, refuelling, crew changeover, etc.

To provide an indication of the variations encountered depending on the selection of dredge, Table 9 below calculates total dredging times required for each dredge based on the above assumptions amending only hopper capacity.

Dredge	Hopper Capacity	Total No. of Trips	Total No. of Days
Cornelis Zanen	8530	1651	166
Volvox Asia	10834	1216	121
Volvox Iberia	6038	2182	217
Alexander Von Humboldt	9000	1462	146
New Era	600	23440	2278

Table 9 Typical trailing suction hopper dredges

7.2.5 General

During the dredging programme the contractor will require time for equipment maintenance and repairs, crew changes and R&R, and other delays that will extend the period by approximately 20%.

7.3 Assessment – Channel Dredging: Rock

7.3.1 General

Rock penetrates the harbour channels at Rocky Point, Acheron Head and possibly Pulling Point. The preferred method is to use a barge-mounted hydraulic excavator (backhoe dredger (BHD)) and hopper barges. If rock proves to be too hard for backhoe excavation then drilling and blasting may be required to fracture the rock.

The rock ranges in strength from highly weathered to moderately weathered basalt, reasonably fractured except at lower dredging depths where the uniaxial rock strength values range from 62-101 MPa as reported by Opus [14].

This lower section may require blasting. The weathered rock has elements of clay, silt and sand embedded within it. The quantity of rock is small at about 25,000 m³, less than 1% of the total dredging project, but productivity will be relatively slow dependant on the size of the BHD and the hardness of the rock.

7.3.2 Rock Blasting

If the rock proves to be too hard for backhoe excavation, there will be a requirement for drilling and underwater blasting. The need to blast may be restricted to the lower depths of rock when the grade changes from highly to moderately weathered and to solid and where the backhoe does not have sufficient prying strength. The extent of blasting will depend on the size of the backhoe and the extent of fracturing of the lower rock. Modern blasting techniques would result in the material being fractured to enable the BHD to then excavate the material. The process of fracturing the rock involves drilling holes from a barge, usually held in position by spuds (legs) supported off the seabed surface. The holes are plugged with

[14] Opus International Consultants Limited: Factual Report of Geotechnical Investigations, August 2008

explosive that is discharged in series to fracture the rock whilst minimising the effects surrounding the area.

7.3.3 Backhoe Dredger

Mechanical dredging using a backhoe is described in section 5.4 with a typical example of a large BHD is shown in Figure 5.5. The BHD has a quick operation cycle of between 20 and 40 seconds but becomes weaker at tearing out material as depths increase. .

The excavator bucket capacity would range between 3.6 and 15 m³ (7.2 and 30 tonne). The dredging depth ranges between 0m and 18m and hence is at the maximum reach capability and therefore lowest breakout capacity for the bottom section. To minimise the need for blasting, large dredgers would be required such as:

- Machiavelli owned and operated by Heron Construction Co Ltd
- Kimahia owned and operated by Heron Construction Co Ltd
- Corbart owned and operated by Boskalis Westminster NV.

Vessel		*Kimahia*	*Machiavelli*	*Colbart*
Excavator		Liebherr P984 100 tonnes	Liebherr P994 230 tonnes	Demag H255S 100 tonnes
Mud Bucket capacity	m³	10.0	19.8	15.0
Heavy digging bucket capacity	m³	4.6	4.6	3.7
Max dredging depth	m	17.0	20.0	19.1

Table 10 Typical backhoe dredges

7.3.4 Rock Disposal Options

Several alternative options will be examined for disposal of the rock but the ultimate use will depend on whether there is an economic use at the time dredging is undertaken. Three options have been identified and for the purposes of determining plant and dredging cycles the following distances to the disposal site have been assumed for each option:

- Wharf protection, Port Chalmers – 2.5 km
- Dump to the designated offshore disposal site, Heyward Point – 14.5 km.
- Dump or offload at a foreshore site requiring rock protection – 8 km to a site near the harbour entrance or mole. Disposal site to have sufficient depth of water.

As noted earlier, due to the proposed deepening of the berth pockets at Port Chalmers it has been necessary to evaluate the effects this deepening will have on the stability of the existing wharf structures. The evaluation (Robinson, 2010)[15], concluded that the placement of rock fill by extending the current rock slope protection and adding a rock buttress at the toe of the new slope will maintain or improve the current stability of the slopes under the wharves.

[15] Hadley & Robinson Ltd: Stability of Slopes Multipurpose and Container Wharves Port Chalmers, February 2010

It is proposed that the required rock fill will be sourced from either Rocky Point or Acheron Head dependent on the quality of material excavated at each of these sites. The volume of rock required for this work is estimated at 15,000 m^3 so would use the bulk of the material excavated from both claims. This is a sustainable use of the resource although there is considerably more work required to place and sequence the work.

Once the wharf protection works were complete and assuming the quantity was more than required for this work, then the options for dumping at Heyward Point or offshore protection works would be utilised.

The cartage of rock would be by hopper barge with bottom dumping the most probable discharge option. The size of barges would be determined by the dredge size and productivity but is more likely to depend on the availability of suitable barges and towage plant. It is assumed that two sets of tugs and barges are required and would be approximately 750 m^3, loaded to 70% capacity due to the density of bulked rock.

7.3.5 Dredging Productivity

i. Loading:

A bucket size of 4.6 m^3 is assumed for reasonably hard excavation and the load rate is assessed to be 2.5 m^3 in-situ volume per minute. A 750 m^3 capacity barge would take 300 minutes to load a bulked 525 m^3.

ii. Travelling Time:

Assuming an average towage speed of a tug with barges of 4.5 knots (8.3km/hr) the round trip for the three options are:

- Dump at Port Chalmers wharves for placing in rock fill buttress – 36 minutes
- Dump at the designated offshore disposal site – 209 minutes
- Dump or offload at a foreshore site requiring rock protection – 115 minutes

An additional 5 minutes is added for mooring alongside the excavator pontoon and 5 minutes to berth for the offloading option.

iii. Offloading:

Dumping to sea or over protection works would take an average of 10 minutes. Offloading at a wharf is calculated to take approximately the same time as loading when filling into trucks.

7.3.6 Dredging Cycle Time and Productivity

The following summarises the rock dredging cycles and timing for 25,000 in-situ m³.

	Port Chalmers Wharf	Dump Offshore Disposal Site	Rock Protection
Loading	300	300	300
Travelling	36	209	115
Dumping	10	10	10
Mooring	10	5	5
Cycle Time (Minutes)	356	524	430
In-situ Load (m³)	525	525	525
No. of loads	48	48	48
Loads per day (2 barges)	4.8	4.8	4.8
Barge Waiting time (min)	244 (69%)	76 (15%)	170 (40%)
Number of days	**10**	**10**	**10**

Table 11 BHD Cycle times and productivity for Rock

It should be noted that the above cycle times are calculated based on the following assumptions:

- Barge size is matched to excavator size with no wait time for the excavator,
- Dredging operation is unrestricted for 24 hours per day, 7 days a week,
- No allowance made for plant downtime including unsuitable weather conditions, equipment breakages, vessel maintenance, refuelling, crew changeover, etc.
- Blasting will not affect BHD work.

As shown in Table 11, there will be significant waiting time for barges on each cycle with the length depending on the disposal site. If the material was to be placed at Port Chalmers wharf smaller barges may be utilised to minimise wait time however this must be countered against the additional number of trips needed to remove the rock. The balanced scenario for each of the three options based on minimal waiting time for the excavator is to use 2 sets of 750 m³ barges.

7.4 Assessment – Swinging Basin, Berth Pockets

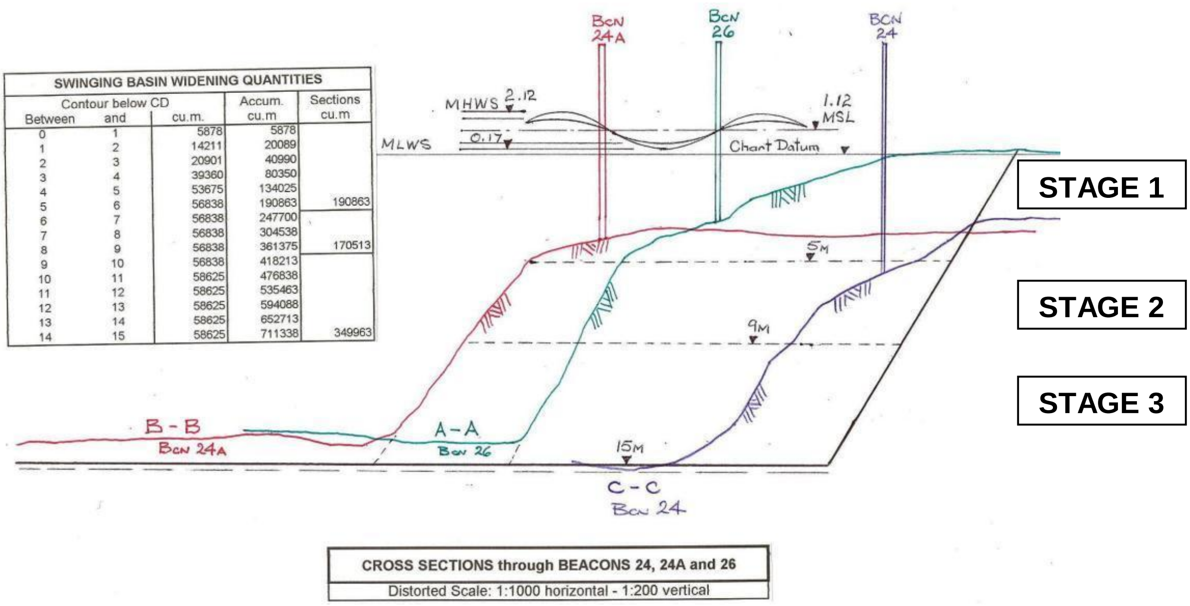
7.4.1 General:

The widening of the Port Chalmers swinging basin by up to 100m at the base of the channel commences at an existing seabed level near chart datum and therefore there is insufficient depth of water for the large TSHD to manoeuvre over the site. A TSHD could dredge in from the sides but with reduced efficiency. Alternative methods to remove the top section of spoil down to a depth of about 9 metres, that would enable a large TSHD to operate, have been examined.

7.4.2 Material Definition and Area Cross Sections:

The material to be dredged is defined within Bore Holes 1 and 2 and Vibracore 6 as “Sand with minor/trace shells”. The grading curve for the sand in VC 6 shows 80% of the sand ranging between 0.15mm and 0.30mm size with only 2% less than 75µms.

Cross sections at three navigation beacon locations to a distorted scale show the extent of the work.



SWINGING BASIN WIDENING QUANTITIES

Contour below CD Between	and	cu.m.	Accum. cu.m	Sections cu.m
0	1	5878	5878	
1	2	14211	20089	
2	3	20901	40990	
3	4	39360	80350	
4	5	53675	134025	
5	6	56838	190863	190863
6	7	56838	247700	
7	8	56838	304538	
8	9	56838	361375	170513
9	10	56838	418213	
10	11	58625	476838	
11	12	58625	535463	
12	13	58625	594088	
13	14	58625	652713	
14	15	58625	711338	349963

Figure 7.2 Swinging Basin Cross Section

The in-situ volumes to be dredged in within each level are:

- Stage 1: Surface to 5m 134,000 m³
- Stage 2: Between 5 and 9m 227,000 m³
- Stage 3: Between 9 and 15m 350,000 m³

The stages are discussed in further detail below with reference to the likely dredging techniques used to complete the work.

7.4.3 Dredging Options:

i. Backhoe (Stages 1 and 2):

The logical option is to use the large backhoe mounted on a pontoon that would be used for the work described in the rock section above. This BHD would be viable for both Stages 1 and 2. The difficulty with a large backhoe is that the bucket size would be able to be increased to excavate the relatively soft sand and would therefore fill the larger barges rapidly. Unless a number of large barges and associated towage are provided the expensive backhoe will have considerable down time. For example, a 20 m³ bucket would load a 750 m³ barge in less than an hour, a rate of 37.5 m³/minute, while the barge cycle would be about 4 hours to disposal site A0. Therefore, there could be up to 2 hours down time (approximately 50% of the excavator time) for each cycle of two barges if the larger backhoe is used.

The alternatives are to use a smaller, less expensive excavator mounted on a barge loading two 750 m³ barges at a rate of 3.1 m³/minute. To dredge to a depth of 5m, the work would take approximately 41 days. As noted above the option of increasing the number of tugs (3 No.) and barges (4 No.) to service the large backhoe could also be considered.

ii. Grab (Stages 1 and 2):

A crane and grab mounted on a barge, similar to the *Vulcan* owned and operated by Port Otago Limited, is an alternative to the backhoe dredger for both Stages 1 and 2. The general layout of the *Vulcan* is shown in Figure 5.3.

The grab would load one of two small split hopper barges, 150 m³ (125 m³ in-situ) capacity, in 120 minutes, a rate of 1 m³/minute. To dredge to a depth of 5m, the work would take approximately 94 days if dredging continuously. The combination of grab loading and the two 150 m³ barges provides a balanced production unit leaving only sufficient downtime for the required regular maintenance.

Larger grab and barge units could improve the productivity. Conversely, if the port’s unit only works 8 hour periods the time to complete the work would be about one year.

iii. Small TSHD (Stages 2 and 3):

Port Otagos’ TSHD, *New Era* is the ideal equipment for Stage 2 of the deepening, from 5 to 9m. The *New Era* has a hopper capacity of 600 m³ for sand that takes 2-3 hours to fill, a rate of 3-5 m³/minute. The New Era would also be capable of dredging areas of Stage 1 at, or near, the top of the tide. With an average of 5 trips to the designated offshore dump site, the dredging for Stage 2 work will take approximately 71 dredging days to complete on a 24/7 basis. The general layout of the New Era is shown in Figure 5.1.

iv. Large TSHD (Stage 3):

A large TSHD dredger could widen the channels by dredging into the sides with one side arm, undercutting the base and allowing the side slopes to collapse. This is not necessarily efficient dredging for steep batter slopes commencing as chart datum but is still practical. Refer to the following Figure 7.3, which demonstrates the difficulty when dredging steep batter slopes.

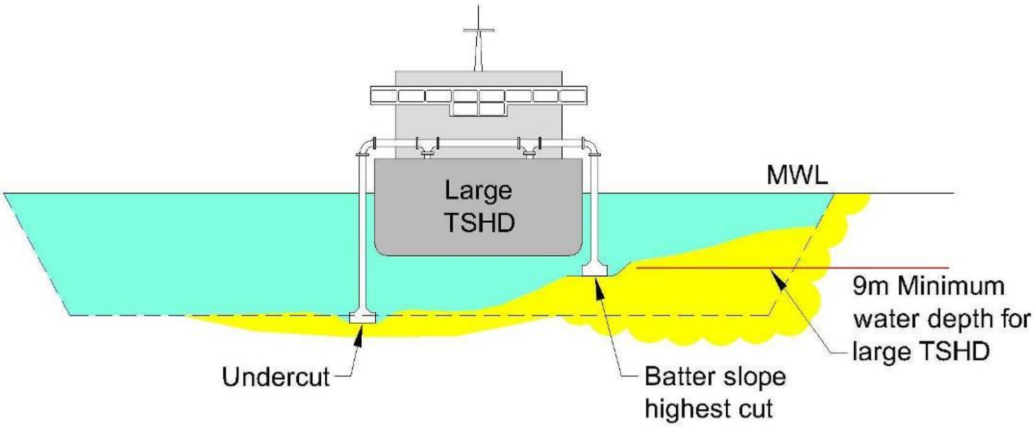


Figure 7.3 Swinging Basin dredging with large TSHD

The alternative option is to continue using the New Era down to the design depth. This option will take longer due to the smaller hopper size and the higher number of cycles required.

v. Water Injection Dredging

An alternative methodology utilising water injection dredging (WID) would enable the shallow areas inaccessible to the deeper draft TSHD to be dredged following WID. Water injection dredging involves injecting water into densely packed or steep slopes whereby breaking down the internal cohesive strength and effectively creating a fluid. This fluid, having a greater density than seawater, then acts under the influence of gravity and "sinks" to the bottom whereby the TSHD can pick it up on a later dredging run. This method can create high levels of turbidity both during water injection and when the bank effectively collapses.

vi. Likely Combination:

The preferred and most likely dredging combination for widening the swinging basin is to use a backhoe dredger or grab dredge loading barges to a depth of 5m, a small TSHD from 5 to 9m and the large TSHD to complete the dredging to channel depth, this is shown in Table 12.

Stage	Dredge Depth	Volume	Preferred Dredge Equipment	Alternative Dredge Equipment
1	0 – 5	134,000 m³	Large BHD and 750m³ barges	Grab dredge *Vulcan* and 150m³ barges
2	5 – 9	227,000 m³	Small TSHD *New Era*	Large BHD and 750m³ barges
3	9 – 15	350,000 m³	Large TSHD	Small TSHD *New Era*

Table 12 Swinging Basin preferred methodology

7.4.4 Dredging Productivity:

The dredging productivity associated with the preferred dredging is shown in Table 13.

	Stage 1	**Stage 2**	**Stage 3**
Primary Dredger used	Backhoe with 4m³ bucket	Small TSHD *New Era*	Large TSHD
Hopper capacity	750	600	10,800
Loading	240	150	80
Travelling	209	111	*94*
Dumping	10	10	10
Mooring / turning	5	5	5
Cycle Time (min)	**464**	**276**	**189**
In-situ load (m³)	525	600	7223
In-situ quantity (m³)	134,000	227,000	350,000
Number of loads	255	378	48
Loads per Day	6.2	5.2	7.6
Number of days	**41**	**73**	**6**

Table 13 Swinging Basin cycle times and productivity

7.4.5 Summary:

There are several options for the contractor to widen the swinging basin, either by using the large TSHD following the use of smaller dredgers to lower the top section until the large TSHD may manoeuvre over the area to be widened. The ultimate methodology will be determined by the successful contractor in consultation with Port Otago.

7.5 Preferred Methodology – Disposal

7.5.1 General

The designated offshore spoil disposal site is located about 6.3km to the east of the harbour landfall beacon. The proposed shape is a circle 2km in diameter providing a disposal site area of 3.14 square kilometres. If the dredged spoil deposited on the site remains within the area the average height of the fill will be about 2.5m.

7.5.2 Discharge – Sands

During the dredging of sands when the overflow has been reached most of the silt fines would have been removed from the sand with the overflow water. Hence, sands to be dumped will have very little fines retained in the hopper. The load per trip is about 70-80% of the hopper capacity, or for a 10,000 m³ TSHD, 7,200 m³ in-situ sand volume.

The dredger will enter the designated disposal site and open the hopper doors to allow the sand to drop out the bottom of the vessel. The dredger may either stop or move dead slow ahead if there is a need to flush the sand from the hopper. Whether the material will form an arch and require help for it to dislodge will depend on the hopper size and shape and on the material being dumped. If the movement of the vessel does not dislodge the material water jets may be used.

The sand will empty from the vessel hopper within about 10 minutes.

7.5.3 Discharge – Silts

When dredging silts the operation ceases soon after overflow has been reached. The load per trip is therefore reduced to about one third of the hopper capacity for reasons outlined in 7.2.3. The hopper will also contain a high percentage of water.

As for the sands, the dredger will enter the designated disposal site and open the hopper doors to allow the silt to drop out the bottom of the vessel. This operation will take about 10 minutes.

Where both sands and silts are being dredged the loading will also likely to cease at overflow to prevent large volumes of silts that do not readily settle into the hopper, moving back into the sea with the overflow water. The discharge volume would therefore also be less than for sand.

7.5.4 Discharge - Rock

As described in 7.3.4 the preferred use of the rock is to place it in a buttress at the base of the existing wharves. The alternative use is to place the rock where it may be of use as protection or otherwise to dispose of the rock at the designated maintenance dredging spoil ground, located at Heyward Point.

7.6 Conclusion

Following the above assessment the most practicable and preferred methodology for completing the dredging works can be summarised in the following table:

Location of Material	Volume	Primary Dredge	Duration (Primary dredge days)	Back-up Plant
Main channel	5,506,507m³	Large Trailing Suction Head Dredge	122	Small TSHD *New Era*
Rocky outcrops	25,000m³	Large backhoe dredge	10	Drill / blasting rig, grab dredge and barges
Swinging basin <5m CD	134,000m³	Backhoe dredge	41	Grab dredge and barges
Swinging basin 5 – 9 m CD	227,000m³	Small TSHD *New Era*	73	Backhoe dredge / grab dredge
Swinging basin 9 – 15 m CD	1,229,000m³	Large TSHD	6	Small TSHD *New Era*
TOTAL	**7,121,547m³**		**252**	

Table 14 Preferred Dredge Selection

It should be noted that the above dredging days shown are based on a number of key assumptions included in the relevant sections above. Key assumptions are:

- Dredging operation is unrestricted for 24 hours per day, 7 days a week,
- No allowance made for vessel downtime including unsuitable weather conditions, equipment breakages, vessel maintenance, refuelling, crew changeover, etc.
- Main channel dredging assumes largest practicable TSHD (10,000m³), an increased duration would occur if a smaller 6,000 to 8,000m³ capacity dredge were contracted, see Table 5.

The total dredging days shown is also cumulative whereby no previous dredging has taken place and assumes that one job, or portion of the project, will follow on the completion of the previous. This is very unlikely to occur with extensive amounts of dredging likely to be carried out prior to the large TSHD being deployed. In all likelihood the total duration of works, if it were to be carried out under one project, would be in the region of 6 months.

8. Dredging Management and Mitigation

8.1 General

The selection of the correct dredger for each different area of work; channel silts and sands, rock outcrops and Swinging Basin widening is important to ensure an efficient operation environmentally, socially, culturally and economically.

In terms of environmental impact, it is essential that any key effects of dredging and disposal are covered by the provision and implementation of a dredging management plan on which the dredging performance contract specification will be based. This plan has been developed in conjunction with the wider Next Generation project documentation and is referred to as the Dredging Environmental Management Plan (DEMP), Port Otago (2009). This DEMP is a separate document and it is anticipated that the draft DEMP is a framework for further development in consultation with the selected Contractor.

As detailed in the DEMP a key aspect to minimise any potential environmental effects is the selection of the correct equipment. This aspect has been a fundamental consideration of the dredge assessment and presented in Section 7, Dredge Evaluation and Assessment.

Potential effects covered in the DEMP include:

- Dredge plant noise
- Explosives / blasting
- Vessel wake
- Navigation / maritime safety
- Dredge vessel operation
- Water quality – turbidity
- Contamination
- Vibration / shock waves
- Public safety and security
- Ecology (flora and fauna)
- Cultural Impacts
- Physical environment changes

Management of each of these effects is covered in detail in the DEMP and will not be repeated here other than to note their influence in the selection of dredging plant and methodologies.

8.2 Dredging Strategy

8.2.1 Flexibility rather than Control

The bulk of dredging is of sands and/or silts along a 13km length of channel commencing offshore at the Landfall Tower, which is 2.5km seaward of Taiaroa Head, and concluding at Port Chalmers. Total flexibility of programme is desired to achieve the best efficiency of dredging and consequentially minimising effects. The flexibility enables the dredging company to determine the best sequence of dredging dependent upon productivity, weather and sea conditions, shipping and state of tide. The resulting effect is to:

- Minimise the duration of dredging, and hence the time of exposure to any environmental and social effects,
- Undertake dredging of the offshore channels in calmer weather and hence, minimise dredging tolerances and the consequential volume of material dredged and disposed,
- Minimise the delays from shipping by planning the areas to be dredged to fit with the shipping schedules,
- Where possible, dredge sand separately from silt to maximise productivity with acceptable levels of turbidity from the overflow. The result is less trips and shorter duration of dredging,
- Separate sands and silt claims to prevent “billowing” at disposal site,
- Sequentially work the disposal ground to ensure even spread.

Environmental efficiency is a dominant factor for commercial dredging productivity particularly under a performance contract where payment is based on material dredged and retained. As dredging productivity drops rapidly upon reaching overflow level in silts there are sufficient economic incentives for the TSHD contractor to cease dredging once this point is reached. Sediment overflow when dredging sands is subject to the quantity of material less than 65-75µm (silts) in the sand mix. The geotechnical investigation test gradients show that the silt fraction within the sand ranges between nil and 4%.

When dredging areas that range between sands and silts there becomes a management requirement to determine when dredging should cease. A method of monitoring turbidity is therefore required to ensure sediment overflow is kept within acceptable limits. Turbidity meters within the harbour that show values on a daily basis would fulfil this monitoring requirement.

Most vessels can also monitor the rate of retention of material in the hopper and hence when productivity drops the overflow volume increases. The monitor is a key tool in assisting in the determination of when dredging should cease.

8.2.2 Dredged Material Disposal Site Location

Dredged material management is referred to in section 8.3 below. The conclusion is that almost all material that will be dredged needs to be disposed of in an offshore location as there are no suitable sites within the harbour.

The location, size and shape of the offshore disposal site was chosen following examination of the following factors:

- The closer the disposal site to the dredging activity the higher the overall dredging efficiency, greater economic viability due to less travel time which leads to a reduction in the overall dredging duration,
- Disposal mound impact on the offshore wave climate,

- Environmental impact on the ecology of the offshore site and surrounding area,
- The requirement for the majority of material to be retained on the site,
- The site turbidity during dumping will have little effect on fish and marine mammals, and commercial and recreational fishing.

The dumping of material over the site will be managed by:

- Requiring the vessel or barge hopper doors only to be opened when over the site and for the vessel or barge to stay within the site boundaries until the complete load has exited the hopper,
- Accurately track the path of the vessel while discharging material with the vessel systematically positioned over the entire site during each discharge so that the material is evenly discharged over the whole site. A real time plan will be produced of the tracked discharge to enable management of the uniform disposal of material,
- The vessel may be stationary or moving when discharging material and the doors may remain open outside the site provided all material has been removed from the hopper prior to exiting the site. This will enable the doors to be closed during the trip back to the harbour channel and hence save valuable cycle time.

8.3 Dredged Material Disposal Management

The principles of dredged material management require the need to take a number of factors into account such as:

- Dredged material should be treated as a resource where possible,
- When dredging sand, beach re-nourishment and/or new beaches should be considered,
- Internationally contaminated material is an important factor but fortunately the Otago Harbour material is virtually uncontaminated,
- Commercial use of the material should be examined, especially when dredging rock,
- Rock for foreshore protection to be considered,
- Logistical factors affecting reusability, including distance between dredge site and beneficial use, site accessibility, dredging equipment required, size of project vs size of disposal site or beneficial use and compatibility of timing,
- Double handling of material can increase environmental and cost impacts.

Section 4 examines the options for material management and concludes that apart from some use of a small proportion of the rock the material should be deposited off shore. The foremost rationale is that the multiple use options involve relatively small volumes of sand and rock in the context of the scale of the project and is therefore inappropriate and would unduly increase the cost and risk profile of the project. The threshold is about 100,000 m³ of sand (less than 2% of the total volume) but this does not necessarily eliminate the beneficial use being achieved. The report concludes that the volume of material required for the alternative beneficial use and the size and timing of operations clearly suit Port Otago's maintenance dredging program that uses the small TSHD *New Era*.

Rock will be excavated in small quantities and at a relatively slow pace suitable for some alternative use. Two benefits have been identified, 1) to provide a rock buttress at the toe of the existing wharves, and 2) bringing the rock ashore and loading trucks for commercial use such as making road aggregate. It is unlikely there will be sufficient economic benefit gained from transferring the rock ashore.

9. Peer Review – Professional Dredge Contractor

Following initial channel design work discussions were held with international dredging Contractor, Van Oord, to provide a secondary expert opinion as to the most practical dredge package for the work. Van Oord was provided with the following information:

- Opus International Consultants - Factual Geotechnical Report, August 2008
- Port Otago Ltd (POL) – Drawing 11005: Proposed Lower Harbour Channel Improvements
- Port Otago Ltd (POL) – Drawing 11090, Sheets 1 to 4: Proposed Channel Design Cross Sections
- Port Otago Ltd (POL) – Drawing 11091: Historical Soundings – Cross Sections
- Port Otago Ltd (POL) – Drawing 11024: Interpretive Geotechnical Long Sections
- Port Otago Ltd (POL) – Drawing 11093: Proposed Channel Design Nautical Chartlet
- Port Otago Ltd (POL) – Drawing 11094: Mass Haul Diagram for Disposal
- Port Otago Ltd (POL) – Drawing 11095: Dredging Material Volume by Claim
- Port Otago Ltd (POL) Spreadsheet detailing material splits and dredging cycle times

In July 2009, Van Oord responded by providing a proposal based on utilisation of the following dredging equipment:

<u>Trailing Suction Hopper Dredger (TSHD) – For fine sands & silts</u>

- TSHD **“Volvox Asia”**

<u>Backhoe Spread – For dredging pre-treated rock</u>

- Backhoe Dredger **“Hippopotes”**
- Two 1,000m³ non propelled Barges **“Murray River” & “Yarra River”**
- One tugboat with ~20T bollard pull **“P.T.Kotor”**

<u>Drill & Blast Spread</u>

- Self elevating platform **“BHD Supply”**
- Two drilling rigs equipped with “down the hole” hammers.
- One tugboat

<u>Ancillary Equipment</u>

- Survey launch (locally sourced)

Indicative costs were also provided but will not form part of this report as this is commercially sensitive information.

The above review carried out by Van Oord confirms the selection of the dredging plant by Port Otago is consistent with international practice.

10. Summary / Conclusions

Port Otago Limited (POL) proposes to expand capacity to service large container ships of 6000 to 8000 TEU (twenty-foot equivalent units). These ships have 50% more capacity and are longer and wider than existing ships that come to the harbour requiring modification to the harbour channel to enable safe passage. Port Otago proposes deepening the approaches to Port Chalmers and the berth area by dredging the channel to a minimum of 15 metres below chart datum to allow the safe and efficient passage of these vessels.

With the exception of a small area of less than 5,000m² on the eastern side of the swinging basin, all dredging is below the intertidal zone, which is the area above chart datum. The total volume estimated to be removed from the Lower Harbour is approximately 7.1 million cubic metres (M m³). Once excavated, it is proposed that the majority of the dredged material is transported to, and disposed of, in an area 6.3km off the Otago Peninsula in a water depth of approximately 27m.

Geotechnical investigations carried out estimated that the material to be dredged was a combination of rock (1%), sand (62%), silt (33%) and clay (4%). A series of chemical laboratory tests were also carried out for the presence of potentially harmful chemicals and concluded that none of the parameters tested for exceeded the guideline values. This indicates the material to be dredged can be deemed non-contaminated and suitable for disposal without prior treatment or capping.

There are environmental, social and economic factors to consider in determining the effects of the channel dredging. The main environmental factor is related principally to turbidity from both the dredging operation and the disposal of material. The social aspects include the project duration, turbidity potentially disturbing recreational fishing, disposal affecting recreation activities, construction noise and dredging influencing boating safety. The economic factors include the project cost, interference with commercial shipping operations and impact on commercial fishing and aquaculture.

A number of dredge types were considered for dredging areas of the harbour channel, with an assessment undertaken to determine the most effective option based on environmental, social and economic factors. Dredge productivity in the different material types encountered in Lower Otago Harbour was considered with dredge efficiency in terms of production rate a key performance indicator. The final combination of dredgers selected will ultimately be determined by the successful Contractor.

The selection of a medium sized (8,000 – 10,000m³) trailing suction hopper dredger (TSHD) for the bulk of the dredging volume, silts and sand, was deemed the most appropriate and efficient dredge plant. The TSHD is essentially a giant underwater vacuum cleaner which pumps a water-sediment mixture from the seabed to an onboard hopper via suction pipelines. The material/water mix discharges into the dredger’s hopper and the heaver material such as the sands settle in the hopper. Once the coarse sediment settles to the bottom the supernatant water is returned to the sea via an overflow weir.

The preferred method to excavate rock penetrating the harbour channel at Rocky Point, Acheron Head and possibly Pulling Point is a barge-mounted hydraulic excavator (backhoe dredger (BHD)) and hopper barges. If rock proves to be too hard for backhoe excavation then drilling and blasting will be required to fracture the rock. The quantity of rock is small at about 25,000 m³, less than 1% of the total dredging project, but productivity will be relatively slow dependant on the size of the BHD and the hardness of the rock.

The rock excavated will be used to extend the rock slope protection beneath the wharves at Port Chalmers. As a result of the berth deepening the addition of a rock buttress at the toe of the new slope will be required to maintain or improve the current stability of the slopes under the wharves. Any rock not utilised for wharf protection will be disposed at the existing Heyward Point disposal site.

In areas where the dredging is at, or close to, chart datum the medium sized TSHD may not be able to operate due to draft restrictions. This will be encountered at areas on the inside on Harington Bend and the widening of the swinging basin. The preferred and most likely dredging combination for widening the swinging basin is to use a backhoe dredger or grab dredge loading barges to a depth of 5m below chart datum, a small TSHD from 5 to 9m and the large TSHD to complete the dredging to channel depth. There may also be a requirement to do this for sections of Harington Bend.

Allowing for a number of key assumptions including 24 / 7 operation of the dredge and no downtime allowance, the total dredging duration is expected to be in the region of 6 months if completed as a large capital dredging project. An option to complete the work as an extension of the current maintenance dredging regime will extend the duration accordingly.

The selection of the correct dredger for each different area of work; channel silts and sands, rock outcrops and swinging basin widening was determined as most likely to ensure an efficient operation environmentally, socially and economically.

To address items of environmental impact, it is essential that any key effects of dredging and disposal are covered by the provision and implementation of a dredging management plan, this has been developed and is a separate document entitled Dredging Environmental Management Plan (DEMP), Port Otago (2010).

In conclusion, to minimise potential effects and impacts on the Otago Harbour environment from intensive dredging activity the following aspects have been incorporated into project planning:

- The channel alignment was finalised with the aim of minimising dredged material volumes without compromising vessel safety, port accessibility and commercial viability,
- Selection of the most efficient dredger for each facet of work, TSHD for the channel silt and sand areas, BHD for the excavation of rock and a series of dredgers to widen the Swinging Basin from chart datum level to a depth suitable for the large TSHD,

- Use of a specially designed weir and “Green Valve” within the TSHD overflow system to reduce entrained air and consequential turbidity,
- Modern practice in rock blasting technology will be utilised to minimise the effect on marine life, adjacent residents and recreational boating while adequately fracturing the rock for a BHD to excavate.

In order to achieve the above:

- Performance Contract prepared to cover both operational and environmental requirements.
- The sequence of dredging must be left flexible to ensure the most efficient operation can be undertaken dependent on tide, weather and sea conditions, shipping and special events within the channel which will minimise project time and associated effects,
- The dredged material disposal site has been located as close as possible to the dredging areas to minimise dredge cycle and project time, risk and cost while ensuring a suitable site with due regard to offshore currents, seabed ecology and marine ecology.

As a result:

- 7.1 million cubic metres of rock, sand, silt and clay will be dredged from the Lower Otago Harbour,
- Silts and sands will be deposited offshore at a designated disposal site to minimise the project time and effect. Where there is a need for sand for beach re-nourishment this is more efficiently supplied from Port Otago’s *New Era* dredge during the continuous maintenance programme of the channels,
- Rock will be utilised to maintain or improve stability of the Port Chalmers wharves following berth deepening.

11.References

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Appendix A – Referenced Project Drawings