2.2 Wind Data

Wind data was obtained from MetOcean Solutions who provided an annual wind rose and seasonal/annual wind speed exceedance probabilities based on hindcast and measured wind speeds at Marsden Point. The measured data covers the period 2nd September 2009 to 1st May 2015 (MetOcean Solution, 2015); refer *Figure 1* and *Table 3*.

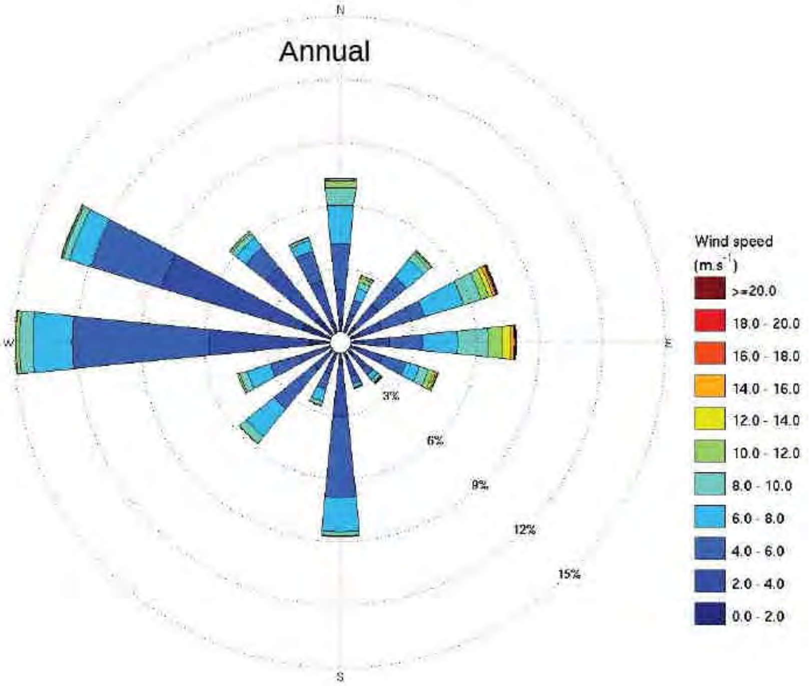

Figure 1: Annual Wind Rose at Marsden Point (MetOcean Solutions, 2015)

Table 3: Seasonal/annual Wind Speed Exceedance Probabilities for Marsden Point (MetOcean Solutions, 2015)

MARSDEN POINT (LOCATION: 174.50 E, -35.84 S)

Seasonal and annual wind speed exceedance probabilities (from 2nd of Septemper 2009 to 1st of May 2015)

U (m/s)	Exceedence (%)				
	Summer	**Autumn**	**Winter**	**Spring**	**Year**
>2	90.44	89.73	91.27	93.61	91.30
>4	60.23	56.96	58.41	65.06	60.30
>6	30.14	26.53	27.36	31.05	28.86
>8	11.56	10.60	13.19	10.88	11.51
>10	3.68	4.68	6.68	2.99	4.43
>12	1.32	2.23	3.30	0.62	1.81
>14	0.61	0.86	1.63	0.12	0.77
>16	0.10	0.28	0.75	0.02	0.27
>18	0.04	0.13	0.48	0.01	0.16
>20	0.00	0.03	0.21	0.00	0.06
>22	0.00	0.02	0.05	0.00	0.02
>24	0.00	0.00	0.02	0.00	0.00

Note: 1m/s ≈ 2 knots.

2.3 Wave Data

Wave data was provided by OMC International from the 'Alpha' Waverider buoy located near the centre of Reach 1 (refer *Figure 2*).

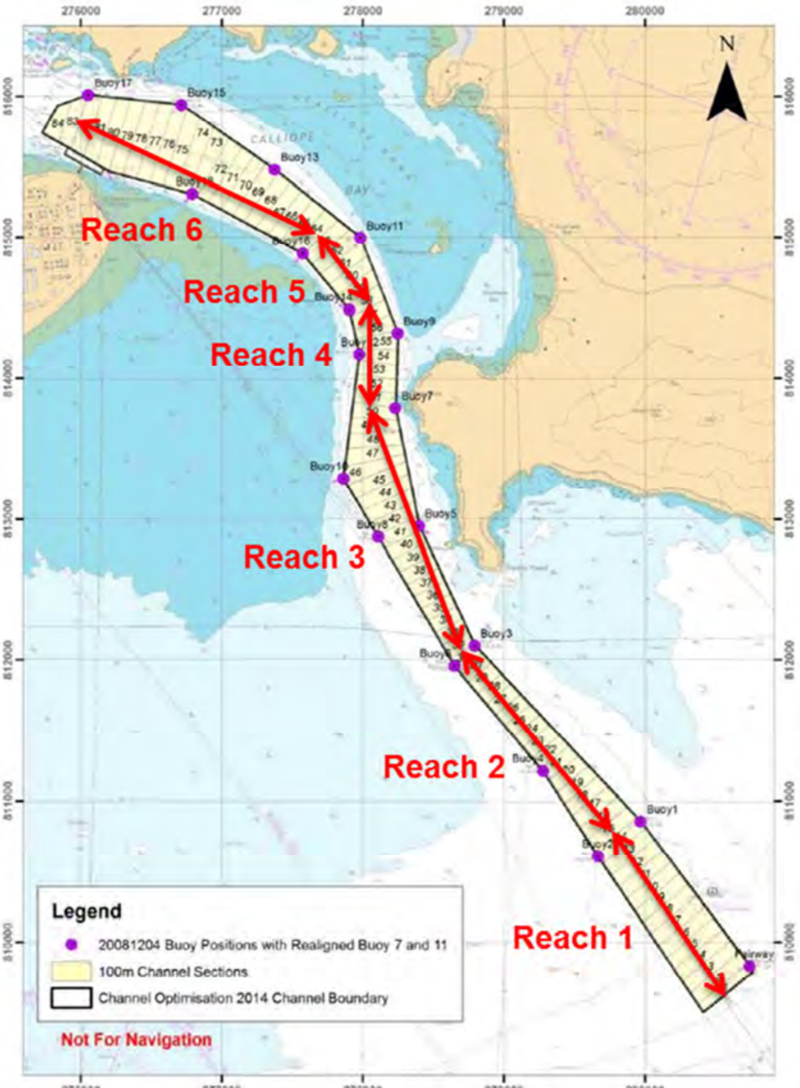

Figure 2: Channel Design Reaches

The various percentiles for swell and sea height have been transformed to several locations along the proposed approach channel using the wave attenuation factors provided by OMC International, refer Table 4.

Table 4: Various Percentile Wave Conditions

<table>
<tr><th>Location</th><th>Sea Height
(H_s, m)</th><th>Swell Height
(H_s, m)</th><th>Sea Period
(T_p, sec)</th><th>Swell Period
(T_p, sec)</th></tr>
<tr><td>Reach 1 (centre)
[1.0]</td><td>50% = 0.22
80% = 0.48
90% = 0.73
99% = 1.55</td><td>50% = 0.43
80% = 0.75
90% = 1.05
99% = 2.40</td><td rowspan="4">50% = 6.67
80% = 6.90
90% = 6.90
99% = 6.90</td><td rowspan="4">50% = 10.53
80% = 20.00
90% = 22.22
99% = 22.22</td></tr>
<tr><td>Reach 2 (centre)
[0.80]</td><td>50% = 0.18
80% = 0.38
90% = 0.58
99% = 1.24</td><td>50% = 0.34
80% = 0.60
90% = 0.84
99% = 1.92</td></tr>
<tr><td>Reach 3 (centre)
[0.36]</td><td>50% = 0.08
80% = 0.17
90% = 0.26
99% = 0.56</td><td>50% = 0.15
80% = 0.27
90% = 0.38
99% = 0.86</td></tr>
<tr><td>Reach 4, 5 & 6
(centre)
[0.24]</td><td>50% = 0.05
80% = 0.12
90% = 0.18
99% = 0.37</td><td>50% = 0.10
80% = 0.18
90% = 0.25
99% = 0.58</td></tr>
</table>

2.4 Current Data

ADCP tidal current data was surveyed and then analysed by Ross Vennell (Department of Marine Science, University of Otago) and was used to characterise the longitudinal and cross currents within each channel Design Reach (RHDHV, 2016b). Plots showing the current vectors at 3-hourly time steps for a typical spring tide are presented in *Figure 3*.

The highest current velocities are generally observed midway between high tide and low tide, with velocities reaching 2 to 2.5 knots over the length of channel analysed and 2.5 to 3.0 knots in the vicinity of Home Point some 3 hours after high tide.

The various percentiles for current velocity have been provided by OMC International (OMC), refer Table 5.

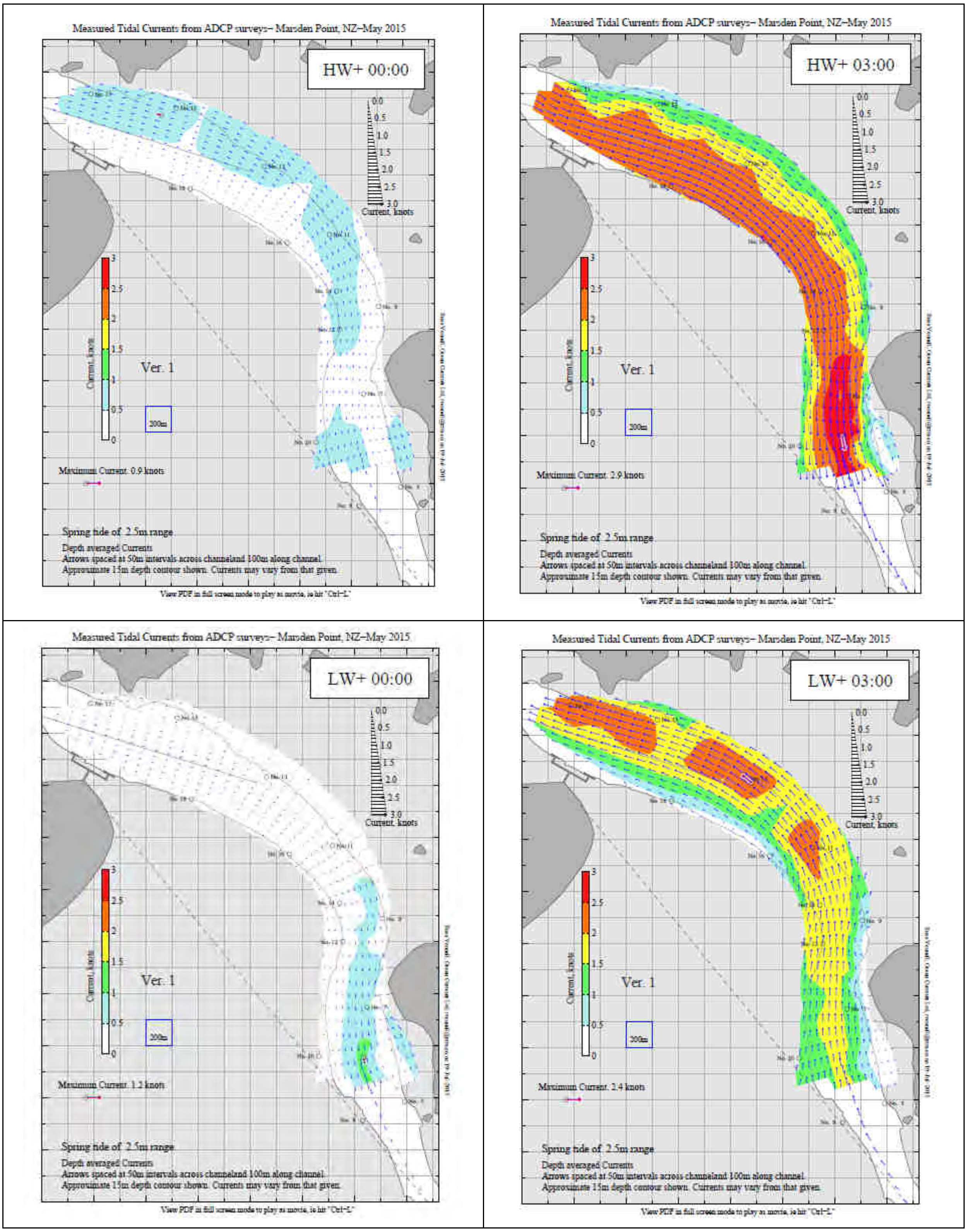

Figure 3: Current vectors at 3-hourly time steps (spring tide) (Source: R. Vennell, 2015)

Table 5: Predicted current velocity at time ship passes for transit Fairway to Berth (OMC International, 2015)

Location	Percentile: Current Velocity (knots)						
	1	10	20	50	80	90	99
Reach 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 2	0.22	0.22	0.25	0.29	0.32	0.32	0.32
Reach 3	0.93	0.94	1.03	1.22	1.34	1.34	1.34
Reach 4	1.20	1.22	1.33	1.58	1.74	1.74	1.74
Reach 5	1.04	1.06	1.16	1.39	1.54	1.54	1.54
Reach 6	1.06	1.07	1.18	1.41	1.57	1.57	1.57

Note: Ship at Fairway approximately 1 hour before HW

3 Channel Alignment

The preferred channel alignment from a navigational safety perspective has evolved through the design process with various options considered (RHDHV, 2016b). The channel options have been refined in accordance with PIANC geometry requirements and feedback received from desktop simulation studies. The three (3) channel alignment options that have been carried forward for further evaluation are Option 2, Option 4-2, and Option 5. A comparison of the mid-channel alignment past Home Point for these options is presented in *Figure 4*.

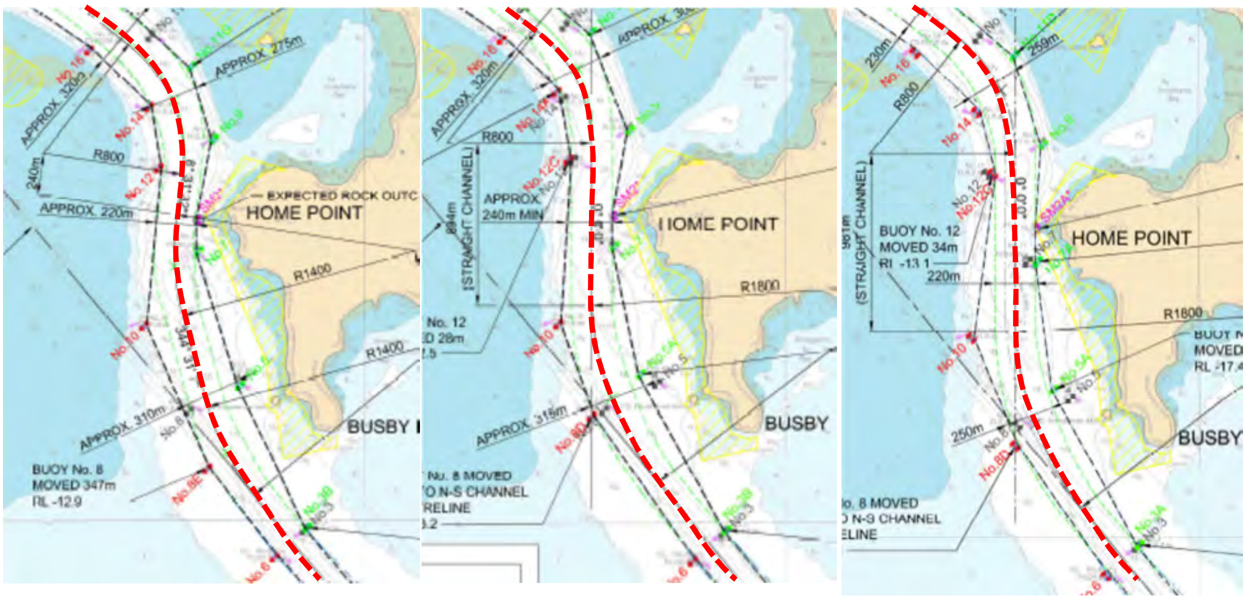

Figure 4: Comparison of mid-channel alignment past Home Point for Design 'Option 2' (left), Design 'Option 4-2' (centre), and Design 'Option 5' (right)

The three channel alignments are being further assessed.

Based on the results of the geophysical study for the nominated channel design, it is anticipated that only Unit 1 (silty and sandy layer) will be encountered in channel options 2 and 4-2 as part of the dredging works (RHDHV, 2015). Channel option 5 passes closer to Home Point and the dredging requirements for this channel option includes the need to remove large boulders and (possibly) a solid rock outcrop.

4 Channel Depth

The proposed channel depth is a function of design vessel draught and operational limits. The design vessel draught that has been adopted for this project is 16.6m. To provide adequate access to the wharf facility under a wide range of conditions, the channel is being designed to allow for 98% accessibility.

For the purposes of the concept channel design (and the estimation of dredging volumes), a siltation allowance of 0.5m and 0.3m has been added to the declared depths for the outer and inner harbour areas respectively (RHDHV, 2016b) with the outer harbour is defined as the area offshore of Buoy 5 / Buoy 8. It is expected that the outer channel will be subject to greater rates of sedimentation, due to being located in a more exposed climate (RHDHV, 2016b).

The declared depth plus siltation allowance is referred to as the 'Dredging Design Level' – being the target (minimum) level for dredging, refer *Figure 5*.

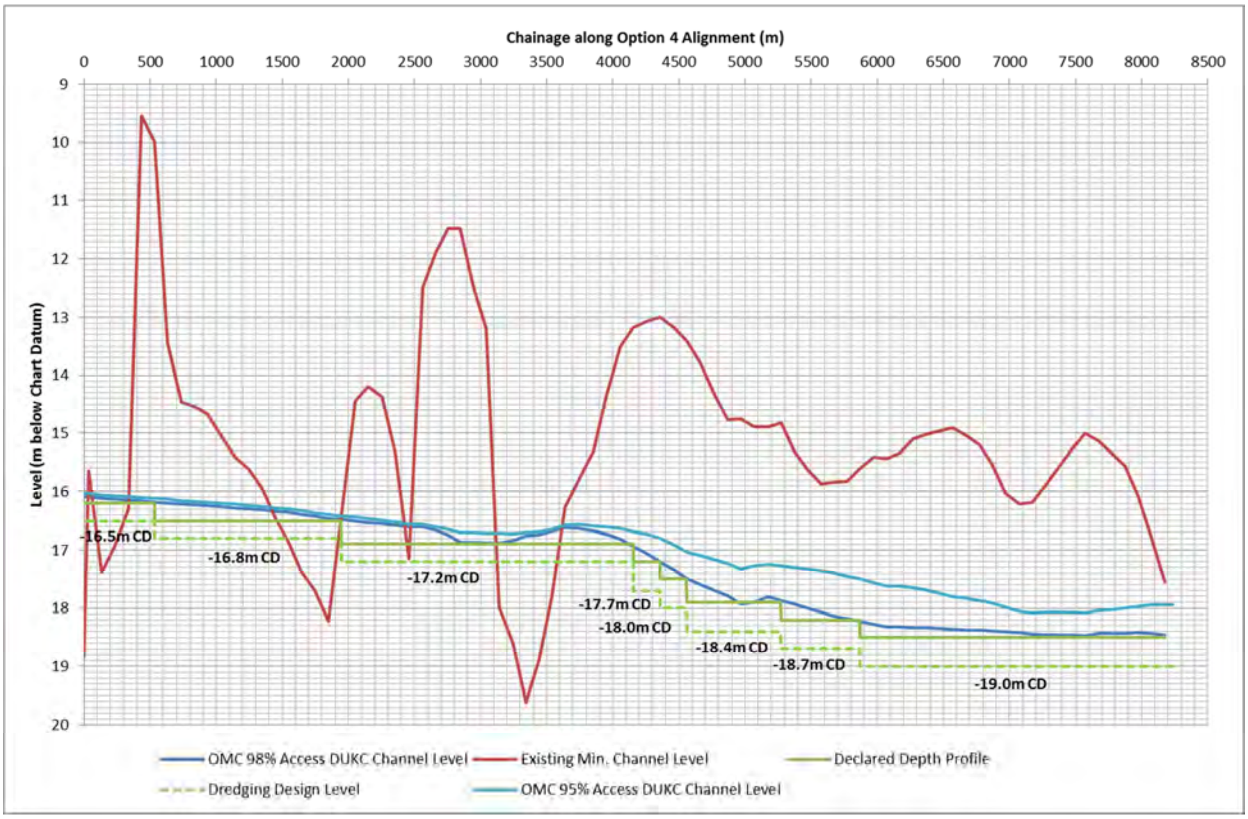

Figure 5: Channel design depths for 98% access channel

5 Dredge Volumes

For the purposes of calculating dredge volumes, each of the channel options being considered has been divided into an inner, mid, and outer channel section (refer Appendix A). The dredge quantities for each channel option and each channel section are presented in Table 6 (excluding over-dredge) and Table 7 (including over-dredge).

Table 6: Dredge volumes for the alternative channel options being considered (excluding over-dredging)

Drawing number	PA1028/MA/1123 RevA	PA1028/MA/1203 RevA	PA1028/MA/1302 RevA[1]
Design volumes (m^3)	**Option 4-2**	**Option 2**	**Option 5**
Inner section	476,000	456,000	508,000
Mid section	50,000	8,000	21,000
Outer section	2,652,000	2,689,000	2,627,000
TOTAL	**3,177,000**	**3,153,000**	**3,156,000**

Source: RHDHV, 2016a

Note: 1. The Option 5 volumes are based on this drawing but for a pro-rata increase for the design 98% access

Table 7: Dredge volumes for the alternative channel options being considered (including over-dredging)

Drawing number	PA1028/MA/1123 RevA	PA1028/MA/1203 RevA	PA1028/MA/1302 RevA[1]
Design volumes (m^3)	**Option 4-2**	**Option 2**	**Option 5**
Inner section	610,000	588,000	631,000
Mid section	57,000	10,000	25,000
Outer section	2,971,000	3,016,000	2,943,000
TOTAL	**3,638,000**	**3,614,000**	**3,599,000**

Source: RHDHV, 2016a

Note: 1. The Option 5 volumes are based on this drawing but for a pro-rata increase for the design 98% access

The approximate length of each channel section is as follows:

Inner section: 2.4km
Mid section: 1.2km
Outer section: 4.7km

It is noted that within the inner section, there is a volume of approximately 72,000m^3 (excluding over-dredging) that will be dredged around the jetty structure (i.e. the berth pocket).

6 Beneficial Reuse and Dredge Disposal Site Options

Beneficial reuse refers to dredged material that is used for social, economic or environmental benefits. Examples of beneficial reuse include:

- Creating wetlands / environmental habitats;
- Land reclamation;
- Beach nourishment (particularly in the case of coastal erosion);
- Use as a construction material; and
- Land rehabilitation

The adjacent Northport facility has already identified the need for additional fill for its current and planned port expansion and is in discussion with RNZ in this regard. Hence, for the purposes of the dredge methodology assessment, the following three broad dredge disposal options are considered:

1) All of the dredged material is disposed at an offshore disposal site (Base Case)
2) A small portion of the dredged material (≈200,000m^3) in the vicinity of the Marsden Point berthing area is pumped into the existing Northport reclamation to fill in existing low lying areas and the remaining material is disposed at an offshore disposal site (Alternative 1);
3) A greater amount of material is dredged and pumped (≈700,000m^3) to expand the existing Northport reclamation area (in line with their current approved resource consents) and the remainder of the material disposed offshore (Alternative 2); and

For the purposes of this study it is assumed that the disposal site will be within 10km of the project site. The offshore disposal sites currently being considered are:

- Disposal site 1.2 located in around 20m water depth and about 3km (and adjacent to) the centre of the outer channel;
- Disposal site 2.2 located in around 25m water depth and about 6km south of the centre of the outer channel (around buoy No 4), where the majority of dredge material will be derived; and
- Disposal site 3.2 located in around 40m water depth and about 7km south east from the centre of the outer channel.

The Northport reclamation site is situated approximately 8.5km upstream from the centre of the outer channel (where the majority of dredging will occur). Refer to indicative locations for the disposal sites on *Figure 6*.

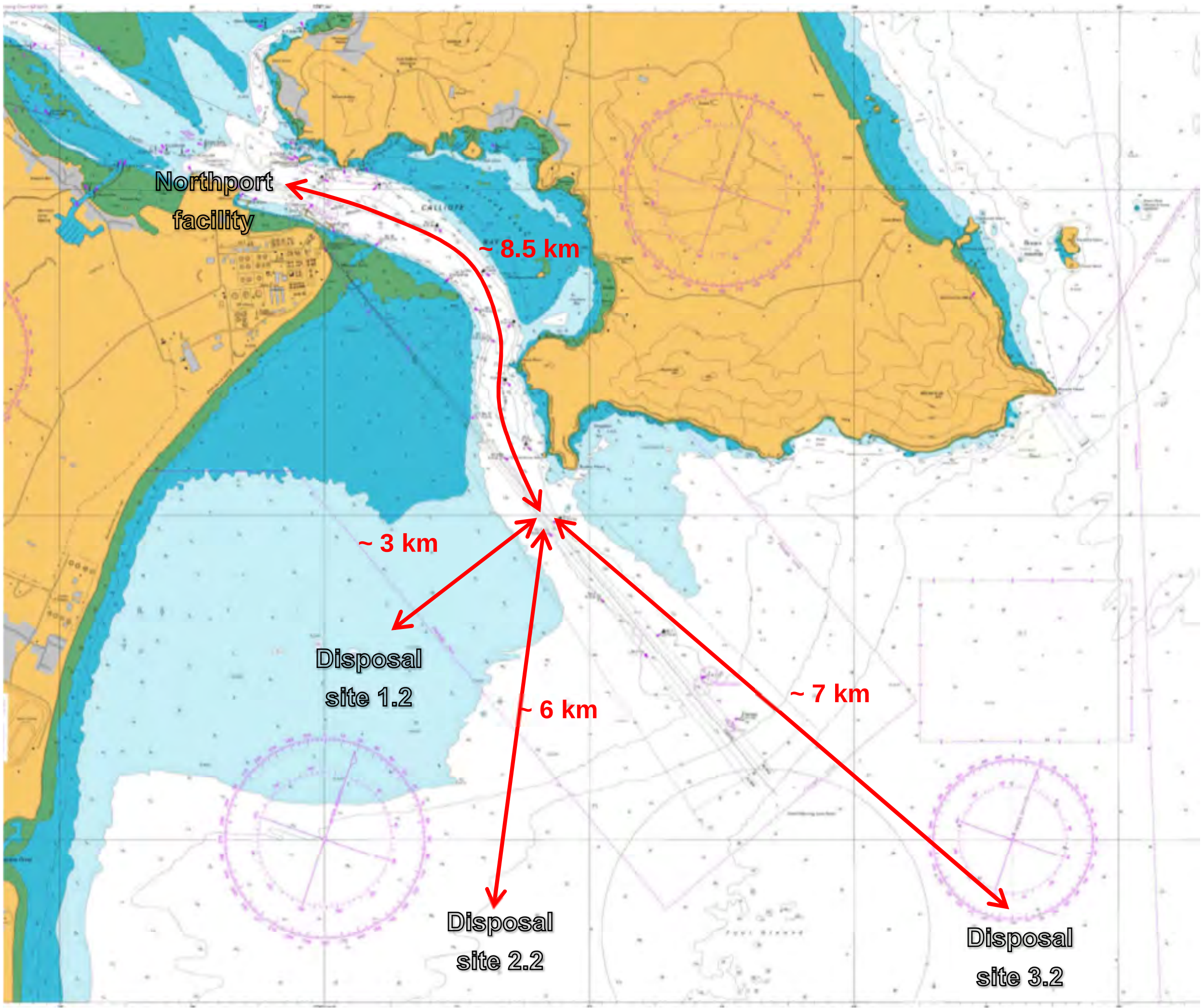

Figure 6: Dredge disposal site options (indicative only and not to scale)

7 Dredging Equipment Options

Dredgers can generally be classified as hydraulic or mechanical.

With a hydraulic dredger, the dredged material is pumped in a slurry form from the dredge face directly to the discharge site or to a temporary storage (e.g. hopper). Examples of hydraulic dredgers include Trailing Suction Hopper Dredgers (TSHD) and Cutter Suction Dredgers (CSD).

With a mechanical dredger, the material being dredged is collected in a bucket or grab and then placed directly into the discharge site, or more commonly into a temporary storage. The temporary storage is then used to transport the material to a discharge site, or the temporary storage will stay on site and the material is then re-handled (e.g. pumped through a pipeline or transported away using a truck or a barge). An example of a mechanical dredger is a Backhoe Dredger (BHD).

The use of a TSHD, CSD and/or BHD accounts for the vast majority of dredging projects.

When developing a dredging methodology for a project the contractor will generally take the following into consideration:

- Site conditions, such as waves, will impact differently on the various types of dredging equipment being considered;
- Required dredging depth;
- Nature and quantity of material to be dredged;
- Destination of dredged material;
- Site constraints, such as navigation limitations; and
- Availability of dredging equipment.

This section describes the types of dredging plant and equipment most commonly used for dredging projects, and assesses the suitability of each for use on the Project.

7.1 Trailing Suction Hopper Dredger (TSHD)

Trailing suction hopper dredgers (TSHDs), or “trailers”, are self-propelled ships with hoppers (dredged material storage internal to the hull). They have articulated dredging pipes, or “drag-arms”, that extend to the sea bottom. They dredge while underway, trailing at low speeds, refer *Figure 7*.

The drag-head (refer *Figure 8*) can be either passive or active. In the case of the passive drag-head, no additional power is applied at the head and material to be excavated is scoured by hydraulic flow induced by the suction at the drag-head. The active drag-head uses power to drive cutting teeth or high-pressure water jets to excavate the material and to aid in forming the solid/water slurry.

Figure 7: Trailing Suction Hopper Dredger (TSHD) (Source: IHC (Artists impression))

Figure 8: Typical TSHD drag-head (Source: Dredge Yard, 2016)

The weight of the drag system ensures that contact is maintained with the seabed in both passive and active drag-heads. The flow generated by the dredge pumps on vessel entrains the disturbed material and allows the material to be transported hydraulically as slurry through the suction lines, the centrifugal pump and into the hopper, where the solids settle out and the material is retained for transport and subsequent placement. Some of the finer fractions of the dredged material will overflow with the excess water from the hopper (subject to environmental controls, if relevant) and these fines will fall back to the seabed again.

The dredged material is transported in the hopper to a disposal site remote from the work site. The material is discharged either through doors or valves or, in the case of a split-hulled vessel, out of the bottom when the hull is longitudinally split. Alternatively, material may be pumped from the hoppers through discharge lines to shore-based placement sites with or without the use of booster pumps, or "rain-bowed" directly on to the site, refer *Figure 9*.

Figure 9: Example of 'rain-bowed' discharge (Source: DredgePoint, 2016)

TSHDs, or trailers, range in size from approximately 1,000m^3 hopper capacity to approximately 40,000m^3 hopper capacity. Production rates, and also mobilisation and demobilisation costs, generally increase with increasing hopper size, as does the daily cost of operating the trailer. Large trailers are therefore generally only deployed on very large dredging projects. The size of trailer deployed also depends on the water depth at which the dredging is to be undertaken. Small trailers can operate in water depths of around 7m whilst many of the larger trailers can operate in depths of up to 60m. Few are designed to dredge at depths of more than 100m.

TSHD's are suitable for the effective dredging of granular materials such as sand, silt and clayish material. Generally, TSHD's are not suitable for dredging rock material, although the removal of coral has been carried out using a drag-head equipped with ripper teeth.

7.2 Cutter Suction Dredger (CSD)

CSDs or "cutters", belong to the type of stationary hydraulic dredgers that use centrifugal pumps as their main means of lifting and transporting dredged material. The pumps produce the flow required to lift the material from the bed and, via the pumping head, to transport solid / water slurry through a pipeline from the dredger to a discharge point. Some of the larger dredgers are self-propelled for moving between sites. CSD operations are referred to as stationary in that they are not sailing whilst dredging, refer *Figure 10*.

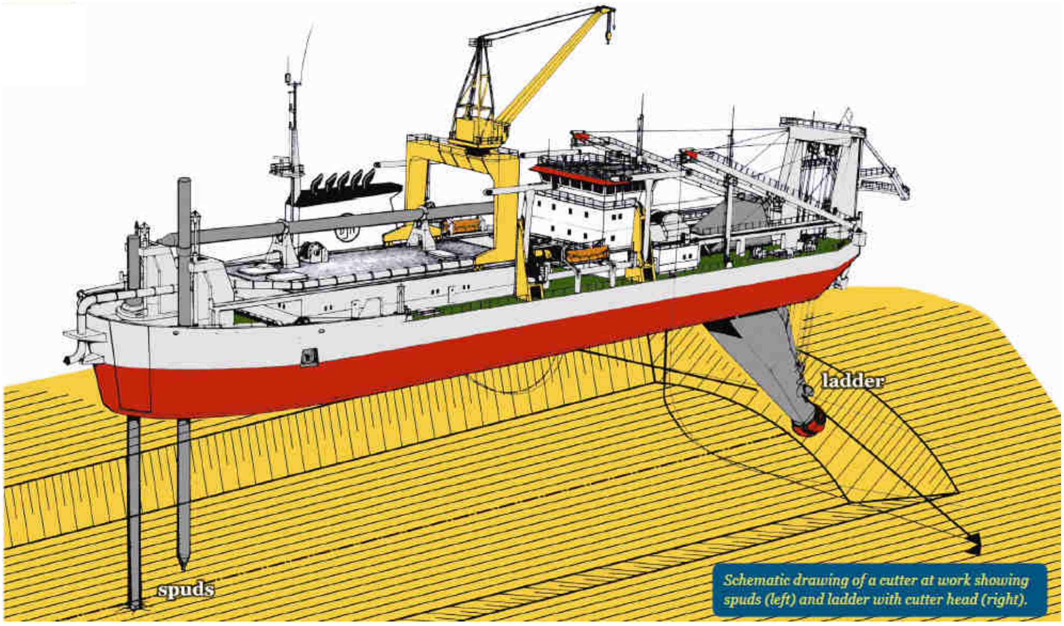

Figure 10: Cutter Suction Dredger (CSD)
Source: IADC, 2016

Cutter suction dredgers use rotating mechanical devices (cutter heads) that are mounted ahead of the suction head to disaggregate material (refer *Figure 11*). The cutters excavate the material and break it into pieces, which are then drawn into the suction pipe as solid/water slurry and pumped to the surface.

Figure 11: Typical cutter heads
Source: IADC, 2016 (left) Damen, 2016 (right)

The suction pipes are mounted on a frame called a ladder. By the use of a submerged pump mounted on the ladder, these dredgers can work effectively at depths approaching 30m or more in special cases. CSDs are characterised by high production rates and the ability to effectively dig silts, clays, sand, gravel, cobbles, and fractured and, in some circumstances, rock (generally non-igneous types, e.g. sandstones and limestones). They work in a stationary mode, normally using spuds at the rear and lateral anchors.

They can either discharge into barges or, more usually, through discharge pipelines to the local placement site. By using booster pumps at intervals along the discharge lines, they can transport and place materials at considerable distances from the work site.

Sea-going barges to transport the dredged material are often self-propelled and, in some cases, tugs or tenders are used to tow or push the transport barges. The material is unloaded from the barges at the dump site by being released through the bottom either through cable or hydraulically operated doors, or in the case of split-hulled barges by splitting the barge longitudinally. Sometimes the barges are unloaded using hydraulic pumps or mechanical equipment.

In the case that material is discharged from the CSD directly to an onshore disposal site, there are essentially three main types of pipeline for transporting material/slurry mixtures:

- Floating pipelines;
- Submerged or “sinker” lines; and
- Onshore lines.

Floating pipelines may either be formed of steel pipes supported at regular intervals by buoyancy units or surrounded by a buoyant case, or be composed of pipes made of a buoyant material. In all cases the pipeline has to be formed in such a way that it is sufficiently flexible to accommodate the movement caused by waves and currents. This may be achieved by making the pipe itself flexible, by inserting ball joints in the line at regular intervals, or by adding lengths of flexible pressure hose. All floating pipelines are made in a modular fashion and are connected together by bolts or quick coupling devices.

Submerged pipelines are made by welding a number of pipes together into a long string. They are floated into place, full of air, and then sunk in the desired location by flooding the pipe. Flanged connections or ball-joints are provided at each end of the line to enable floating or onshore lines to be connected.

Onshore lines consist of relatively short lengths of standard pipe, bolted together. Various devices are incorporated in the line so that it can be moved, to extend it or to switch the flow into different sections of the discharge area. The line may also be equipped with manual or hydraulically operated valves, Y-pieces and bends of different angles.

For material discharged onshore, once the solid / water mix is discharged on site, the water is drained off back into the sea though a system of internal bunds, weir boxes and dewatering channels. Bulldozers are typically used to move and spread the material around from the end of the pipe. Often, in the case of a solid / water mix containing very fine material, the fines are required to settle first in a stilling basin before the excess water can be channelled back to sea.

Not all cutter suction dredgers are suitable for the dredging of rock material and, in general terms there are three main criteria to be considered. These are:

- The cutter head;
- Installed power; and
- Mass inertia.

Most of the cutter heads commonly in use for soils are of the "crown" type with the main body formed in a cast steel alloy. The types of cutter are typically plain bladed cutters for weak materials such as sand and clay or serrated blade cutters for stiff clays and dense sands. However for rock dredging, the cutters require being of heavy construction and are typically larger in diameter then conventional cutters. The cutting blades incorporate integral sockets for the mounting of a variety of replaceable teeth. The shape of the blades is designed to maintain the maximum number of teeth in contact with the rock face regardless of dredging depth. The teeth may range from a chisel form for weaker rock to a pick point form for stronger rock masses. The teeth are made from a highly wear resistant alloy steel and are usually attached by means of a single sprung pin to reduce the time needed to replace the teeth. Despite the wear resistant teeth, it is common that all teeth need to be replaced at regular intervals, and depending on the rock properties this might be as frequent as every half hour.

Equally important is the installed cutting and pumping power on board the cutter suction dredger. A high power electrical or hydraulic engine is required to rotate the cutter head. After the rock is broken up by the cutter head underwater, the rock pieces, typically with a maximum size of about 30cm, are transported to the surface through the suction pipe. This is achieved through the use of a high power pump attached to the ladder. Additional pumping power is also provided on the cutter suction dredger to discharge the solid / water slurry through the pipeline away from the dredger to the discharge site.

Sufficient mass inertia is also required to prevent the cutter head from bouncing off the rock face. A large and heavy duty ladder is, therefore, required in combination with strong lateral anchor winches.

Since the CSD operates from a fixed location and requires the use of a mooring spread, including anchor chains, CSD operations can lead to navigation hazards if inappropriately notified / lit.

CSDs are generally not suitable for dredging in close proximity to fixed structures leading to a risk of damage to the structure and/or the dredger. There may be exceptions to this, such as the use of a small CSD around a mooring dolphin, but this requires that the Contractor take additional care to prevent damage to the dolphin. For this reason it requires calm environmental conditions.

7.3 Backhoe Dredger (BHD)

BHDs are mechanical dredgers consisting of an excavator mounted on a dredging pontoon. The word backhoe refers to the action of the shovel which digs by drawing earth backwards, rather than scooping material with a forward action like a bulldozer.

BHDs are generally suited to soils made of an unconsolidated, heterogeneous mixture of clay, sand, pebbles, cobble and boulders. BHDs are also suitable for dredging fragmented or soft rock. Since BHDs can generate a reasonable cutting force, they are suitable for a variety of soils that contain stones, such as heavy clay, blasted rock, and soils thought to contain fractured rocks, boulders or rubble.

Removal of unweathered unfractured igneous rock is beyond the capability of BHDs (and CSDs). In this case, the only option that could be considered is drilling, blasting and excavation of the material to achieve the required channel depths and/or widths.

To ensure stability and counter the large digging forces of the BHD, the pontoon is anchored and its position maintained by spud poles, refer *Figure 12*.

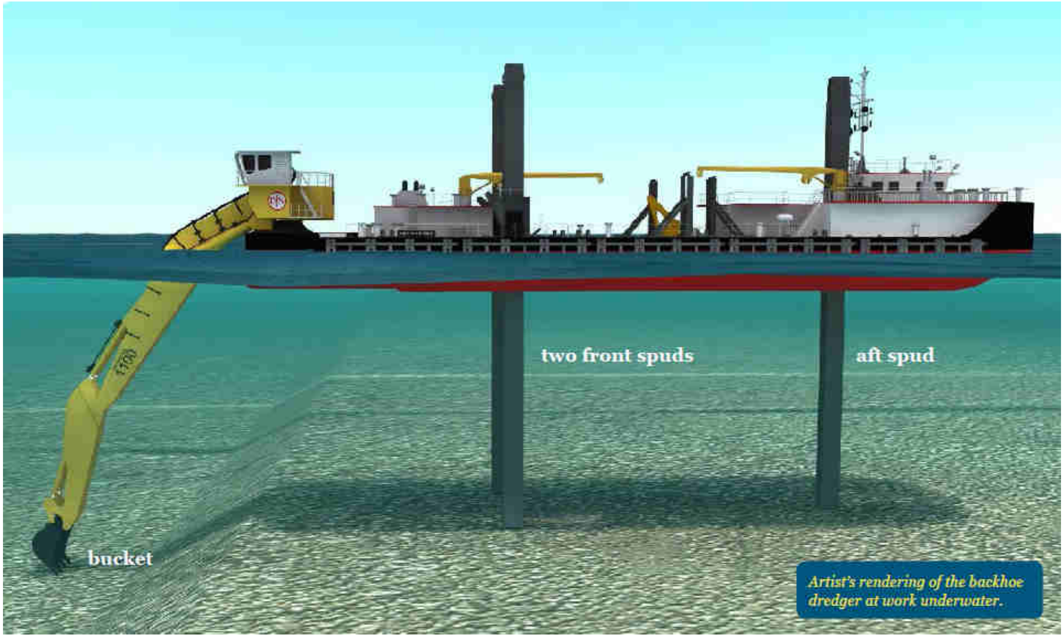

Figure 12: Backhoe Dredger (BHD)
Source: IADC, 2016

The dredging depth that can be achieved depends on the size and reach of the excavator. *Figure 13* shows a 100t excavator with a downward reach of approximately 14m (left) and a 150t excavator with a downward reach of approximately 18m (right).

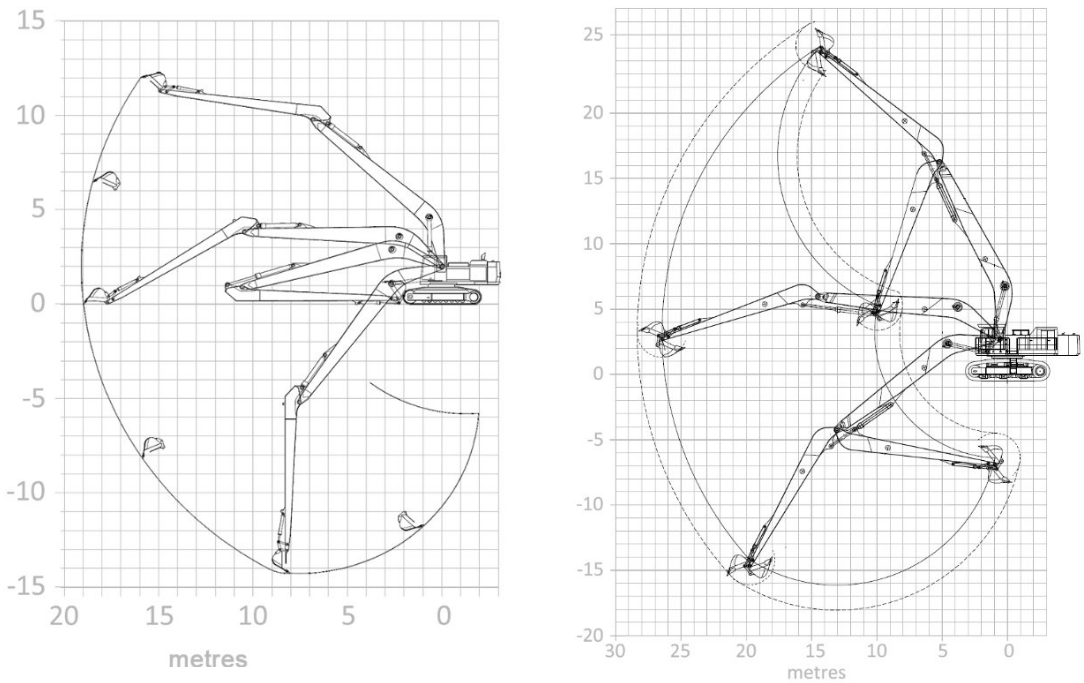

Figure 13: Typical longreach excavators
Source: Coastwide Civil, 2016

The current maximum depth that can be achieved with the largest BHDs is approximately 25m to 30m. All BHDs, regardless of size, have a similar dredging cycle:

1. The bucket is lowered into the water;
2. The bucket is filled by dragging it through the material to be dredged. During this process the bucket is also tilted to prevent dredged material from falling out of the bucket;
3. The bucket is lifted out of the water;
4. The excavator swivels and dumps the contents of the bucket into a barge (refer *Figure 14*); and
5. The excavator swivels back and the process starts again.

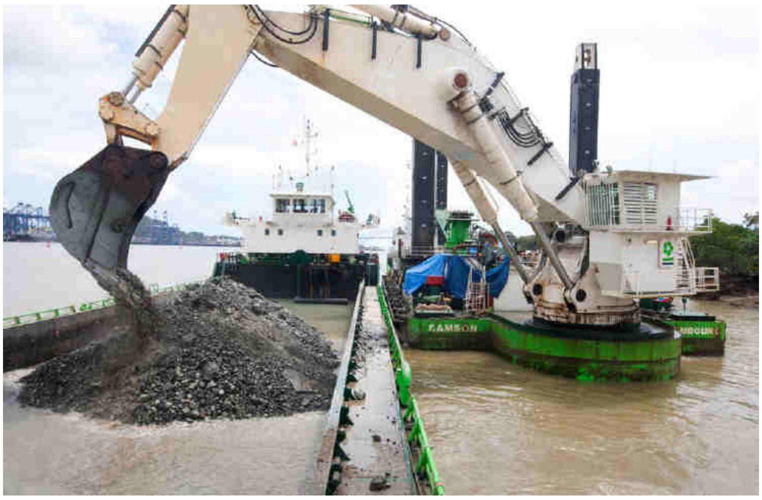

Figure 14: BHD discharging into a barge
Source: IADC, 2016

In order to achieve maximum effectiveness at each setup location, the excavator is positioned so that it can operate in an arch around the end of the pontoon, as shown in *Figure 14* and *Figure 15*.

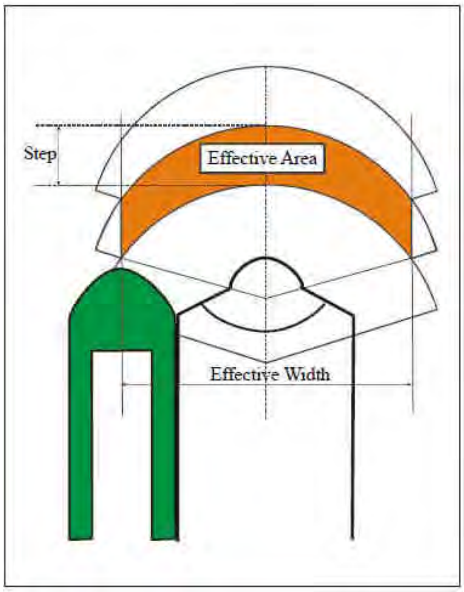

Figure 15: Effective dredge area of a BHD (Source: Vlasblom, 2003)

Most BHDs are equipped with accurate positioning systems in order to be able to dredge precise underwater profiles.

Some pontoons, and particularly those used for very large BHDs, may be self-propelled, but the majority will need to be towed or transported to the work site.

It is noted that, as with the CSD, the BHD operates from a fixed location. The BHD will use spuds for stability and the use of lateral anchors is not necessarily required. BHD operations can lead to navigation hazards when operating within a confined channel, however this would be to a lesser extent when compared to CSD operations.

The production rates that can be achieved with a BHD generally depend on the following factors:

- Work methods, such as:
  - BHDs can be used to dredge material alongside a fixed structure, such as a quay wall, but the production rate may be affected by the need for additional care to prevent damage to the structure / BHD;
  - Size of the bucket used;
  - Number and size of barges being used; and
  - Dredge disposal requirements.

- Working conditions, such as:
  - Location of the dredge site;
  - Currents and waves; and
  - Presence of other vessels.

- Materials to be dredged, such as:
  - Type of material being dredged;
  - Hardness and strength of material being dredged; and
  - Presence of vegetation or debris.

7.4 Limiting Working Conditions

The limiting working conditions for the various types of dredging equipment being considered are presented in Table 8.

Table 8: Limiting working conditions for dredgers

	Small TSHD	Medium/ Large TSHD	Small CSD	Medium/ Large CSD	Small BHD	Medium/ Large BHD
Wind (knots)	< 25	< 40	< 20	< 20	< 20	< 25
Waves Hmax (m)	< 2.0	< 3.5	< 1.0	< 1.5	< 1.5	< 2.0
Currents Vmax (knots)	< 3.0	< 5.0	< 2.0	< 2.0	< 3.0	< 4.0

Based on the environmental conditions presented in Section 2, the following limiting conditions will apply:

- Wind
  - > 25 knots ≈ 2% occurrence
  - > 20 knots ≈ 4% occurrence

- Waves
  - > 1.0m (Reach 1) ≈ 11% occurrence
  - > 1.5m (Reach 1) ≈ 6% occurrence
  - > 1.0m (Reach 2) ≈ 8% occurrence
  - > 1.5m (Reach 2) ≈ 4% 0ccurrence
- Currents
  - > 1.5knots (Reach 4) ≈ 60% occurrence
  - > 1.5knots (Reach 5) ≈ 30% occurrence
  - > 1.5knots (Reach 6) ≈ 34% occurrence
  - 2.0 – 2.5 knots Peak velocities throughout channel
  - 2.5 – 3.0 knots Peak velocities around Home Point / Reach 4

Therefore potential downtime in terms of percentage occurrence is presented in Table 9

Table 9: Potential downtime as a percentage occurrence

	Small TSHD	Medium/ Large TSHD	Small CSD	Medium/ Large CSD	Small BHD	Medium/ Large BHD
Wind (knots)	2%	-	4%	4%	4%	2%
Waves Hmax (m)	< 1%	< 1%	11% (R1) 8% (R2)	6% (R1) 4% (R2)	6% (R1) 4% (R2)	< 1%
Currents Vmax (knots)	Peak period (R4)	-	Peak period (All)	Peak period (All)	Peak period (R4)	-
Ranking	**3**	**1**	**6**	**=4**	**=4**	**2**

Notes:
'R1', 'R2' and 'R4' refer to Reach 1, Reach 2 and Reach 4 respectively.
'All' refers to the full length of the channel, i.e. Reaches 1 to 6.
'Peak period' refers to the part of the tidal cycle during which the maximum current velocities occur (i.e. HW +3hrs).
'-' indicates negligible downtime expected

It should be noted that the downtime percentages noted in Table 9 are specifically for periods in which the dredging equipment is in place and operating. CSDs and BHDs require to be moved from time to time to cover the areas to be dredged and, in the process, can be extremely vulnerable to the prevailing conditions at the time whilst being moved. During these periods, the working conditions can be limited to the ability of the tugs and/or its own ability to move from location to location and then reset its anchors/spuds to allow it to continue to work.

The implication of this is that as the support tugs are likely to have limiting operating conditions even lower than those noted in Table 10, CSDs and BHDs may have to wait until it is possible for tug operations to re-commence, thereby significantly affecting production and, hence, increasing the cost of dredging operations.

THSDs would not be affected in this manner and can continue to operate up to the specified limiting working conditions.

8 Examples of Potentially Available Dredging Equipment

The following Table 11, Table 12 and Table 13 provide details of typical dredging equipment that could be used on this project.

Table 11: Details of TSHDs that could potentially be used for the dredging works

	TSHD 1	TSHD 2	TSHD	TSHD 4
Name	Brage R	Brisbane	Balder R	Volvox Asia
Hopper capacity (m^3)	2,150	2,900	6,000	10,834
Length (Loa, m)	89.6	84.1	111.3	133.9
Breadth (B, m)	13.6	16.0	19.4	26.0
Draught unloaded (T_U, m)	3.47	3.0	3.7	6.0
Draught loaded (T_L, m)	5.69	6.25	7.0	9.47
Main engines (kW)	1492	1850	5,970	12,120
Speed empty (knots)	9.0	13	15	15
Speed loaded (knots)	7.5	11	14	14
Crew	7	13	13	13
Built	1996	2001	2011	1999
Owner	Rohde Nielsen	Port of Brisbane	Rohde Nielsen	Van Oord
To be mobilised from [1]	NSW, Australia	Queensland, Australia	NSW, Australia	Red Sea, Middle East

[1] Best estimate / home base

Table 12: Details of CSDs that could potentially be used for the dredging works

	CSD 1	CSD 2	CSD 3
Name	Eastern Aurora	Kotuku	Nu Bounty
Length (Loa, m)	116	23.8	41.3
Breadth (B, m)	14.9	7.0	10
Draught (T, m)	2.1	1.5	2.0
Max dredge depth (m)	27.0	18.5	22.0
Total power installed (kW)	7426	623	1500
Speed (knots)	9.0	6.0	-
Crew	-	-	-
Built	1994 (2011)[2]	-	-
Owner	Hall Contracting	Heron Construction	Neumann Contractors
To be mobilised from [1]	Queensland, Australia	Auckland, NZ	Queensland, Australia

[1] Best estimate / home base [2] Year rebuilt

Table 13: Details of BHDs that could potentially be used for the dredging works

	BHD 1	BHD 2	BHD 3
Name	Gunger R	Machiavelli	Simson
Pontoon dimensions (m)	52.6 x 15.3 x 3.4	53.0 x 15.0	66.9 x 23.0 x 4.3
Spuds (no.)	3	3	3
Bucket capacity (m^3)	5.4 to 11.0	4.0 to 5.7	15 to 40
Max dredge depth (m)	22	-	26
Crew	9	-	-
Built	-	2005	-
Owner	Rohde Nielsen	Heron Construction	Van Oord
To be mobilised from [1]	Queensland, Australia	Auckland, NZ	Rio de Janeiro, Brazil

[1] Best estimate / home base [2] Year rebuilt

Actual availability of dredging equipment will need to be checked with the various dredging contractors once the dredging commencement date has been confirmed.

Technical specifications for each of the dredgers presented in the tables above have been included in Appendix B.

9 Environmental Impacts, Safety Concerns and Management Measures

To properly understand the potential environmental impacts and safety concerns, it is necessary to think of dredging operations as consisting of four phases: excavation, lifting, transportation and placement.

Excavation is the physical removal of sediment from the seabed and can be done using hydraulic forces and/or mechanical forces.

Lifting is the vertical transport of the dredged material from the seabed to the water surface. Once again, this can be achieved using hydraulic means or mechanical means.

Transportation is the process of transferring the dredged material from the excavation site to the placement site.

Placement of the dredged material at the designated site can be either placed underwater or onshore.

This section describes some of the main environmental impacts and safety concerns that need to be taken into consideration when assessing dredging methodology options.

9.1 Turbidity

Turbidity is the ***cloudiness*** caused by sediment in suspension and is a measure of the light transmission properties of water. This cloudiness produces a temporary visual / amenity impact. Turbidity can also result in reduced photosynthesis in marine flora, with associated reduction in habitat productivity. In extreme cases it can lead to fatalities in marine fauna and flora.

Suspended sediment concentrations are sometimes erroneously described as turbidity. It is important to note that a high concentration of sand in suspension can have a very low turbidity whilst a low concentration of fine silt or clay in suspension can have a very high turbidity. Therefore, in order to determine whether turbidity is likely to be a concern, the composition of material to be dredged needs to be properly understood.

Turbidity is measured by shining a light through the water and is reported in nephelometric turbidity units (NTU). Examples of turbidity samples are presented in *Figure 16*.

Figure 16: Turbidity samples (numbers indicate NTU)
Source: USGS, 2016

Options for controlling turbidity include operational controls and engineered controls. Operational controls are measures taken by the dredger operator to reduce the impacts during dredging. These can include:

- Reducing the dredging rate;
- Changing dredging operations based on site conditions (such as tide, currents, etc.); and
- Modifying dredging operations (e.g. depth of the cutter head in the case of a CSD operation).

Engineered controls include:

- Coffer dams;
- Turbidity (silt) curtains; and
- Air bubble curtains.

With respect to engineered controls, the coffer dam solution adds considerable additional cost and is not practical if dredged material is to be transported to an offshore disposal site. Air bubble curtains are less reliable than the other options and are better suited to sites where the turbidity levels are expected to be low. The most common engineered solution is, therefore, the use of a turbidity curtain.

The use of a turbidity curtain to cordon off a large area is not a practical solution for this project as it would have an impact on the use of the navigation channel. It might be useful next to the marine reserve areas, however it should be noted that turbidity curtains are not suitable for sites that have large currents. Any requirements for controlling turbidity over a large area would, therefore, need to be implemented through operational controls.

A comparison of the turbidity generating potential of each of the dredgers being considered, and the measures that can be implemented to reduce turbidity, are presented below.

9.1.1 TSHD

TSHDs cause turbidity as a result of the intake bypass, overflow, and turbulence from the ships propeller.

The bypass system, or lean mixture overboard system (LMOS), is used to prevent water being discharged into the hopper when the sediment concentration is low (e.g. start and end of a dredging run).

Overflowing starts when the solid/water mixture reaches the overflow weir and typically continues until the hopper is sufficiently loaded with sediment. Modern TSHDs discharge the overflow at keel level rather than at water level and make use of a ‘Green valve’ to prevent air entrainment in the overflow. By preventing air entrainment and discharging the overflow as low as possible, the released overflow mixture will settle to the seabed in as efficient manner as possible. Other methods for reducing turbidity include releasing excess water close to the drag-head or reusing it as jet water in the drag-heads. It is important to note that restrictions placed on the overflow can result in reduced production rates (i.e. longer overall dredge time) and higher costs.

With respect to the turbulence generated by the ships propeller, the effect is greatest in shallow water. Means to reduce turbidity in shallow water include careful navigation (i.e. staying away from shallow water to the greatest extent practicable).

9.1.2 CSD

The cutting action of the cutter-head dislodges sediment along the seabed and is a potential cause of turbidity. Most of the material thrown into suspension at the cutter-head is however captured by the suction pipe within the cutter-head. Since this turbidity is generated at seabed level, it has less of an impact within the water column than turbidity generated at the water surface level.

The exception to this is where the CSD is cutting into (sedimentary) rock materials using its cutter teeth. In this case the grinding of the rock face can produce a significant amount of fine plumes which the suction pipe may not be able to capture effectively, especially if operating in areas of higher water currents. As a result, such operations can generate significant turbidity plumes.

Turbidity can be reduced by limiting the swing speed and revolutions of the cutter-head. This will, however, lead to reduced efficiency of the dredging process.

In the event that the material dredged using a CSD is to be pumped into barges, as opposed to pumping the material through a pipeline, another potential cause of turbidity is the overflow from the barge. Measures to reduce overflow include filling the barge to a lesser extent. This will, however, lead to reduced dredging efficiency as less material is placed in each barge.

9.1.3 BHD

BHD operations can result in relatively high turbidity when dredging silts and fine sands where a significant amount of material can be lost as the bucket is lifted through the water column. Measures to prevent losses include limiting the hoisting speed, but this negatively impacts on the production rates.

Since BHD operations are undertaken at a fixed location, the impact is generally limited to the vicinity of the dredging operation. Also, the use of a silt curtain (where possible) is often a practical solution when using a BHD and it is therefore generally easier to control turbidity with BHD operations when compared to CSD and TSHD operations.

9.1.4 Summary

Typically, CSDs generate the least turbidity, and are comparable with TSHDs when used without overflow (except in the case of rock dredging). TSHDs used with overflow and BHDs have a high potential for generating turbidity, however, it is generally easiest to control turbidity with a BHD operation.

When placing dredged material at an offshore disposal site, and assuming the same process is used when comparing all three dredging processes (i.e. placed using a barge), dredged material that has been fluidised tends to result in increased turbidity. This is due to the fluidising action of hydraulic dredgers (TSHD and CSD) resulting in sediments that take longer to consolidate than material that has been dredged mechanically (BHD) and, therefore, a higher likelihood of turbidity at the placement site.

A ranking of the various dredger types against potential for generating turbidity is provided in Table 14.

Table 14: Dredger relative ranking based on potential to generate, and control, turbidity

	TSHD	CSD	BHD
Dredge location, no mitigation measures	3	2[3]	3
Dredge location, with mitigation measures	2[1]	2[3]	1[2]
Disposal site	2	2	1[4]

Note: The lower the ranking the better (i.e. best score possible = 1)
[1] No overflow permitted.
[2] Including the use of silt curtains
[3] Assuming no rock is encountered, otherwise greater potential to generate turbidity
[4] Mechanically dredged material has slightly lower potential for generating turbidity than hydraulically dredged material

9.2 Sedimentation

Sedimentation refers to the process of sediment settling onto the seabed. Sedimentation can lead to the smothering of benthic communities, such as corals and seagrasses.

Due to the fact that it is a relatively small percentage of the dredged material that results in sedimentation at the dredge site and essentially all of the dredged material results in sedimentation at the disposal site, sedimentation is generally more of a concern at the disposal site than at the dredge site. Sedimentation at the disposal site will occur where the dredged material is disposed and can also occur at adjacent sites if there are currents present.

Sediment plume dispersion modelling is, therefore, required to determine potential sedimentation impacts. In the event that sedimentation is a risk that needs to be mitigated, a possible option includes the placing of material using a tremie, as shown in *Figure 17*., albeit that this is not practical for all disposal operations (e.g. deeper sites, higher currents/waves, will affect production).

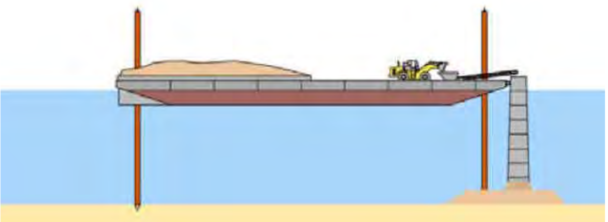

Figure 17: Placement using a barge with a tremie
Source: PIANC, 2008

9.3 Using Currents to Manage Dredging Impacts

Dredging operations can be coordinated according to tidal currents in order to minimise environmental impacts.

Turbidity is positively affected by currents in that the currents disperse the sediment that is in suspension allowing more light to penetrate to the seabed. Sedimentation is, however, negatively affected by currents in that it can lead to negative impacts on areas outside the dredge disposal site.

In order to determine whether environmental benefits can be achieved from coordinating dredging operations according to tidal currents, the following assessments are required:

- Likelihood of turbidity considering the material that will be dredged and compared against baseline monitoring, and
- Assess the areas around the proposed dredge disposal site and the risk that sedimentation would pose to these areas.

It is also worth noting that dredging operations coordinated around tidal currents inevitably lead to a longer dredging program. It is, therefore, important that the potential benefits of a coordinated dredging campaign are assessed against the impacts of a prolonged dredging program. Refer also the following section.

9.4 Spill Risk and Exhaust Emissions

Potential environmental impacts that are not directly related to dredging, but associated with the presence of a dredger include spills of oil and fuel and exhaust emissions. The longer the duration of the dredging works, the greater the risk of a spill and the greater the amount of exhaust emissions. It is noted, however, that dredging operations have improved over the years with respect to environmental awareness and that the risk of an oil or fuel spill is considered unlikely with modern professional dredging operations.

Any management plan that involves extending the project duration will create additional environmental impacts due to increased fuel consumption, exhaust emissions, prolonged disturbance, etc. The net benefit of any proposed management plan, therefore, requires careful assessment.

9.5 Noise

Dredging equipment, like any other type of construction equipment, emits noise. Dredger noise at the source can be reduced by isolation of exhaust systems and by keeping engine room doors shut. There is very little difference in the noise created by TSHD, CSD and BHD operations. The exception to this being where blasting is also required, however then the noise is attributed to blasting operations and not to the actual dredger.

Cases where dredgers have been identified as being particularly noisy are mainly due to mechanical noises (e.g. the chain drive of a bucket dredger, which is an older style of dredger no longer generally used).

The sound produced during dredging operations is largely influenced by the material type that is being dredged. The harder or more consolidated a material is, the more energy the dredger will need to apply and this translates into increased noise. The main sources of noise for each of the three types of dredging equipment being considered is presented in *Figure 18*.

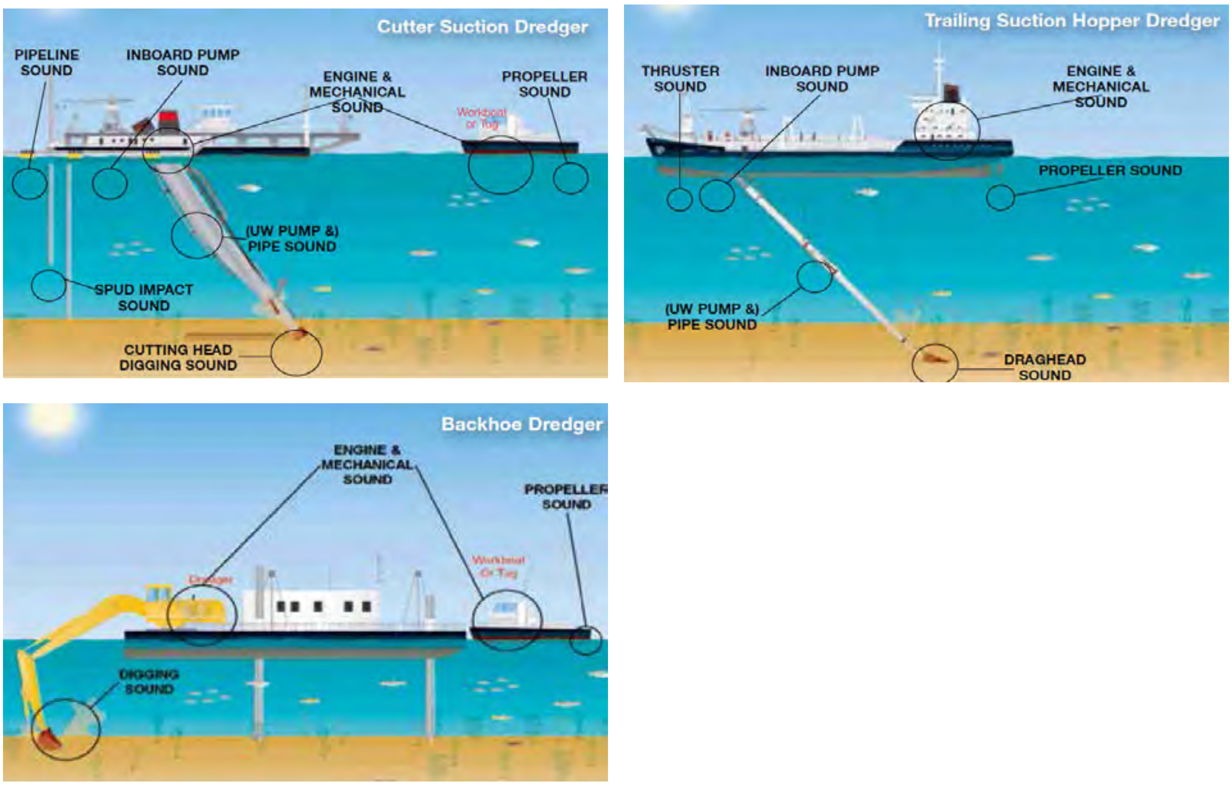

Figure 18: Potential sources of noise on dredgers
Source: WODA, 2013

A number of studies have been undertaken to determine the sound levels generated during dredging operations. Some of the results that have been published (or referenced) in various papers are presented in Table 15.

Table 15: Typical sound levels associated with dredging works

Dredger Type	Distance from Dredger (m)	Sound (dB)	Frequency (Hz)	Source
CSD	1	172 – 185	100 – 500	1
CSD	Unknown	100 – 110	70 – 1000	1
TSHD	Unknown	120 – 140	70 – 1000	1
TSHD	1	179 (peak)	Unknown	1
TSHD	Unknown	186 – 188	100 – 500	1
BHD	Unknown	179	315 (peak)	2
BHD	Unknown	163	20 – 80	2

[1] USACE, 2015 [2] WODA, 2013

It is important to note that the measurements presented in Table 15 are not standardised and that not all of the sound sources presented in *Figure 18* have been captured. It is, therefore, not possible to draw any direct comparisons. However the results do indicate that each of the three dredging equipment being considered are likely to produce sounds that are of the same order of magnitude. The conclusion therefore is that all three should be considered equal when assessing likely impact due to noise.

The sound levels generated by dredging should also be taken in context of other biological and manmade sound sources which may exist at the time of the works, CEDA (2011) provides a number of these, as shown in Table 15, which places the dredging operations at source levels lower than, for example, harbour porpoise clicks and large vessel shipping operations.

Table 16: An overview of biological and manmade sound sources listed in decreasing order of source levels at 1m (CEDA, 2011).

Sources: 1). Review by OSPAR 2009; 2). Review by Thomsen et al. 2011; 3). Zimmer 2004; 4). Møhl et al. 2003; 5). Villadsgaard et al. 2007; 6). Review by Thomsen et al. 2009; 7). Review by Robinson et al. 2011; 8). Au & Banks 1998.

Sounds in the aquatic environment						
Sound source	**Source level at 1m**	**Bandwidth**	**Main energy**	**Duration**	**Directionality**	**Source**
Explosives	272dB-287dB re 1µPa zero-to-peak	2Hz-~1kHz>	6Hz-21Hz	~1ms	Omni-directional	1)
Seismic air gun arrays	220dB-262dB re 1µPa peak- to-peak	5Hz-100kHz	10Hz-120Hz	10ms-100ms	Downwards	2)
Pile driving	220dB-257dB re 1µPa peak-to-peak	10Hz >-20kHz	100Hz-200Hz	5ms-100ms	Omni-directional	1), 2)
Echosounders	230dB-245dB re 1µPa rms	11.5kHz-100kHz	Various	0.01ms-2ms	Downwards	2)
Low-frequency military sonar	240dB re 1µPa peak	0.1kHz-0.5kHz	-	6s-100s	Horizontally focussed	3)
Sperm whale click	236dB re 1µPa rms	5kHz-40kHz	15kHz	100µs	Directional	4)
Mid-frequency military sonar	223dB-235dB re 1µPa peak	2.8kHz-8.2kHz		0.5s-2s	Horizontally focussed	1)
Sparkers, boomers, chirp sonars	204-230 dB re 1µPa rms	0.5-12kHz	Various	0.2ms	Downwards	2)
Harbour porpoise click	205dB re 1µPa peak-to-peak	110kHz-160kHz	130kHz-140kHz	100µs	Directional	5)
Shipping (large vessels)	180dB-190dB re 1µPa rms	6Hz >-30kHz	<200Hz	Continuous	Omni-directional	1)
TSHD	186dB-188dB re 1µPa rms	30Hz>-20kHz	100Hz-500Hz	Continuous	Omni-directional	6), 7)
Snapping shrimp	183dB-189dB re 1µPa peak-to-peak	<2kHz-200kHz	2kHz-5kHz	Milliseconds	Omni-directional	8)
CSD	172dB-185dB re 1µPa rms	30Hz>-20kHz	100Hz-500Hz	Continuous	Omni-directional	6), 7)
Construction and maintenance ships	150dB-180dB 1µPa rms	20Hz-20kHz	<1kHz	Continuous	Omni-directional	1)
Drilling	115dB-117dB re 1µPa (at 405m and 125m)	10Hz-~1kHz	<30Hz-60Hz	Continuous	Omni-directional	1)

9.6 Navigation Risk

Dredging operations present a potential navigation risk, particularly when working in existing navigable waterways.

TSHD operations present a similar threat to normal shipping, in that the vessel is sailing whilst dredging. It is, therefore, relatively easy for a vessel to avoid passing a TSHD in high risk sections of the channel (e.g. channel bends) by timing its approach. The vessel that wants to pass could also wait for the TSHD to complete a filling cycle and to leave the channel before proceeding through the channel. This may result in a relatively short delay, but ensures safe navigation.

The CSD and BHD operations require that the equipment drops one or more spuds and may also require anchor lines, particularly in the case of a CSD, to be deployed. This creates a fixed obstacle in the navigation channel that other vessels need to navigate past. Waiting for the dredger to move may not be a practical solution as the dredger may stay in one area for an entire day (or longer). CSD and BHD operations generally also require the use of barges, which present additional navigation hazards.

There are numerous steps that can be taken to reduce navigation hazard risk, including:

- Issue notice to mariners regarding dredging operations;
- Additional temporary navigation aids;
- Ensuring dredging plant is included in local vessel traffic service (VTS) monitoring; and
- Adequate lighting at night.

9.7 Constrained Working Space

Sometimes it is necessary for dredging works to be undertaken at a site that has a constrained working space available. An example is: dredging alongside a quay or jetty structure.

TSHDs are not suitable for dredging in a constrained working space. The TSHD needs to be able to manoeuvre safely and therefore a safe distance between the dredger and the structure must be maintained. The recommended horizontal tolerance for a TSHD is 2.0 to 2.5m (in general).

CSDs are a better option when dredging in a constrained working space and have a recommended horizontal tolerance of 0.5m (in general). The use of a CSD to carry out dredging alongside a quay or jetty structure is however not considered normal practice and, therefore, not generally recommended.

BHDs provide the best solution when dredging in a constrained working space and have a recommended horizontal tolerance of 0.25m (in general). BHDs are therefore commonly used for carrying out maintenance dredging alongside a quay or jetty.

10 Indicative Dredging Costs and Dredging Program

For the purposes of estimating costs and dredge duration, the following volumes have been assumed:

Berth pocket:	82,000m^3
Inner section:	461,000m^3
Mid section:	54,000m^3
Outer section:	2,812,000m^3

These volumes include 50% of the overdredge volume (see Table 6 and Table 7).

Based on the volumes presented above, an indicative cost estimate and dredging program has been determined for the following scenarios (for the Option 4-2 channel design):

Base Case Scenarios

A1) Dredging is undertaken using a BHD (5m^3 bucket) and a TSHD (2,900m^3 hopper). The BHD is used to dredge the material at the berth pocket and the TSHD is used to dredge the rest. All dredged material is disposed at the offshore disposal site. The material dredged using the BHD is disposed of using barges. The offshore disposal site is assumed to be within 10km of the project site.

A2) As per scenario A1, except TSHD has a 6,000m^3 hopper capacity.

A3) As per scenario A1, except TSHD has a 11,000m^3 hopper capacity.

Reclamation Scenarios

B1) Dredging is undertaken using a BHD (5m^3 bucket) and a TSHD (2,900m^3 hopper). The BHD is used to dredge the material at the berth pocket and the TSHD is used to dredge the rest. All material dredged from the inner and mid sections (597,000m^3) is to be placed in NorthPort's consented Berth 4 reclamation. Actual reclamation volumes to be confirmed should this consented reclamation option be progressed.
All material dredged in the outer section (2,812,000m^3) is to be disposed at the offshore disposal site. The material dredged using the BHD is disposed of using barges. The offshore disposal site is assumed to be within 10km of the project site.

B2) As per scenario B1, except TSHD has a 6,000m^3 hopper capacity.

B3) As per scenario B1, except TSHD has a 11,000m^3 hopper capacity.

The indicative dredging cost and program for each scenario, as presented in Table 17 and Table 18, are rough order of magnitude (ROM) numbers. These costs are not intended for budgeting purposes, but rather as an indication of how the various scenarios compare in terms of cost. Likewise the durations presented should not be used for developing a project program, but instead used as an indication of how the various scenarios compare in terms of duration.

Table 17: Indicative production rates and dredging costs – offshore disposal options

Scenario	Dredging Equipment	Disposal Scenario	Indicative Cost (NZ$)	Program (weeks)
A1	BHD + TSHD (2,900m^3)	All offshore	Mob/demob [1]: 3.5 million	2
			Dredging: 33.5 million	22
			Total: 37.0 million	**24**
A2	BHD + TSHD (6,000m^3)	All offshore	Mob/demob [1]: 4.0million	2
			Dredging: 32.0 million	16
			Total: 36.0 million	**18**
A3	BHD + TSHD (11,000m^3)	All offshore	Mob/demob [2]: 15.0 million	5
			Dredging: 29.0 million	7
			Total: 44.0 million	**12**

[1] *Based on mobilisation from Brisbane, Australia*
[2] *Based on mobilisation of TSHD from Middle East*
[3] *Program duration for 'mob/demob' is for mobilisation only.*

Table 18: Indicative production rates and dredging costs – reclamation and offshore disposal options

Scenario	Dredging Equipment	Disposal Scenario	Indicative Cost (NZ$)	Program (weeks)
B1	BHD + TSHD (2,900m^3)	Reclamation & offshore	Mob/demob [1]: 3.5 million	2
			Dredging: 35.5 million	24
			Total: 39 million	**26**
B2	BHD + TSHD (6,000m^3)	Reclamation & offshore	Mob/demob [1]: 4.0million	2
			Dredging: 32.5 million	16
			Total: 36.5 million	**18**
B3	BHD + TSHD (11,000m^3)	Reclamation & offshore	Mob/demob [2]: 15.0 million	6
			Dredging: 31.0 million	8
			Total: 46.0 million	**14**

[1] *Based on mobilisation from Brisbane, Australia*
[2] *Based on mobilisation of TSHD from Middle East*
[3] *Program duration for 'mob/demob' is for mobilisation only.*

Notes:

1. The indicative costs presented above are based on a total dredge volume of approximately 3.4Mm^3 (i.e. including 50% over dredge).
2. Scenarios B1, B2 and B3 exclude mobilising / demobilising of pipelines and other landside reclamation costs.
3. The base assumptions used in determining the costs and dredge durations are as follows:
   i) 24-hour dredging operations
   ii) Dredging is carried out during all tidal conditions

The estimated dredge cycle for each of the scenarios presented above is provided in Table 19.

Table 19: Dredging cycle for each scenario considered

Dredger & Hopper Capacity	Cycle time to offshore disposal site (min)			Cycle time to reclamation site (min)	
	Inner section	Mid section	Outer section	Inner section	Mid section
TSHD Brisbane (2,900m^3)	L = 54 T = 10 S = 37 D = 10 R = 31 **T = 142**	L = 54 T = 10 S = 31 D = 10 R = 27 **T = 132**	L = 54 T = 10 S = 19 D = 10 R = 17 **T = 110**	L = 54 T = 10 S = 8 D = 119 R = 6 **T = 196**	L = 54 T = 10 S = 14 D = 119 R = 11 **T = 208**
TSHD Balder R (6,000m^3)	L = 113 T = 10 S = 29 D = 10 R = 27 **T = 189**	L = 113 T = 10 S = 24 D = 10 R = 23 **T = 180**	L = 113 T = 10 S = 15 D = 10 R = 14 **T = 162**	L = 113 T = 10 S = 6 D = 78 R = 5 **T = 212**	L = 113 T = 10 S = 10 D = 78 R = 9 **T = 220**
TSHD Volvox Asia (11,000m^3)	L = 82 T = 10 S = 29 D = 10 R = 27 **T = 158**	L = 82 T = 10 S = 24 D = 10 R = 23 **T = 149**	L = 82 T = 10 S = 15 D = 10 R = 14 **T = 131**	L = 82 T = 10 S = 6 D = 116 R = 5 **T = 219**	L = 82 T = 10 S = 10 D = 116 R = 10 **T = 228**

L = loading / dredging, T = turning, S = sailing (full), D = dumping / discharge, R = returning (empty), T = total

It is noted that although the TSHD Volvox Asia has a larger hopper capacity than the TSHD Balder R, the loading / dredging time is shorter due to the larger diameter dredge pipes and higher production rate.

See also alternative dredge and disposal scenarios presented in Appendix C.

11 Overall Assessment

This technical note has presented several alternate methodologies for executing the dredging works. The dredging plant considered includes Trailing Suction Hopper Dredger (TSHD), Cutter Suction Dredger (CSD), and Backhoe Dredger (BHD). Each of the dredging plant considered has been assessed in terms of operational constraints, environmental constraints, and economic and program considerations. Table 20 provides a summary of the assessment carried out in the form of a proposed relative ranking (the lower the ranking, the better the option being considered).

Table 20: Assessment of alternatives – Relative ranking

Assessment Criteria	TSHD	CSD	BHD
Capable of dredging all material expected along:			
- Shipping channel – Option 2	Yes	Yes	Yes
- Shipping channel – Option 4-2	Yes	Yes	Yes
- Shipping channel – Option 5 (Inner channel)	Yes	Yes	Yes
- Shipping channel – Option 5 (Mid channel)	No [1]	No [2]	Possibly [3]
- Shipping channel – Option 5 (Outer channel)	Yes	Yes	Yes
Suitable for dredging berth pocket (i.e. working within a constrained area)	No	Possibly	Yes
Ranking with respect to potential downtime due to wind, waves and current			
- Small dredging plant	3	6	=4
- Medium to large dredging plant	1	=4	2 [4]
Potential to generate turbidity:			
- At the dredge location (no mitigation measures)	3	2 [5]	3
- At the dredge location (with mitigation measures)	2	2 [5]	1
- At the disposal site	2	2	1 [6]
Expected noise:			
- Channel Options 2 and 4-2	1	1	1
- Channel Option 5 (rock excavation / drilling and blasting may be required)	3	3	3
Potential navigation risk to other vessel	1	3	2
Relative cost	1	2	6
Relative program (i.e. overall duration of dredging works)	1	1	7

Notes:
The lower the ranking the better (i.e. best score possible = 1)
[1] Option 5 includes the removal of large boulders and rock at Home Point which the TSHD cannot remove.
[2] The CSD would not be able to remove the large boulders. It may be able to remove the rock, provided that it is not of excessive strength (typically less than 50 MPa)
[3] The BHD can remove the boulders but may not be able to remove the rock unless it is weathered, and/or fractured and/or prior drilling and blasting
[4] The need for relocating in adverse conditions can make this option worse than using a small TSHD
[5] Assuming no rock is encountered, otherwise greater potential to generate turbidity
[6] Mechanically dredged material has slightly lower potential for generating turbidity than hydraulically dredged material

Based on the assessment presented in this report, the use of a TSHD to dredge the shipping channel and the use of a BHD to dredge the berth pocket is considered to be the preferred dredging methodology. This assessment is applicable to Channel Options 2 and 4-2.

In the event that Channel Option 5 is adopted, a TSHD will not be suitable for removing the boulders and dredging the harder material found near Home Point. This material would need to be removed using a BHD, with the possibility of drilling and blasting should any solid rock prove too difficult to remove with the BHD alone.

Should dredge material be required to fill the Northport reclamation area, there are means for both the TSHD and BHD to undertake this work, however, the most efficient method for doing this type of work would be to use a CSD.

Hence, the ultimate dredging methodology is very sensitive to: the quantity and type of material to be dredged; the location and nature of the disposal site; and any working limiting conditions of the site (waves, currents, ship draft, etc.).

This report has focused on the technical aspects associated with the dredging works. It is acknowledged that there are additional factors, such as a more extensive review of environmental impacts, which would need to be taken into consideration when selecting the preferred dredge methodology.

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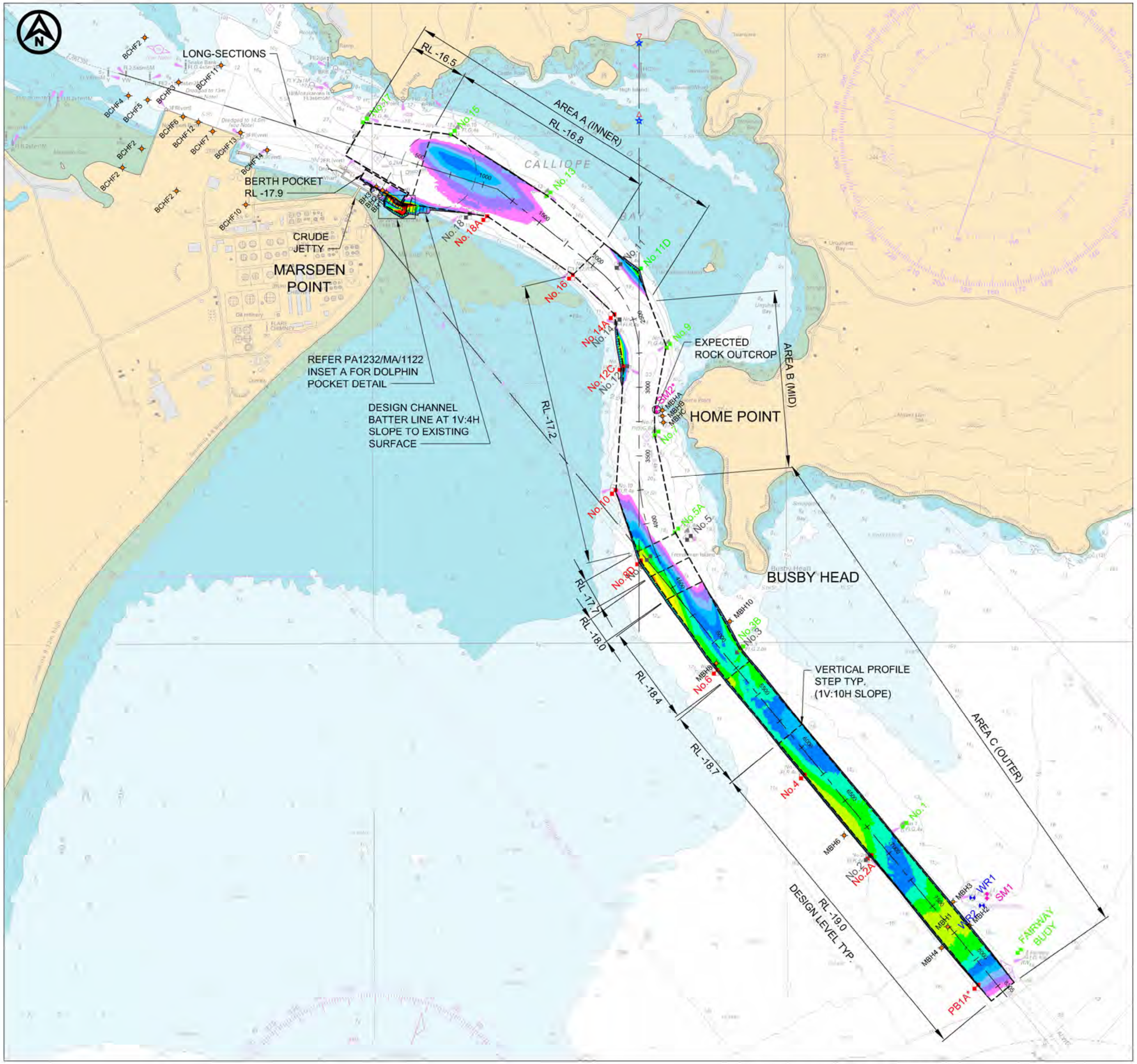
Appendix A – Channel Design Option Drawings

Drawing No	Rev	Title	Subtitle
PA1028/MA/1123	A	Channel Design Option 4-2, Dredge Footprint	16.6m Draft Vessel, 98% Access, 1V:4H Channel Batter
PA1028/MA/1203	A	Channel Design Option 2, Dredge Footprint	16.6m Draft Vessel, 98% Access, 1V:4H Channel Batter
PA1028/MA/1302	A	Channel Design Realignment	Option 5 Dredge Footprint

PA1028–MA–1123 **DO NOT SCALE**



PLAN - DREDGE FOOTPRINT
1:15,000 (A1)

DREDGING QUANTITIES

AREA	DREDGING VOLUME, TO DESIGN LEVEL (m³)	DREDGING VOLUME, INCLUDING OVERDREDGING (m³)
AREA A (OUTER)	2,652,000	2,971,000
AREA B (MID)	50,000	57,000
AREA C (INNER)	476,000	610,000
TOTAL	3,177,000	3,638,000

LEGEND:

- DESIGN TOE LINE
- DESIGN CHANNEL CENTRELINE
- PROPOSED RELOCATED BUOYS (e.g. No. 11A)
- STARBOARD BUOYS
- PORTSIDE BUOYS
- WAVERIDER BUOYS
- SPECIAL MARK BUOYS
- EXISTING BUOYS TO BE RELOCATED
- HISTORICAL BOREHOLES (e.g. MBH1) (HAWTHORN, 2009) (e.g. BCHF1) (BCHF, 1992-1993)

DREDGED DEPTH BELOW EXISTING SURFACE (m):

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- 5.0 - 5.5
- 5.5 - 6.0
- 6.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- 10.0 - 11.0

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. DREDGING DESIGN LEVELS VARY ALONG CHANNEL AND ARE BASED ON AN APPROXIMATION OF THE 98% ACCESS PROFILE FOR 16.6m VESSEL DRAFT DEVELOPED BY OMC (2015) TO DEFINE DECLARED DEPTHS. ADDITIONAL ALLOWANCES HAVE BEEN ADDED FOR SILTATION TO DETERMINE DREDGING DESIGN LEVELS.
5. DREDGING ALLOWANCES:
   a. A SILTATION ALLOWANCE OF 0.5m (OUTER HARBOUR) AND 0.3m (INNER HARBOUR) HAS BEEN ADOPTED WITH THE OUTER HARBOUR DEFINED AS BEING OFFSHORE OF BUOY No. 5.
   b. AN OVERDREDGING ALLOWANCE OF 0.3m HAS BEEN APPLIED TO ESTIMATE DREDGING VOLUMES.

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m
1:15000 (A1) 1:30000 (A3)

20 0 20 40 60 80 100m
1:1000 (A1) 1:2000 (A3)

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	02.12.15	REVISED FROM 95% ACCESS	BAM	RM	

REVISIONS

CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN OPTION 4–2 DREDGE FOOTPRINT
16.6m DRAFT VESSEL, 98% ACCESS
1V:4H CHANNEL BATTER

HASKONING AUSTRALIA PTY LTD
SYDNEY

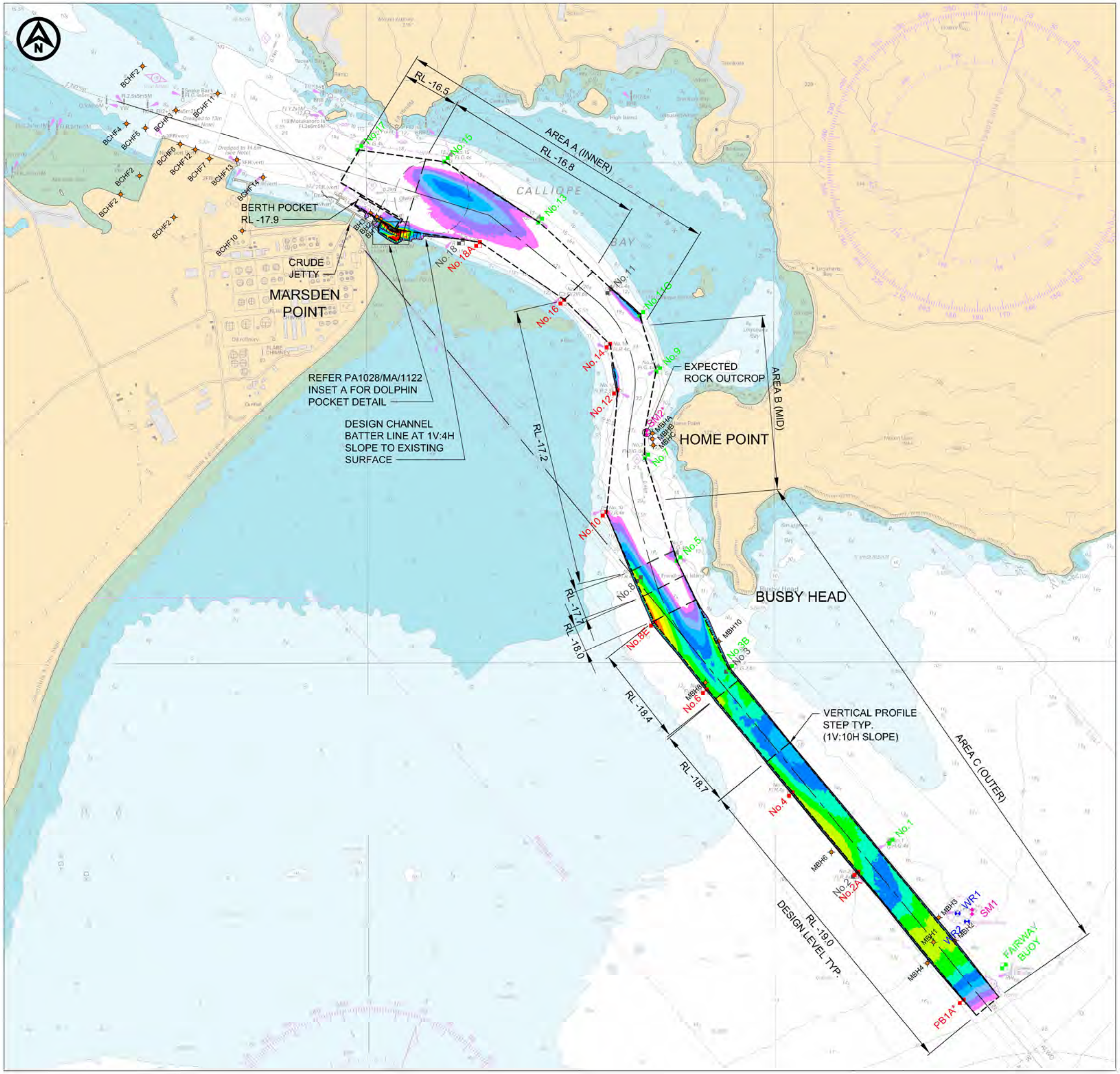
DRAWN BAM | DATE 02/12/2015 | JOB No. PA1028

AUTOCAD REF. PA1028–MA–OP4–2H–98%

SCALE AT A1 AS SHOWN

DRAWING No. PA1028/MA/1123 | REVISION A

PA1028/MA/1203 **DO NOT SCALE**



DREDGING QUANTITIES

AREA	DREDGING VOLUME, TO DESIGN LEVEL (m³)	DREDGING VOLUME, INCLUDING OVERDREDGING (m³)
AREA A (OUTER)	2,689,000	3,016,000
AREA B (MID)	8,000	10,000
AREA C (INNER)	456,000	588,000
TOTAL	3,153,000	3,614,000

LEGEND:

- DESIGN TOE LINE
- DESIGN CHANNEL CENTRELINE
- PROPOSED RELOCATED BUOYS (e.g. No. 11A)
- STARBOARD BUOYS
- PORTSIDE BUOYS
- WAVERIDER BUOYS
- SPECIAL MARK BUOYS
- EXISTING BUOYS TO BE RELOCATED
- HISTORICAL BOREHOLES (e.g. MBH1) (HAWTHORN, 2009) (e.g. BCHF1) (BCHF, 1992-1993)

DREDGED DEPTH BELOW EXISTING SURFACE (m):

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
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- 6.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- 10.0 - 11.0

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. DREDGING DESIGN LEVELS VARY ALONG CHANNEL AND ARE BASED ON AN APPROXIMATION OF THE 98% ACCESS PROFILE FOR 16.6m VESSEL DRAFT DEVELOPED BY OMC (2015) TO DEFINE DECLARED DEPTHS. ADDITIONAL ALLOWANCES HAVE BEEN ADDED FOR SILTATION TO DETERMINE DREDGING DESIGN LEVELS.
5. DREDGING ALLOWANCES:
   a. A SILTATION ALLOWANCE OF 0.5m (OUTER HARBOUR) AND 0.3m (INNER HARBOUR) HAS BEEN ADOPTED WITH THE OUTER HARBOUR DEFINED AS BEING OFFSHORE OF BUOY No. 5.
   b. AN OVERDREDGING ALLOWANCE OF 0.3m HAS BEEN APPLIED TO ESTIMATE DREDGING VOLUMES.

CHART DATUM

NOT FOR CONSTRUCTION

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REV	DATE	DESCRIPTION	BY	CHK	APPD
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REVISIONS

CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN OPTION 2 DREDGE FOOTPRINT **16.6m DRAFT VESSEL, 98% ACCESS 1V:4H CHANNEL BATTER**

HASKONING AUSTRALIA PTY LTD SYDNEY

DRAWN BAM | DATE 02/12/2015 | JOB No. PA1028

AUTOCAD REF. PA1028-MA-OP2D-98%

SCALE AT A1 1:15000

DRAWING No. PA1028/MA/1203 | REVISION A

\\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1028 REFINING NZ CAD\E11
WORKING DRAWINGS\PA1028-MA-OP2D-98%.DWG 12/2/2015 6:01 PM

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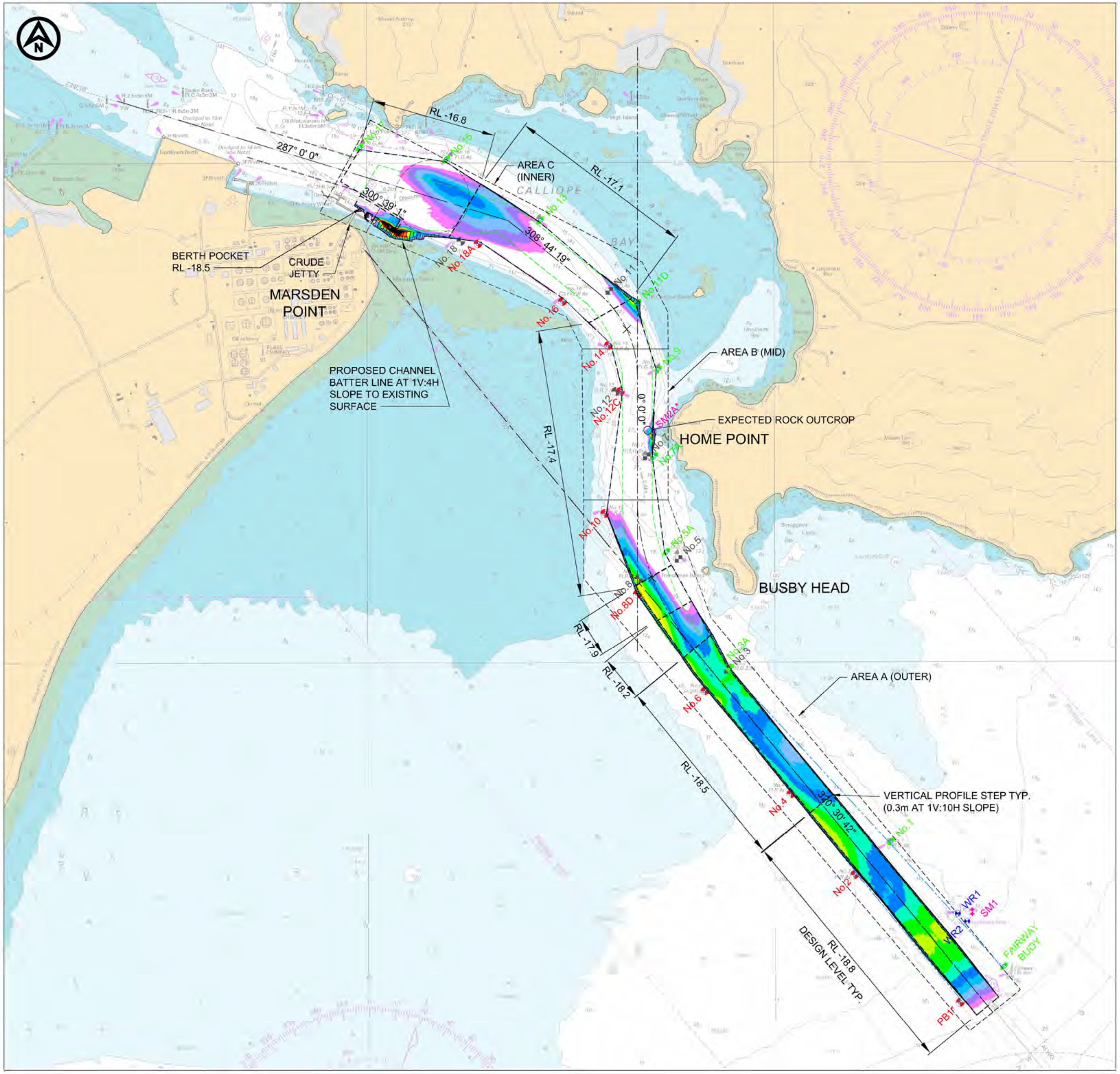

DREDGING QUANTITIES

AREA	DREDGING VOLUME, TO DESIGN LEVEL (m³)	DREDGING VOLUME, INCLUDING OVERDREDGING (m³)
AREA A (OUTER)	2,400,000	2,710,000
AREA B (MID)	21,000	25,000
AREA C (INNER)	558,000	704,000
TOTAL	2,979,000	3,439,000

LEGEND:

- PROPOSED CHANNEL TOE LINE
- DESIGN CHANNEL TOE LINE
- BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)
- STARBOARD BUOYS
- PORTSIDE BUOYS
- WAVERIDER BUOYS
- SPECIAL MARK BUOYS
- EXISTING BUOYS TO BE RELOCATED AND PREVIOUS REVISIONS
- RELOCATED BUOYS (e.g. No. 11A)

DREDGED DEPTH (m):

0.0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5
3.5 - 4.0
4.0 - 4.5
4.5 - 5.0
5.0 - 5.5
5.5 - 6.0
6.0 - 7.0
7.0 - 8.0
8.0 - 9.0
9.0 - 10.0
10.0 - 11.0

NOTES:

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2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. DREDGING DESIGN LEVELS VARY ALONG CHANNEL AND ARE BASED ON AN APPROXIMATION OF THE 95% ACCESS PROFILE FOR 16.8m VESSEL DRAFT DEVELOPED BY OMC (2014) TO DEFINE DECLARED DEPTHS. ADDITIONAL ALLOWANCES HAVE BEEN ADDED FOR SILTATION TO DETERMINE DREDGING DESIGN LEVELS.
5. DREDGING ALLOWANCES:
   a. A SILTATION ALLOWANCE OF 0.5m (OUTER HARBOUR) AND 0.3m (INNER HARBOUR) HAS BEEN ADOPTED WITH THE OUTER HARBOUR DEFINED AS BEING OFFSHORE OF BUOY No. 5.
   b. AN OVERDREDGING ALLOWANCE OF 0.3m HAS BEEN APPLIED TO ESTIMATE DREDGING VOLUMES.

CHART DATUM

NOT FOR CONSTRUCTION

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1:15000 (A1) 1:30000 (A3)

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	10.09.15	DRAFT FOR REVIEW	BAM	MP	

REVISIONS

CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ Your Energy Hive

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN REALIGNMENT OPTION 5 DREDGE FOOTPRINT

HASKONING AUSTRALIA PTY LTD SYDNEY

Royal HaskoningDHV Enhancing Society Together

DRAWN BAM | DATE 10/09/2015 | JOB No. PA1028

AUTOCAD REF. PA1028–MA–OP5A–DESIGN LEVEL

SCALE AT A1 1:15000

DRAWING No. PA1028–MA–1302 REVISION A

Appendix B – Dredging Equipment Technical Specifications

BRAGE R

Brage R working in Gijon, Spain, dredging in total 3,080.000 m3 of which 1.930.000 m3 was precision works filling caissons

BRAGE R

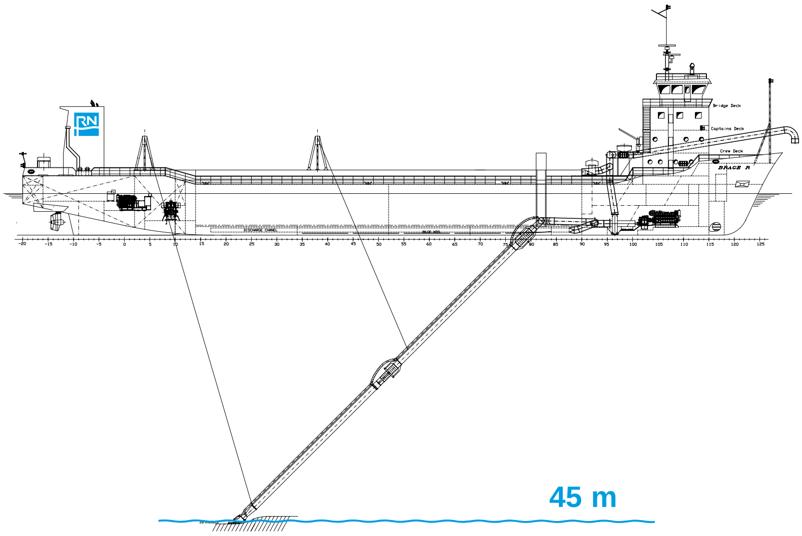
The Brage R is a very efficient gravel dredger able to screen the material on the winning area, bringing only the highest quality ashore.

The very square hopper of the Brage R also gives an advantage and high efficiency in maintenance dredging as the material will settle well, why lesser over flow will occur. This is appreciated as an environmental management tool.

The hopper load is discharged by pumping either over the bow using the rainbow method or through a pipe line more than 1500 meter long or by dumping using the 18 bottom doors.

The Brage R has for its size an impressive dredging depth of 45 m which makes her a very attractive tool on smaller jobs with demanding dredging depths. These demands are often seen on harbour development projects as well as shallow water beach nourishment projects.

The Brage R is equipped with the latest technology for navigation and dredging.



Principal Dimensions

Gross tonnage	2176	GT
Length overall	89.59	m
Breadth	13.60	m
Draught loaded	5.69	m
Draught unloaded	3.47	m
Hopper capacity	2150	m3
Main engines	1492	kW
Bow thruster	235	kW
Pump ashore power	1230	kW
Total installed power	4480	kW
Speed empty	9.0	Knots
Speed Loaded	7.5	Knots
Crew	7	
Flag		Dutch
Class		Germanischer Lloyd

Nordic mythology

Brage is the god of poetry. He plays the harp all day and is greatly admired for his inspiration and eloquence with words. He is very wise and silver-tongued. Brage is the son of Odin, and he is married to Idun, the keeper of the golden apples of youth.

ROHDE NIELSEN A/S • Nyhavn 20 • DK-1051 Copenhagen K.
Phone +45 33 91 25 07 • Fax +45 33 91 25 14 • E-mail: mail@rohde-nielsen.dk • www.rohde-nielsen.dk

THE LATEST TECHNOLOGY AT YOUR FINGERTIPS

The trailer hopper suction dredger "Brisbane" is an impressive hi-tech vessel owned and operated by the Port of Brisbane Corporation and commissioned in 2001. The dredger is available to carry out development and maintenance works anywhere in Australia, and is also capable of operating in international waters.

The dredger is equipped with the latest state of the art dredge automation control and navigation systems. The hopper capacity is 2,900m^3 and dredge material can be pumped ashore or disposed of at sea through bottom dump valves.

The pumping system consists of 2 x 750kw Warman pumps, capable of pumping dredge material at least 1500 metres from the mooring location. The shore disposal operation can be at berth or from a mooring through a floating pipeline.

Environmentally, the vessel is also at the leading edge with features including a low turbidity hopper loading system and under keel discharge of overflow waters through an anti-turbidity valve. The hopper can also be pumped dry to maximise efficiency in the non-overflow dredging mode.

THE "BRISBANE" SPECIFICATIONS

Type of vessel:	Twin screw trailing hopper suction dredger
Classification:	Lloyd's Register +100 A1 +LMC UMS TM Hopper Dredger
Owner:	Port of Brisbane Corporation
Designer/builder:	NQEA Australia
Length overall:	84.10 metres
Length, waterline:	81.70 metres
Beam:	16.00 metres
Draft:	(maximum) 6.25 metres (minimum) 3.0 metres
Displacement:	5,890 tonnes at 5.50 metres draft
Main engines:	2 x Caterpillar 3606 DITA @ 1850kw
Propulsion:	2 x variable pitch propellers with nozzles
Bow thruster:	1 x 310kw
Dredge pumps:	2 x Warman 28/24 @ 750kw each
Jet water pumps:	2 x Warman 10/8 @ 310kw each
Dredging depth:	25 metres
Hopper capacity:	2,900m^3
Maximum cargo:	4206 tonnes
Maximum speed:	13 knots
Maximum speed, fully loaded:	11 knots
Discharge:	Pump ashore by bow coupling or bottom dump
Crewing:	13

BALDER R and NJORD R

ROHDE NIELSEN A/S • Nyhavn 20 • DK-1051 Copenhagen K.
Phone +45 33 91 25 07 • Fax +45 33 91 25 14 • E-mail: mail@rohde-nielsen.dk • www.rohde-nielsen.dk

The first generation of the RN-6000 Maste Class

BALDER R and NJORD R

The first generation of the RN-6000 Maste Class.

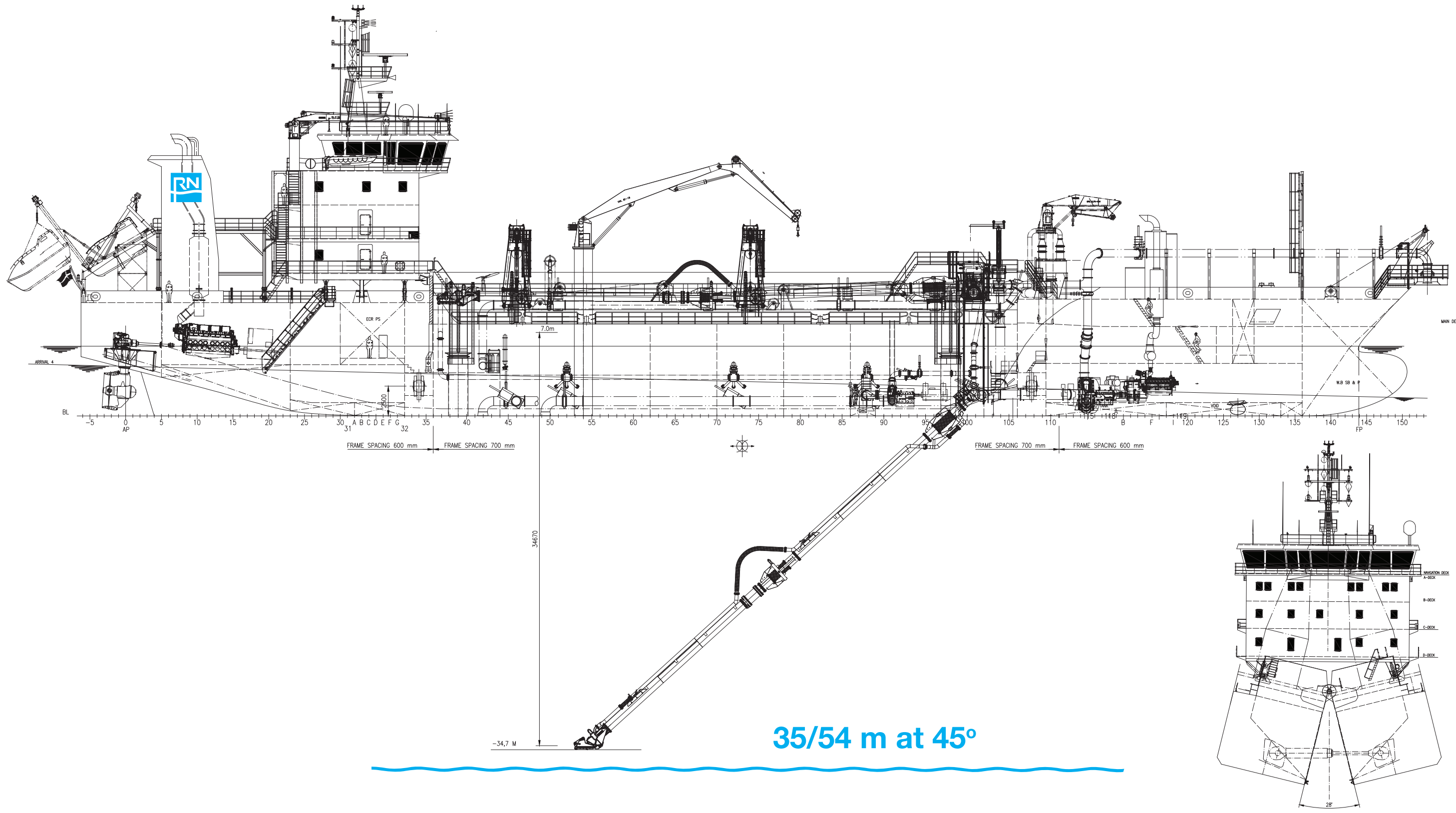
The new Rohde Nielsen vessels are slender split hopper suction trailers built for operating worldwide. Probably the biggest and most versatile split hopper suction trailers ever built!

The load can be dumped quicker by split rather than by single hull dredgers, whether it is material from maintenance dredging in sands, sticky clay or other types of soil characteristics. When placing a load of sand for shoreface nourishment, this can be done very precisely and with high compaction by split dumping, which is a method required more and more.

The new buildings are state of the art vessels, specially designed for operation in shallow waters, ideal both for the maintenance of fairways and harbours, beach replenishment and land reclamation projects. In order to optimize capital dredging, and especially maintenance dredging, a trailer dredger with two dredge pipes is often a must. Our new vessels are equipped as two dredgers in one with double loading and discharge pumping systems which can work in parallel or in series. Together with onboard crane facilities and fully equipped workshops, standing time is minimised, which is vital when working world wide and in areas where land support facilities are often not available. With very high efficienc , relativly low energy consumption and very high number of workable days, the vessels will outperform the competition.

Each of the two dredge pipes has an inner diameter of 700 mm which in total gives a volume area equal to one pipe of 990 mm.This compares more than favourably with similar dredgers of equal volume capacity. Specially designed heavy-duty drag heads are available for hard soil.

The hopper load can be discharged by backpumping to the sea bed or into a trench through the suction pipe, over the bow as rainbowing approximately 150 m or through the bow connection to a pipe line of ND600/700/800º up to a distance of approximately 4 km.



The design has been produced based on some 40 years of practical experience combined with the most up to date dredging technology and environmental requirements. The improved hydrodynamic design with a relatively slim hull gives a fuel reduction of 20% compared with a standard wide body single hull dredger and all engines will fulfi the latest IMO and TIER2-standards. The rudder-propellers and the hopper sealing can be exchanged afloat. No dry docking is required. If in dry dock our newly developed hopper sealing can also be exchanged without splitting the hulls.

With a powerful bow thruster and two rudder-propellers the vessels are extremely manoeuvrable allowing dynamic positioning.

All equipment is delivered with the technology of the future from leading suppliers within the dredging industry and to the highest standard and quality.

In 1989 Rohde Nielsen A/S invented the first one-man-operated bridge with the Viking R. To optimize this feature, the accommodation and bridge are placed aft, giving maximum 360º view over the entire vessel and surroundings. The bridge wings are closed giving protected and optimal working conditions under the various climatic environments envisaged.

Technical data

Gross tonnage	5189	GT
Length overall	111,30	m
Breadth	19,40	m
Draught loaded	7,00	m
Draught unloaded	3,70	m
Hopper capacity:	6000	m3
Main engines:	2 x 2985	kW
Bow thruster:	2 x 450	kW
Pump ashore power:	2 x 2117	kW
Total installed power:	10504	kW
Speed empty:	15,3	kn
Speed loaded:	14,0	kn
Crew:	7-14	
Flag:	Danish	
Class:	Bureau Veritas	

All the vessels in Rohde Nielsen A/S fleet have names f om the Nordic Mythology, where the Vikings of Scandinavia had ocean going ships, which were fast, long and slender.

The Danish sea faring tradition was founded by the Vikings who were known to be skilled and fearless sea farers.

Balder: *The wisest of all gods. Considered the god of light, joy, spring and beauty. The tiny silver horseman is said to be Balder as warrior.*

Njord: *Frigg's brother. God of sea, weather, wind and fi e, and therefore very close to the fishermen and sea fa ers.*

Volvox Asia

General properties

IMO number: 9174737
MMSI number: 244517000
Callsign: PFBG
Vessel type: TSHD
Flag: NL
Owner: Van Oord NV
Manager: Van Oord NV
Built in: 1998
Shipyard: Hyundai Heavy Industries Co. Ltd.
Yard number: 812

Physical properties

Length (OA): 133.93 m
Length (BP): 127 m
Width: 26.04 m
Depth: 11 m
Draft (loaded): 9.47 m
Engine specs: MAN B&W 32-40, 4-stroke , 18 cyl's, 720 rpm
Speed (loaded): 15 knts
Total power: 21453 kW
Hopper volume: 10834 m³
Dredging depth: 35 m
Suction pipe diameter: 1.1 m
Number of dredging pipes: 2

Page review

Status: Active

Last Updated

2 years 31 weeks ago

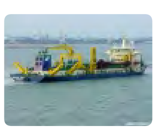
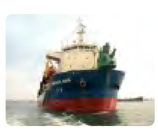
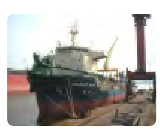
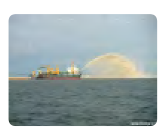
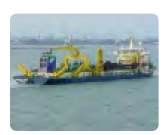
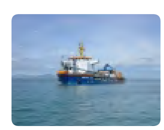
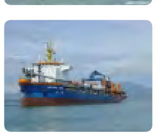
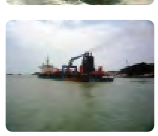
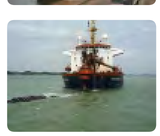
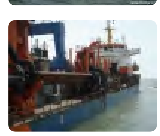
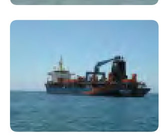
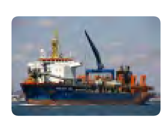
History

Timeframe	Equipment	Manager	Review
1998 - 2002	Goryo Ho No 5	HEC - Hyundai Engineering & Construction Co Ltd	original build
2002	Volvox Asia	Van Oord Nederland BV	sold and renamed

About this equipment

Extended dredging pipe installation is removed during drydocking 2009. Max. dredging depth is 35 m.

Images

Technical files and datasheets

Files are available for users with a professional account.

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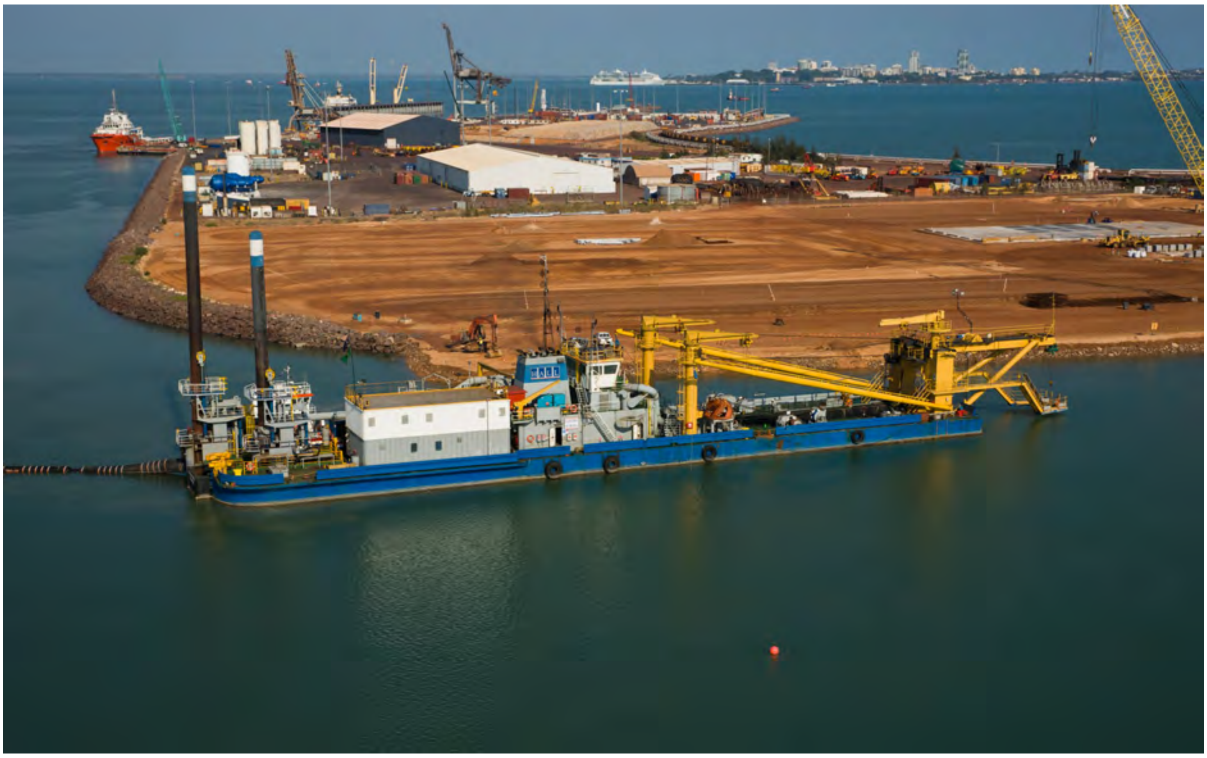
EASTERN AURORA

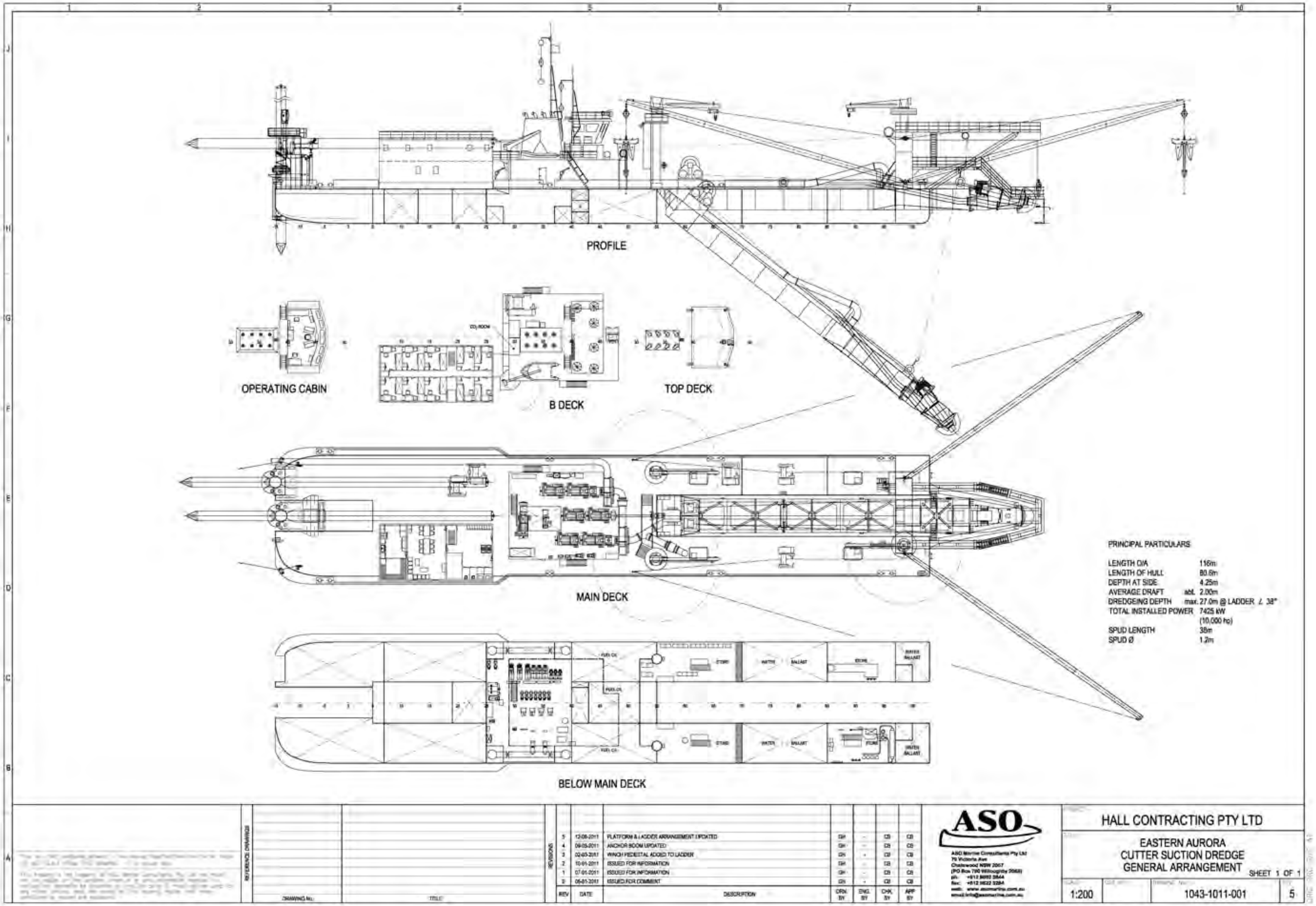
IHC CUTTER SUCTION DREDGE (1994—Rebuild 2011 Class GL)



SPECIFICATIONS

Power	7,426kW Total Installed
Ladder Pump **Deck Pumps x 2**	IHC 1,752kW IHC 3,816kW
Cutter	1107kW
Pipe	700mm dia. Suction 750mm dia. Delivery
Length OA **Hull Length** **Beam**	116m 80.6m 14.9 metres
Dredging Parameters	27m @ 38 degrees
Maximum Pumping Distance	7,000m (sand and silty materials)
Anchors	2—Anchor Booms plus spud carriage

EASTERN AURORA– GENERAL ARRANGEMENT

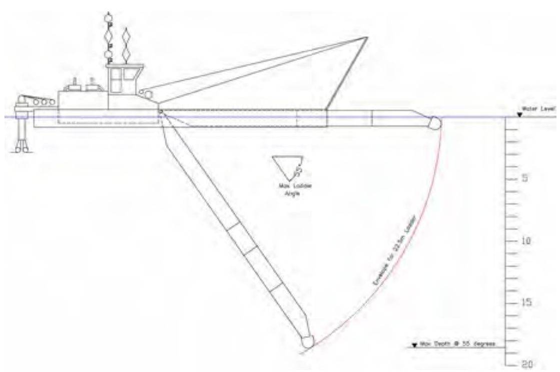


KOTUKU

1200m3 Barges | Backhoe Combi | Beaver | Combi | Ex 700 Longreach | Kaheru & Karaha | Kaiwea | Kimahia | Kotuku | Kurutai | Machiavelli | Mesenge | Pacific Way | Pugmill | Rua | WH 761 & WH 762 | White Pointer | ZX 330

Cutter Suction Dredge

Length:	23.8m
Width:	7m
Draught:	1.5m
Weight:	80 tonnes
Pump size:	12/10FG ladder pump
Pump type:	Warman Sand & Gravel
Pump Drive:	Hydraulic – Rexroth A2FM -1000
Suction size:	300mm
Discharge size:	350m
Main Engine:	Cummins KTA19 M1 (600hp)
Auxiliary engine:	Cummins 6BTA M1 (235hp)
Normal Dredge Depth	16.5m
Maximum dredge depth:	18.5m
Cutter:	VOSTA 5 Blade RH
Positioning:	Spuds or X tree winches.



NEUMANN CONTRACTORS

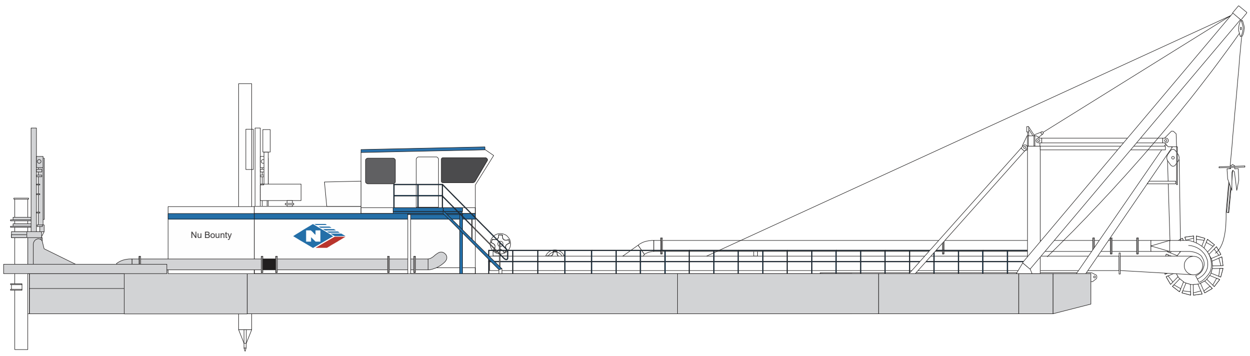
VESSEL PROFILE

Vessel Name: **Nu Bounty**

Registration Number: **25128QE**

Trading Name: **DRG007**

Length 41.30m
USL Class 2E
Builder.. Neumann Equipment
Nominal Production Rate: 650m3/hr
Total Horsepower: ....1,950 hp
Horsepower on Pumps: ....1,400 hp
Pipeline Diameter: ....450 mm
Maximum Digging Depth:...22 metres
Hull Material ....Steel
Superstructure Material ....Steel/Aluminium
Gross Weight .... 240 Tonnes



VESSEL PROFILE

NEUMANN *CONTRACTORS* – Nuban Street, Currumbin, Qld. 4223 PO Box 8, Currumbin, Qld. 4223
Ph: (07) 5589 2746 Fax: (07) 5589 2775 Email: neumann.contractors@neumann.com.au Website: www.neumanncontractors.com.au

NEUMANN CONTRACTORS

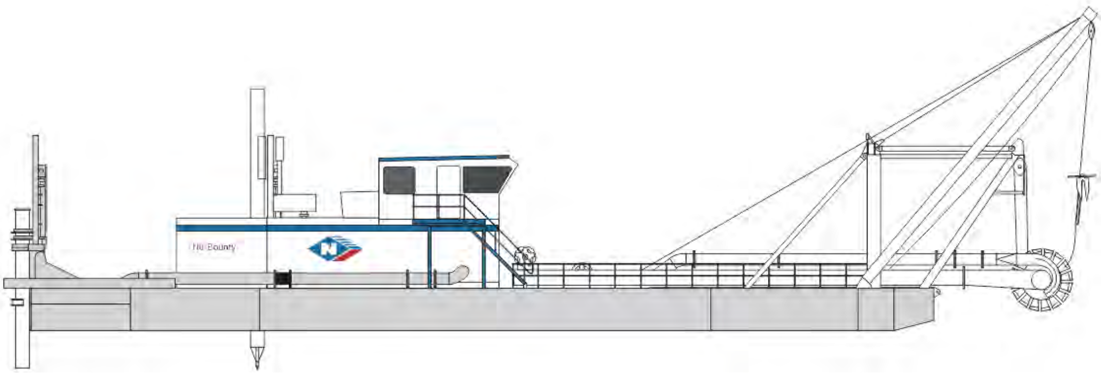
VESSEL PROFILE

Vessel Name: **Nu Bounty**

Registration Number: **25128QE**

Trading Name: **DRG007**

Length (in shortened configuation).....................................35.1m
USL Class .... 2E (Smooth Waters)
Owners Name .... Neumann Contractors
Owners Address...................Nuban Street, Currumbin Qld 4223
Homeport... Currumbin, Queensland
Builder.. Neumann Equipment
Nominal Production Rate: 650m3/hr
Total Horsepower: ....1,950 hp
Horsepower on Pumps: ....1,400 hp
Pipeline Diameter: ....450 mm
Maximum Digging Depth: ....15 metres
Hull Material ....Steel
Superstructure Material ....Steel/Aluminium
Gross Weight .... 220 Tonnes
Ship Type...Dredge – Non-Propelled
Hull/Deck Colour... Grey/Grey
Supestructure Colour................................White with Blue Trim



VESSEL PROFILE

GUNGNER R

Gungner R deepening a navigation channel in the Port of Rio, Brazil.

Backhoe Aquadigger

The Gungner R is a very powerful heavy-duty Backhoe Aquadigger

The spear relates to the tooth system on the buckets improving digging performance when penetrating hard compacted soil and rock.

Pontoon Characteristics:

Dimensions:	52,55 m x 15,25 m x 3,35 m
Classification:	Bureau Veritas, B.V. International Tonnage Certificate Bureau Veritas B.V. International Load Line Certificate
Spuds:	3 stabilizing spuds with a diameter of 1.70 m, square built of special steel.
Basic length:	28,60 m
Lifting capacity:	Approx. 204 ton per spud
Max. working depth:	Approx. 22.00 m (depending on excavator equipment)
Miscellaneous:	- Spud carrier: stroke 7.00 m by hydraulic winch - Spud control system: Fully computerized, automatic tide and levelling control - Accommodation for 9 persons - Built-in fuel tanks: 126 m^3 capacity - Auxiliary hoist crane: 18,1 ton & 3 m / 12,2 ton & 6 m / 2,5 ton & 15 m - Air-conditioning - For tropical conditions +40°C and heating for winter conditions -25°C

Excavator Characteristics:

Make:	Komatsu PC 3000A Aquadigger, flexible mount
Engine:	Cummins KTTA 38, 940 kW at 1,800 rpm (1082kW at peak load)
Hydraulic:	3 variable displacement axial piston pumps, flow 3 x 900 l/m, max. pressure 310 bar
Equipment:	For working depth up to 22 m
Monoblocs:	14 m
Sticks:	7,1 m and 11 m
Bucket:	5,4 m^3 up to 11 m^3 SAE
Miscellaneous:	- Excavator mounted with special heavy duty rubber shock absorbing system - High placed large cab (2,2 m width, 3,7 m length) - “Bucket Position Indicator” and additional dredging equipment - Full control from excavator cabin of spud movement and shifting of barges alongsisde - Last dredging kinematics - Sealed attachment bearings - Seawater proofed installations - Fire fighting system - Xenon lights

Excavator Position Monitor:

- IHC systems B.V.
- XPM-NG (New Generation)
- Automatic steering - Swing limitation
- Outreach limitation - Pontoon damage limitation
- Profile/depth dredging

Environment:

- EnviroLogic, 3046 Hydraulic Fluid
- Biodegradable, non-hazardous ISO 46 grade
- Hydraulic fluid
- Engine oil management system (minimizing of oil disposal)
- Sewage treatment installation
- IAPP, certification
- Low noise certification (Komatsu PC 3000A)

Extra Equipment

On request:
- Longer boom and stick for dredging deeper than -22,0 m
- Hydraulic hammer for rock breaking

Nordic mythology

The one-eyed God of war and death, Odin is the King of all Nordic Gods. Odin has a divine spear named Gungner. Gungner’s critical attack launches a powerful long range lightning strike and pierces everything it touches. In one strike it can defeat a whole army.

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&
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AUCKLAND NEW ZEALAND
TELPHONE: (09) 299-9767 FAX: (09) 299-9510

Specification Sheet: Machiavelli

Machiavelli loading 750m3 hopper barge.

SeaTools dredging monitor.

NAME	**Machiavelli**
TYPE	**De Donge 'D' Type Backhoe Dredge**
OFFICAL NUMBER	**876411**
PORT OF REGISTRY	**Auckland New Zealand**
YEAR BUILT	**2005**
CLASS	**Bureau Veritas**
OPERATORS	**Heron Construction Company Ltd**
GROSS TONNAGE	**684 tonne**
DISPLACEMENT	**1,200 tonne**
OVERALL LENGTH	**53.0m**
BREADTH	**15.0m**
EXCAVATOR	**Liebherr P994**
MONOBLOC LENGTH	**16.0m**
DIPPER LENGTHS & BUCKET SIZES	**5.6m and 5.7m3**
	8.0m and 4.5m3 and 4.0m3
	9.5m and 4.5m3 and 4.0m3
DREDGING CONTROL	**DipMate by Seatools**
POSITION CONTROL	**Twin Trimble 5800 RTK GPS**
AFT SPUDS	**Two @ 30m long x 60 tonne each**
FORWARD SPUD	**One @ 30m long x 60 tonne in carrier**
SPUD CARRIER STROKE	**7.5m**
JACKUP CAPACITY	**780 tonnes**

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Specification Sheet: Kurutai

CALL SIGN	ZMA 2815
OFFICAL NUMBER	875798
IMO NUMBER	9038921
PORT OF REGISTRY	Auckland
YEAR BUILT/PLACE	1991, Auckland, New Zealand
CLASS	MNZ, NZ Safe Ship Management
OPERATORS	Heron Construction Company Ltd
GROSS TONNAGE	199
NETT	94
DISPLACEMENT	312
OVERALL LENGTH	23.46m
BREADTH	8.0m
MAX. DRAFT	3.8m
MAIN ENGINES	2 x Detroit 16V 149 TI
POWER	2560 hp
AUXILLARIES	1 x Cummins, 1 x Detroit 6V71
PROPELLORS	Twin screw, 4 blade Kaplan type
NOZZLES	Fixed, Kort each with single rudder
BOLLARD PULL	30 tonnes
TOWING SPECIFICATIONS	Tow winch 80 tonne brake capacity Tow wire – 730m x 48mm dia, fitted with tandem tow link.

ELECTRONICS

SATCOM	Furuno Saturn C Felcom 15 & PP-510
RADIO TELEPHONE	Furuno FS1550 – 15
VHF RADIO TELEPHONE	Sailor RT 2048
2182 WATCH RECEIVER	Sailor RT 501
EPIRB	Kannad 406 FH Auto
RADAR TRANSPONDER	Kannad Rescuer
RADAR	Furuno
GPS	Furuno GP 50
PLOTTER	Furuno GP 1610CF
ECHO SOUNDER	Furuno LS 6100
AUTO PILOT	FAP 330

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Specification Sheet: WH 761 and WH 762

Empty hopper being pushed to Machiavelli.

28 tonne boulder loaded into hopper with Machiavelli.

TYPE	Non propelled split hopper barge
MARITIME NEW ZEALAND NUMBER	WH 761: 124434, WH 762: 124435
YEAR BUILT/PLACE	1970, Carrington NSW
CLASS	MNZ, NZ Safe Barge Certificate
OPERATORS	Heron Construction Company Ltd
GROSS TONNAGE	630
LENGTH BETWEEN PERPENDICULARS	55.8m
LENGTH OVERALL	59.4m
BREADTH MOULDED	10.97m
BREADTH MAX	11.04m
DRAFT LOADED	3.5m
DRAFT LIGHTSHIPS	1.3m
DISPLACEMENT LIGHTSHIPS	439 tonne
LOAD DEADWEIGHT	1400 tonne
HOPPER CAPACITY	765 m3
HOPPER DIMENSIONS AT COAMING	31.24m x 7.47m
HOPPER BOTTOM OPENING	2.4m (max)

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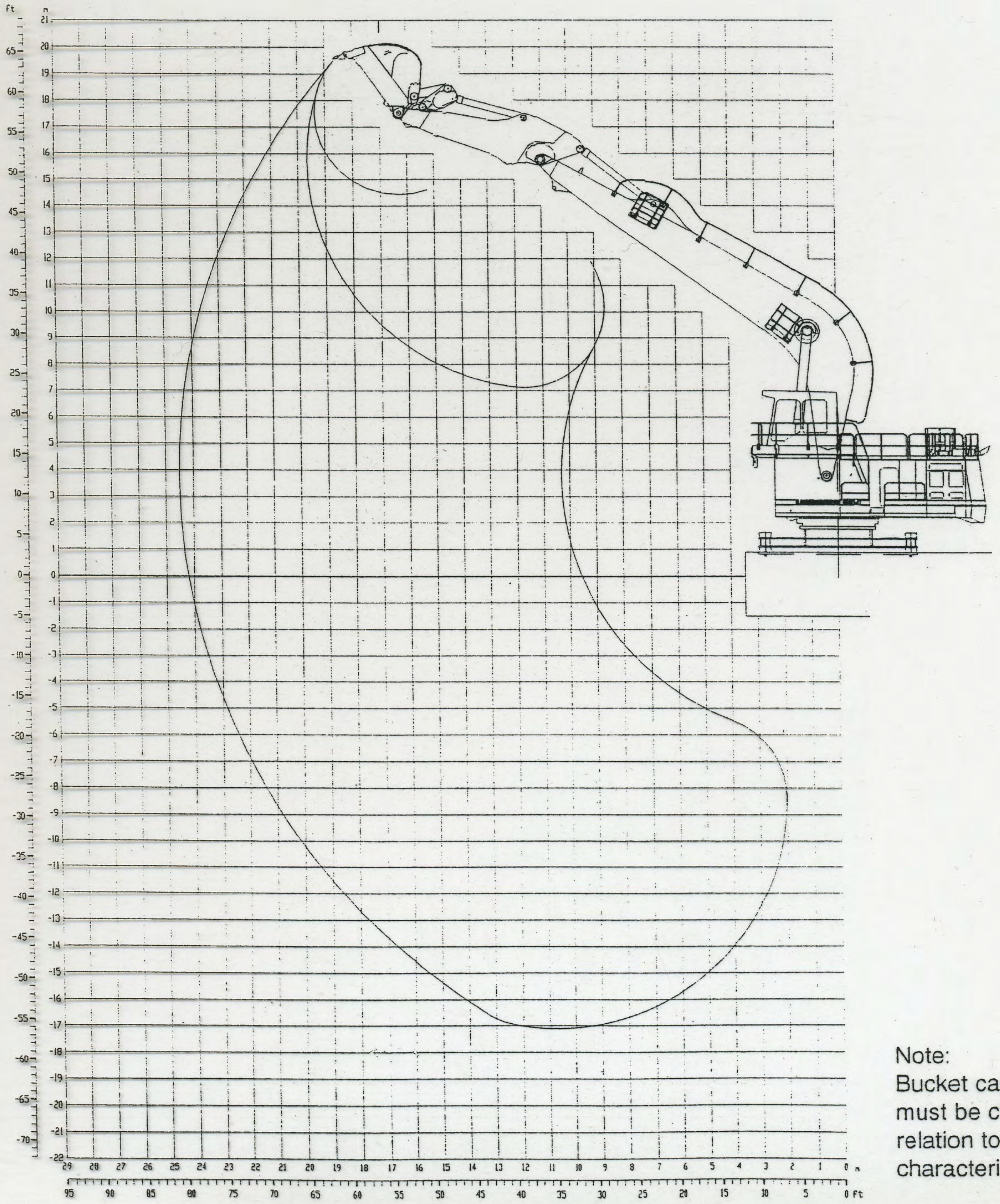
Dipper Dredge - Machiavelli

Available dredging equipments

Monobloc	16.00 m.
Stick	5.60 m.
Bucket	5.70 $m.^3$ SAE



Note:
Bucket capacity must be chosen in relation to the soil characteristics.

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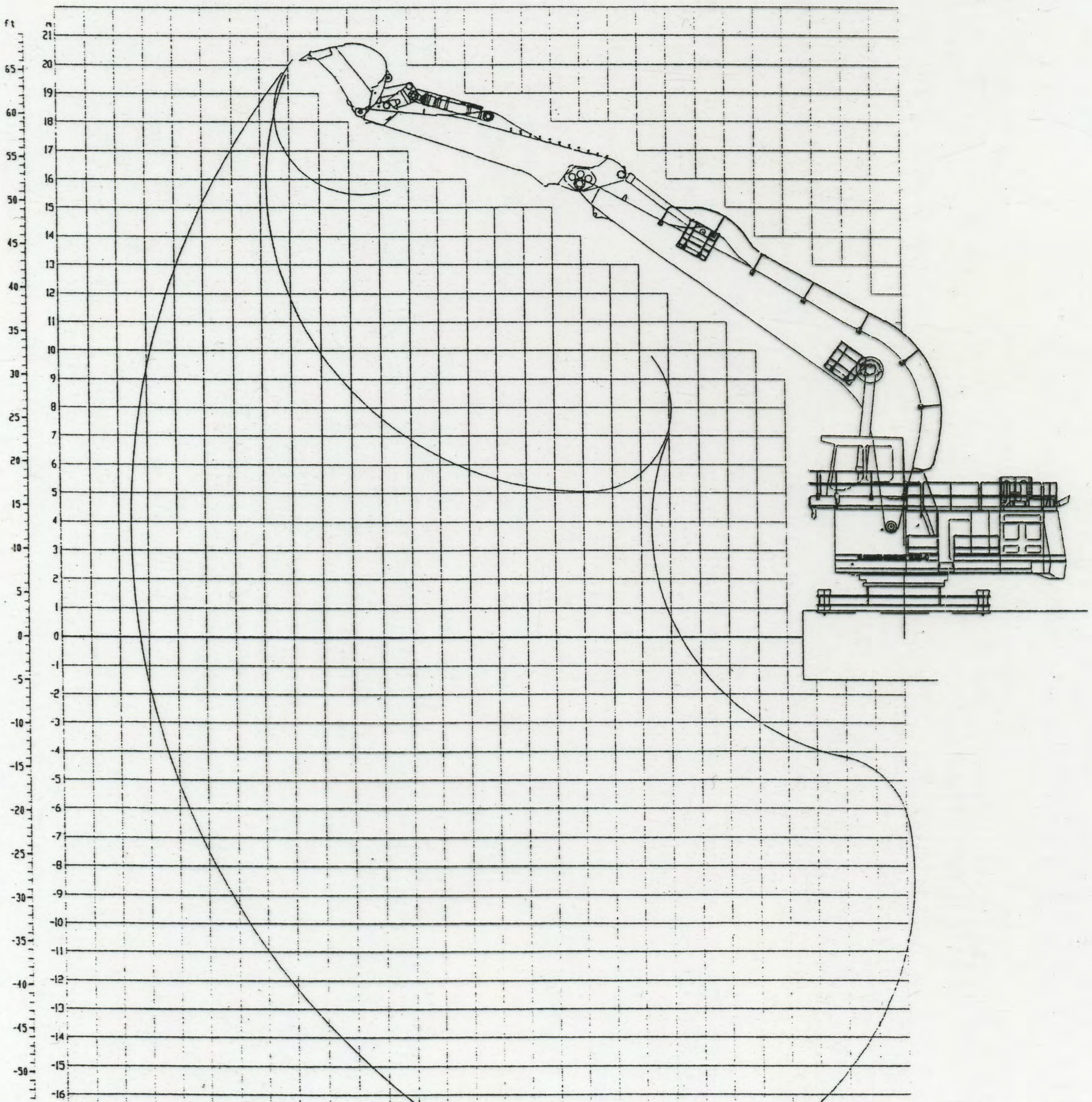
Dipper Dredge - Machiavelli

Available dredging equipments

Monobloc	16.00 m.
Stick	8.00 m.
Bucket	4.50 m.³ SAE



Note:
Bucket capacity must be chosen in relation to the soil characteristics.

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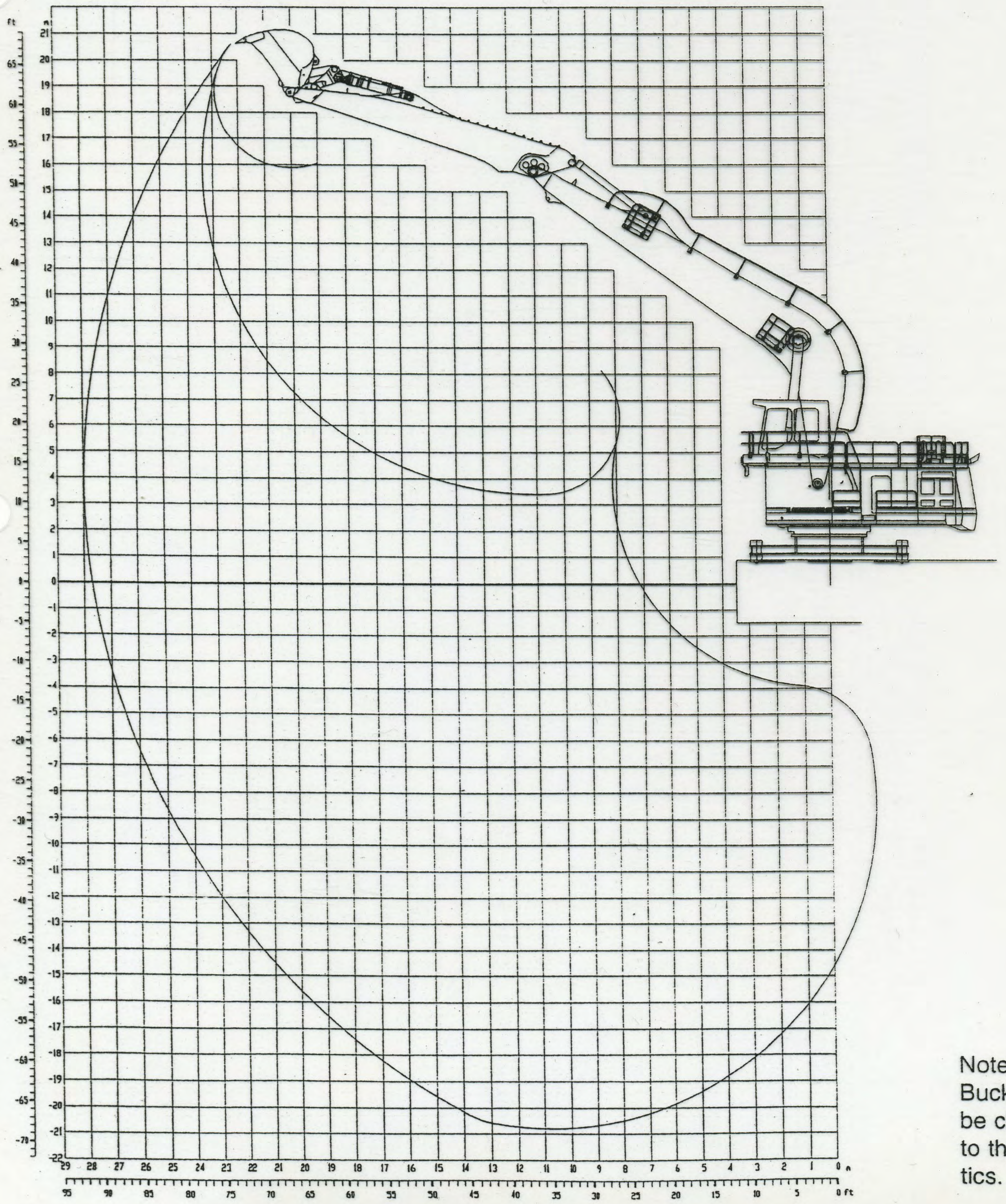
Dipper Dredge - Machiavelli

Available dredging equipments

Monobloc	16.00 m.
Stick	9.50 m.
Bucket	4.50 m.³ SAE



Note:
Bucket capacity must be chosen in relation to the soil characteristics.

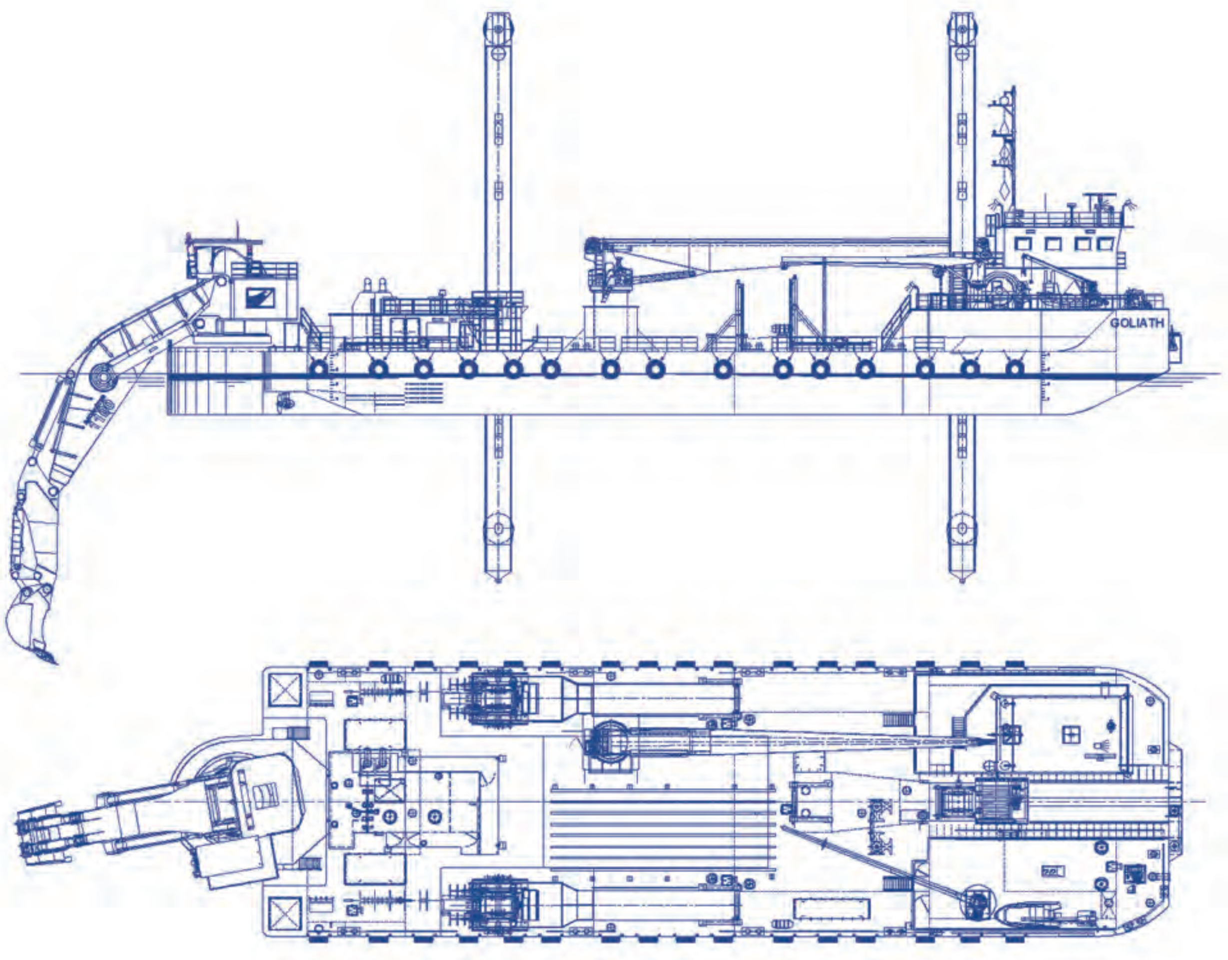
Van Oord
Marine ingenuity

Equipment

Backhoe dredger
Goliath / Simson

Van Oord

Marine ingenuity



Goliath / Simson

Name	Goliath / Simson		
Type	Backhoe dredger Backacter 1100		
Classification	Bureau Veritas, I ✠ Hull • Mach, Special Service/ Dipperdredger Assisted propulsion, unrestricted navigation		
Year of construction	2008 / 2009		
Dimensions	Length overall	66.85 m	
	Breadth overall	23.04 m	
	Moulded depth	4.25 m	
	Draught summer	3.25 m	
Tonnage	1,674 GT - 502 NT		
Excavator type	Backacter 1100		
Grab capacity	15 m³, 20 m³, 25 m³ and 40 m³		
Maximum dredging depth	26 m		

Total power installed	4,126 kW
Engine capacity excavator	3,800 kW
Installed propulsion power	1,000 kW - Only for self-manoeuvring at dredging site

Contact

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August 2015

Appendix C – Alternative Dredging and Disposal Scenarios

In addition to the dredging and disposal scenarios presented in Section 10, a number of alternative scenarios have also been assessed. This section provides a summary of all the scenarios considered during the course of the project.

Round 1

An indicative cost estimate and dredging program has been determined for the following scenarios (for the Option 4-2 channel design):

A1) All dredging is undertaken with a TSHD and the dredged material disposed at an offshore disposal through bottom-dumping from the TSHD. The offshore disposal site is assumed to be within 10km of the project site.

A2) All dredging is undertaken with a TSHD. A relatively minor portion of the dredged material (200,000m^3) is pumped to an onshore reclamation and the remainder disposed at the offshore disposal site through bottom-dumping from the TSHD.

A3) All dredging is undertaken with a TSHD. A large portion of the dredged material (700,000m^3) is pumped to an onshore reclamation and the remainder disposed at the offshore disposal site through bottom-dumping from the TSHD.

B1) Scenario B1 and A1 are identical

B2) All dredging is undertaken with a CSD and the dredged material disposed at the offshore disposal site using barges with bottom-dumping.

B3) All dredging is undertaken with a BHD and the dredged material disposed at the offshore disposal site using barges with bottom-dumping.

B4) Dredging is undertaken using a BHD and a TSHD. The BHD is used to dredge the material around the berth (approximately 72,000m^3) and the TSHD is used to dredge the rest. All dredged material is disposed at the offshore disposal site. The material dredged using the BHD is disposed of using barges.

The indicative dredging cost and program for each scenario, as presented in Table 21 and Table 22, are rough order of magnitude (ROM) numbers. These costs are not intended for budgeting purposes, but rather as an indication of how the various scenarios compare in terms of cost. Likewise the durations presented should not be used for developing a project program, but instead used as an indication of how the various scenarios compare in terms of duration.

Table 21: Indicative production rates and dredging costs – alternative disposal options

Scenario	Dredging Equipment	Disposal Scenario	Indicative Cost (NZ$)	Program (weeks)
A1	TSHD (2,900m^3	All offshore	NZ$ 29 million	21
A2	TSHD (2,900m^3)	200,000m^3 to reclamation Remainder offshore	NZ$ 30 million	22
A3	TSHD (2,900m^3)	700,000m^3 to reclamation Remainder offshore	NZ$ 31 million	24

Table 22: Indicative production rates and dredging costs – alternative dredging equipment options

Scenario	Dredging Equipment	Disposal Scenario	Indicative Cost (NZ$)	Program (weeks)
B1	TSHD (2,900m^3)	All offshore	NZ$ 29 million	21
B2	CSD (3,350kW)	All offshore	NZ$ 48 million	19
B3	BHD (5m^3)	All offshore	NZS 192 million	135
B4	BHD (5m^3) + TSHD (2,900m^3)	All offshore	NZ$ 34 million	21

Notes:

1. **The indicative costs presented above are based on a total dredge volume of approximately 3.2Mm^3 (i.e. excluding any overdredge allowances).**
2. The over-dredge volume is estimated to be approximately 450,000m^3 and would add 10% to 14% to the costs and program duration presented in Table 21 and Table 22. The actual volume dredged is likely to be somewhere between the design dredge volume and the over-dredge volume.
3. Scenarios A2 and A3 exclude the reclamation costs. It is estimated that the reclamation costs will be approximately NZ$ 1 million for mobilising / demobilising pipelines and a landside cost of NZ$ 9/m^3.
4. Although Scenario A1 / B1 provides the lowest cost, there are practical limitations with regard to dredging around the berth using a TSHD. Scenario B4 would, therefore, be best to deliver the requirements of the dredging campaign as it includes dredging around the berth.
5. The program duration excludes mobilisation/demobilisation.
6. The dredging duration for the CSD operation is slightly shorter than the TSHD operation. The reason for this being that the CSD is continuously dredging and loading barges, whilst the TSHD has breaks in dredging in order to travel to the dredge disposal site. A slightly larger TSHD (or slightly smaller CSD) could result in the TSHD dredging program being shorter than the CSD dredging program.

Round 2

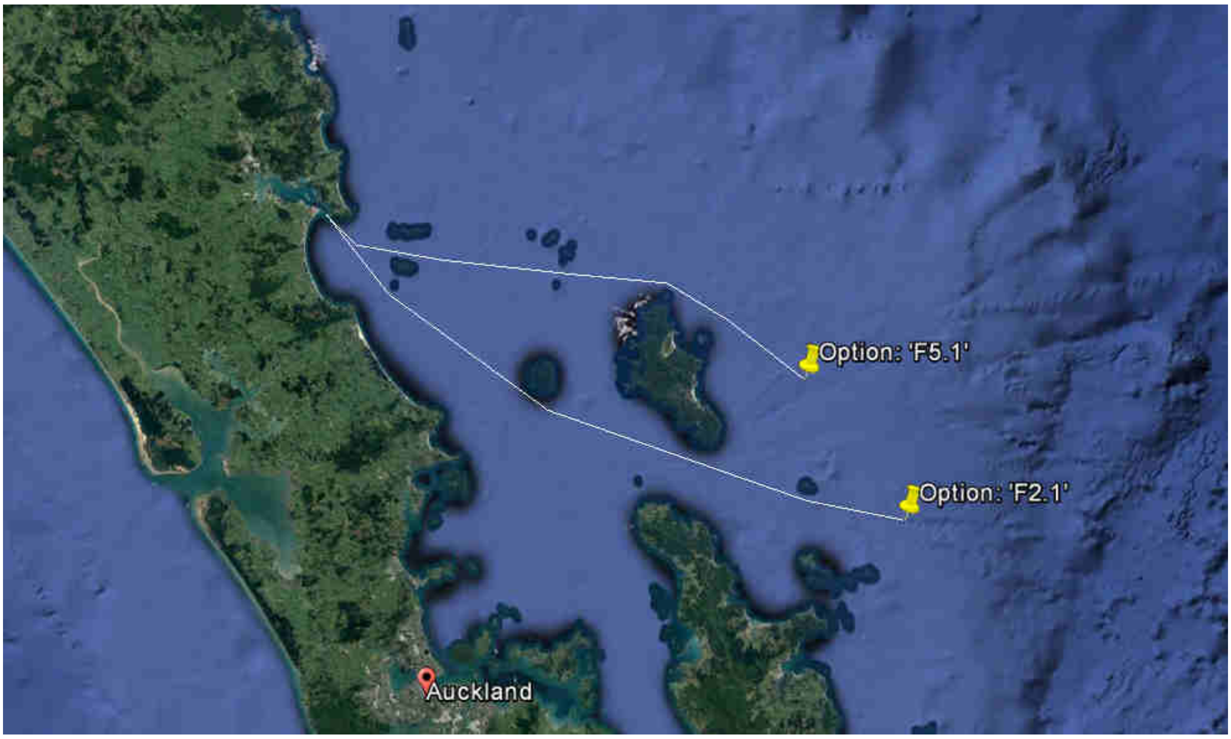
An indicative cost estimate and dredging program has been determined for the following scenarios (for the Option 4-2 channel design):

A1) All dredging is undertaken with a **TSHD** and the dredged material disposed at an offshore disposal through bottom-dumping from the TSHD. The offshore disposal site is assumed to be within **10km** of the project site.

A2) All dredging is undertaken with a **TSHD** and the dredged material disposed at an offshore disposal through bottom-dumping from the TSHD. The offshore disposal site is 'F5.1' and is approximately **125km** from the project site.

A3) All dredging is undertaken with a **TSHD** and the dredged material disposed at an offshore disposal through bottom-dumping from the TSHD. The offshore disposal site is 'F2.1' and is approximately **160km** from the project site.

Figure 19: Alternative dredge disposal sites



The indicative dredging cost and program for each scenario, as presented in Table 23, are rough order of magnitude (ROM) numbers. These costs are not intended for budgeting purposes, but rather as an indication of how the various scenarios compare in terms of cost. Likewise, the durations presented should not be used for developing a project program, but instead used as an indication of how the various scenarios compare in terms of duration.

Table 23: Indicative production rates and dredging costs – alternative disposal options

Scenario	Dredging Equipment	Disposal Scenario	Indicative Cost (NZ$)	Program (weeks)
A1	TSHD (2,900m^3)	≈ 10km	NZ$ 29 million	21
A2	TSHD (2,900m^3)	≈ 125km	NZ$ 177 million	135
A3	TSHD (2,900m^3)	≈ 160km	NZ$ 222 million	170

Notes:

1. **The indicative costs presented above are based on a total dredge volume of approximately 3.2Mm^3 (i.e. excluding any overdredge allowance).**
2. The over-dredge volume is estimated to be approximately 450,000m^3 and would add 10% to 14% to the costs and program duration presented in Table 23. The actual volume dredged is likely to be somewhere between the design dredge volume and the over-dredge volume.
3. The program duration excludes mobilisation/demobilisation.
4. Dredge disposal sites F5.1 and F2.1 require the dredger to sail through open waters for a larger percentage of the time. There is therefore a higher risk of downtime / delay due to wave conditions. As an example, an increase in downtime / delay of 5% would result in the following additional costs and program extensions:
   Disposal site F5.1: Additional NZ$ 8 million and additional 7 weeks; and
   Disposal site F2.1: Additional NZ$ 10 million and additional 9 weeks.

Appendix B: Shipping channel – concept design report prepared by Royal HaskoningDHV

REPORT

Refining NZ Crude Shipping Project

Shipping Channel - Concept Design Report

Client: Refining NZ

Reference: M&APA1028R002D08

Date: 12 November 2016

Status: Consultation Draft

REFINING NZ
Your Energy Hive

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Enhancing Society Together

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Document title:	Refining NZ Crude Shipping Project Shipping Channel – Concept Design Report
Document short title:	RNZ Channel Design
Reference:	M&APA1028R002D08
Date:	12 November 2016
Project name:	Refining NZ Crude Shipping Project
Project number:	PA1028
Author(s):	Matt Potter, Richard Mocke, Justin Cross
Status:	Consultation Draft
Drafted by:	As above
Checked by:	Justin Cross
Date / initials:	12 November 2016 / JGC
Approved by:	Dan Messiter
Date / initials:	

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EXECUTIVE SUMMARY

Refining NZ (RNZ) is exploring the possibility of undertaking dredging of the Whangarei Harbour entrance to enable fully laden Suezmax vessels to access and berth at the Crude Jetty, located at the RNZ refinery at Marsden Point.

Royal HaskoningDHV (RHDHV) has been engaged by RNZ to investigate the design of a navigation channel (and associated dredging requirements) to provide high water access for fully laden Suezmax tankers to the Crude Jetty. This investigation involved the following key tasks:

- preliminary assessment of required channel widths based on international best practice guidelines (PIANC, 2014);
- facilitation of a Channel Design Workshop with a number of stakeholders responsible for the safe management, operation and navigation of the Whangarei Harbour waterways and port facilities, including representatives from RNZ, Northport, NorthTugz and the Whangarei Harbour Master;
- development and documentation of concept design alignment options for testing in desktop simulation studies;
- completion of two rounds of desktop simulation studies;
- assessment of channel design options in close consultation with Workshop stakeholders;
- selection of preferred channel design option(s);
- full bridge simulation study; and
- proposed installation of new, and reconfiguration of some existing, aids to navigation.

It should be noted that whilst the focus of the investigation was the provision of high water navigation access for fully laden Suezmax vessels, other smaller vessels such as Aframax and Logships were also considered as part the desktop simulation studies.

A Channel Design Workshop was held on 17th April 2015, during which preliminary PIANC channel design widths and several alternate channel alignments were presented by RHDHV and discussed with representatives from Refining NZ, NorthTugz, Northport and the Harbour Master. As an outcome of the Channel Design Workshop, the Option 2 and Option 4 channel alignments were selected for further refinement and desktop simulation.

An early version of Channel design Option 2 is shown schematically on **Figure E1** and aimed to increase the distance between changes in channel alignment through the critical Home Point stretch to 1.3km within the existing fairway (although this straight section would be altered and reduced after curved bend geometry was subsequently taken into account). This alignment falls within the existing marked channel noting that, in some locations, the existing marked channel (that is the water area within the existing buoys) was wider than the minimum channel width that would be required for the design vessel(s).

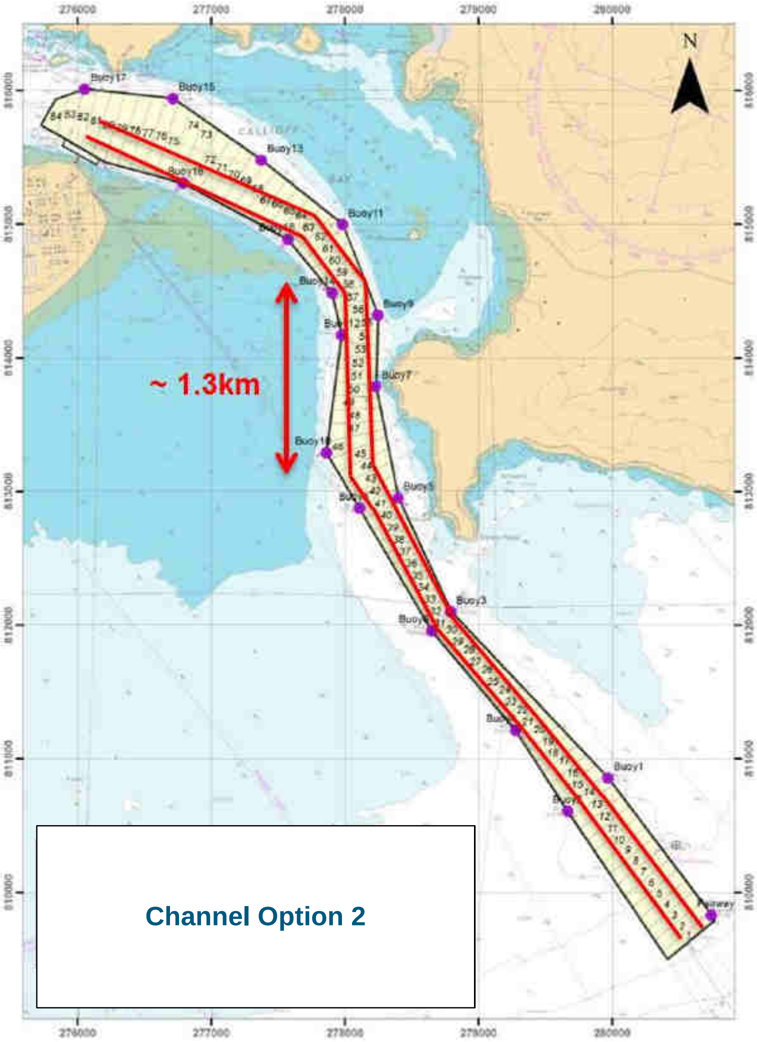


Figure E1: Channel Design 'Option 2' (delineated in red)

Channel design Option 4 was also identified during the Channel Design Workshop and is shown schematically in **Figure E2**. The principal benefits achieved by the Option 4 alignment are:

- the simplification of the channel route into three (3) main headings (from five (5) heading changes in Option 2), by creating a single bend from Buoy 14 to Buoy 16;
- the reduction of the number of bends (to two only) that need to be navigated by vessels;
- increasing the distance between changes in channel alignment, particularly through the critical Home Point stretch (from ~0.9km to ~1.6km taken from centre to centre of the bends); and,
- maximising the use of the existing leads on the fairway approach channel (which required the channel to lie outside the existing fairway around Buoy No 8).

As discussed below, channel design Option 4 was subsequently refined in accordance with PIANC geometry requirements and feedback received from the desktop simulation studies.

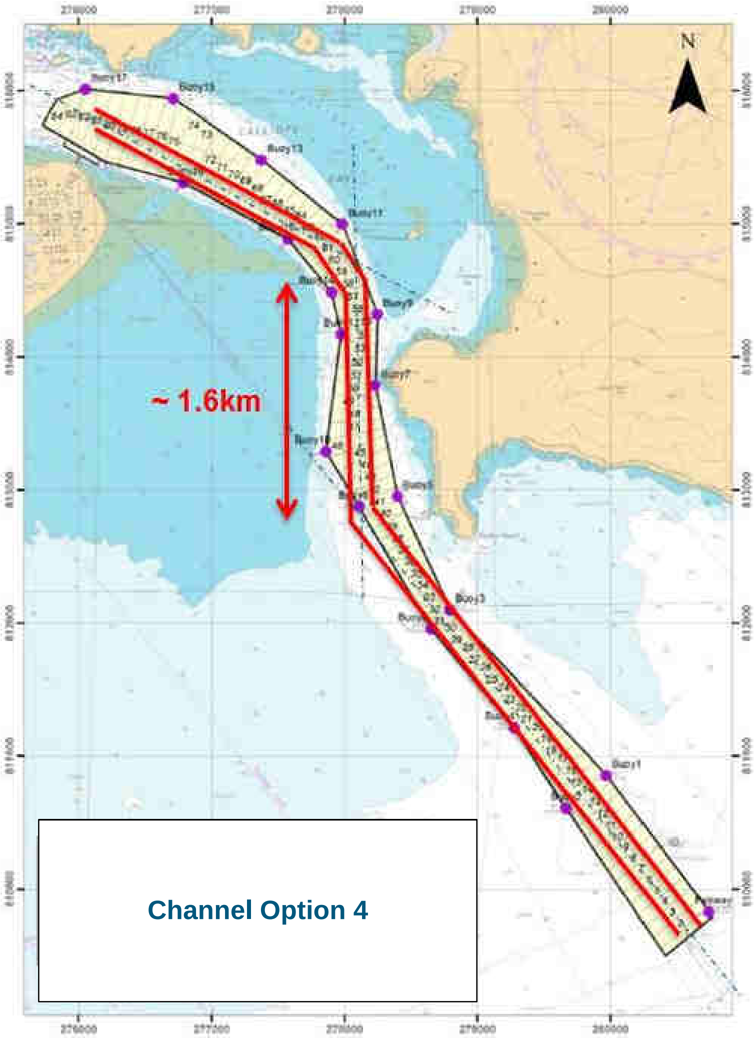


Figure E2: Channel Design 'Option 4' (delineated in red)

To the extent possible[1], these alternative navigation channel alignments were designed in accordance with the PIANC guidelines (PIANC, 2014) to provide high water access for fully laden Suezmax vessels. These alignments were tested in two rounds of a Desktop Simulation Study.

Round 1 of the Desktop Simulation Study was used to validate two different channel designs (denoted as Option 2 and Option 4) and to investigate berthing and tug utilisations and emergency response measures in the new channel designs.

During the final stages of the first round of the Desktop Simulation Study discussions were held between the simulation team and the NorthTugz pilots, Tugmasters and the Harbour Master around concerns over Bend No. 2. This resulted in some minor refinement of Bend No. 2 and the development of the Option 4-1 alignment (see **Section 3.5.1**).

[1] The PIANC guidelines provide recommendations regarding minimum channel bend radius. Meeting these recommendations was not possible throughout the full extent of the channel due to existing site constraints.

Following the development of the new channel alignment associated with Option 4-1, the pilots maintained some concern regarding Bend No. 2 as the radius of 580m was less than the PIANC recommendation of 1370m.

To address this issue more effectively, Option 4-1 was further modified prior to the second round of the Desktop Simulation Study (refer **Section 4.2**) in order to accommodate a gentler bend with an 800m radius at this location. This was achieved through the slight re-adjustment of the existing buoys, specifically Buoy 14 which was moved to the north-west. In addition, the north-south (N-S) channel alignment was moved (32m) to the east so that the eastern toe line of the channel lined up with the existing position of Buoy 7. This modified channel alignment is referred to as Option 4-2 (see **Section 3.5.2**).

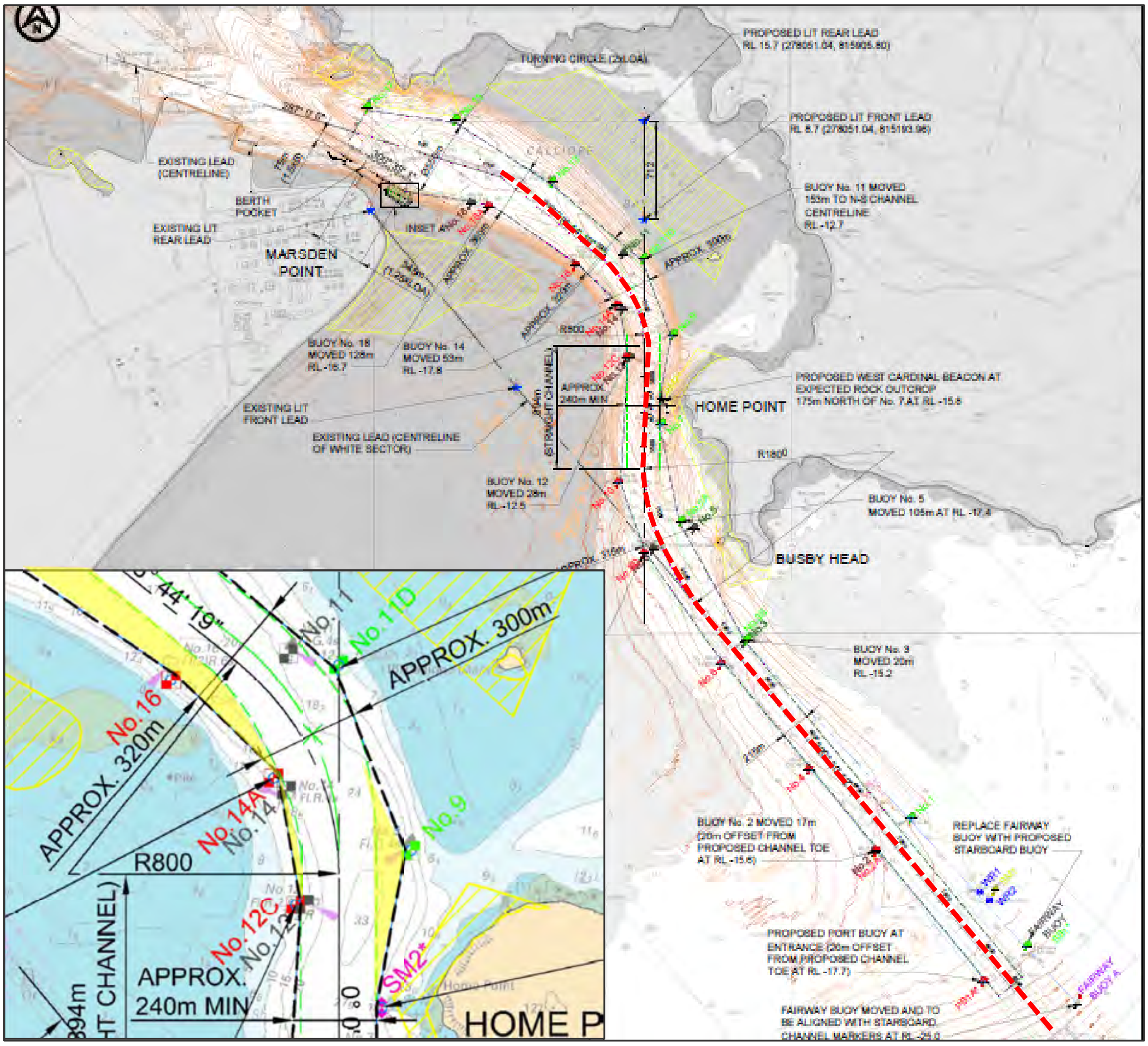


Figure E3: Channel Design 'Option 4-2' (delineated in red), with inset showing the gentler 800m radius bend

The resultant channel design, Option 4-2, provided several benefits in addition to those listed for Option 4, including:

- widening of the bend around Buoy 14;
- reduction in dredging of the area adjacent to Mair Bank (Buoys 12/14); and
- improvement of navigation in the vicinity of the Home Point rock outcrop.

In addition to the channel alignment Option 4 modifications, an additional channel alignment (Option 5) was developed as an alternative to avoid any dredging adjacent to Buoys 12/14 along Mair Bank. The Option 5 channel alignment involved a movement of the N-S channel alignment further to the east, but requires dredging in the vicinity of Home Point. This new channel alignment also requires the relocation of the existing No 7 and No 12 buoys.

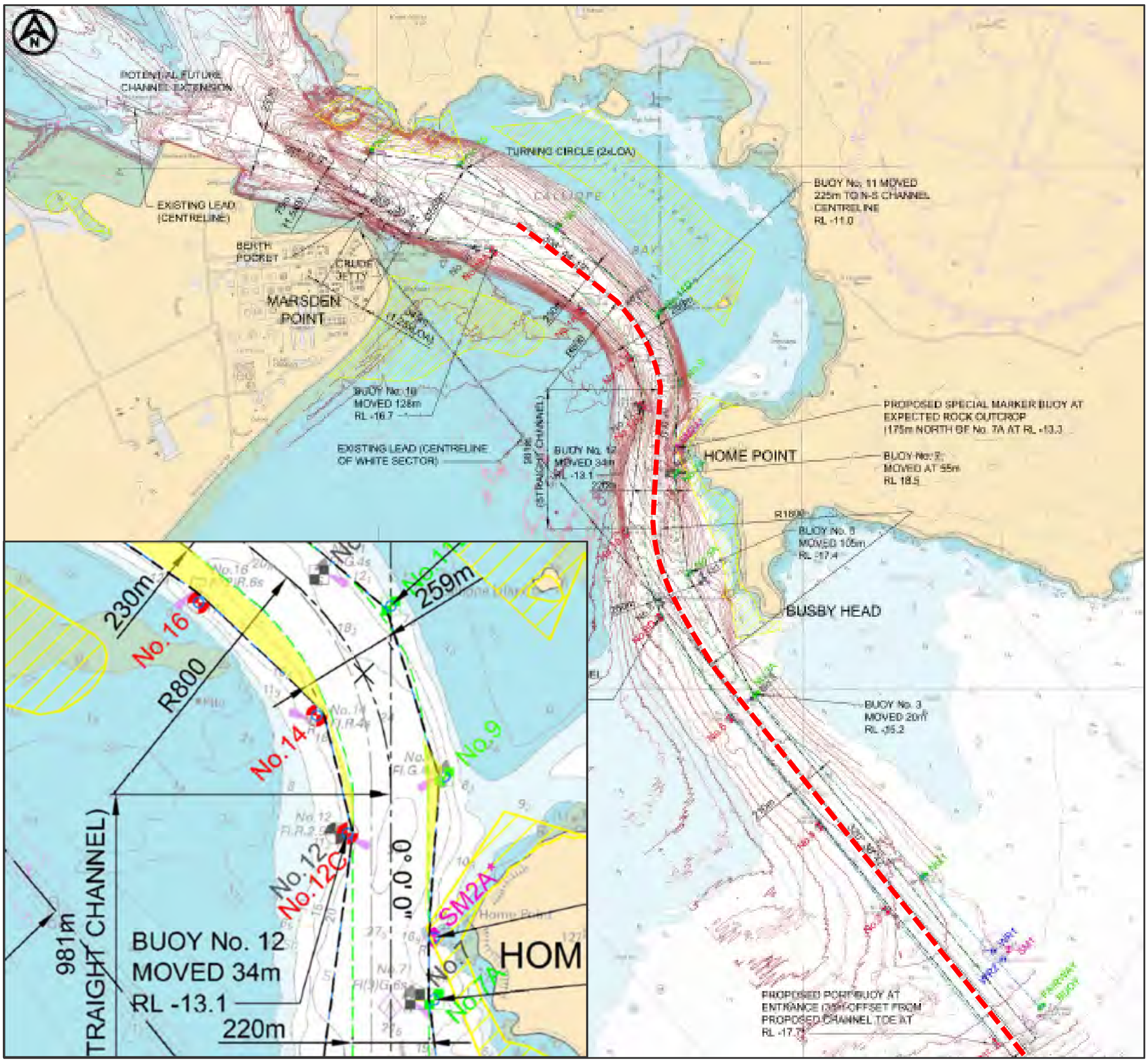


Figure E4: Channel Design 'Option 5' (delineated in red), with inset showing less sea room alongside buoy 9 as indicated by the yellow shading along the eastern side of the channel

In the second round of simulation the two additional channels designs (Option 4-2 and Option 5) were validated. Additional berthing simulation was done to investigate a new berth pocket and further emergency response measures were tested in the two new additional channel designs.

Participants in the simulations included Bruce Goodchild of Be-Software, RNZ, RHDHV, NorthTugz pilots and Tugmasters and the Harbour Master. The Desktop Simulation Study facilitated the testing of alternative channel alignments and navigation marker configurations under a wide range of different operating conditions, including:

- different design vessel types (Suezmax and Logships);
- loaded, partially loaded and ballasted vessels;
- average to limiting environmental conditions (e.g. wind, waves);
- day and night transits;
- different states of the tide;
- different tug configurations;
- arrivals, departures and berthing; and,
- emergency scenarios (e.g. loss of rudder control, loss of engine power and complete vessel blackout).

The simulations also included a number of runs that would be outside of the current operating parameters of the port (e.g. full ebb tide departures of Suezmax vessels).

Although transits through the Option 2, Option 4-2 and Option 5 channel alignment were completed successfully by the pilots, the outcome of the Desktop Simulation Study indicated that the Option 4-2 channel alignment was the preferred channel alignment from a navigation perspective.

Figure E5 illustrates the channel centreline alignments for Option 2, Option 4-2 and Option 5.

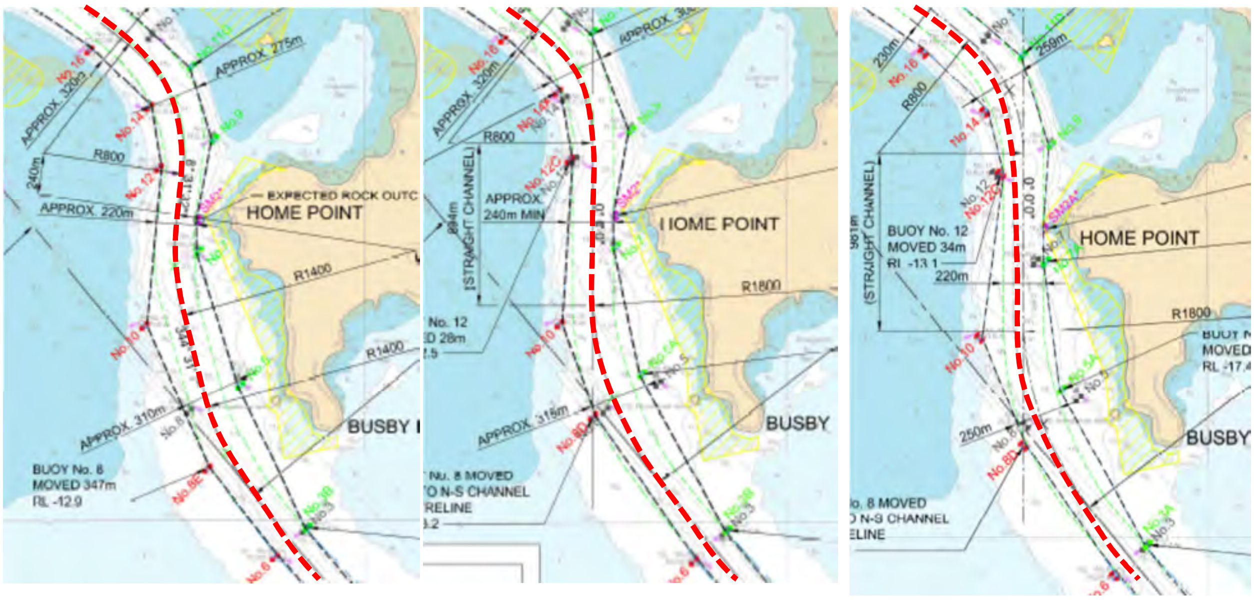


Figure E5: Comparison of mid-channel alignment past Home Point for Design 'Option 2' (left), Design 'Option 4-2' (middle) and Design 'Option 5' (right)

Whilst Option 2 is considered adequate, the need to incorporate channel bends within the existing marked channel meant that this option resulted in the requirement to execute an "S-Bend" manoeuvre past the critical Home Point stretch, which is considered to represent a navigation hazard amongst all pilots. By allowing the channel to slightly encroach outside the existing marked channel for Option 4-2, a longer straight section was possible at this critical location and, hence, was considered to be more favourable from a navigational perspective by the pilots.

Whilst Option 5 also provided a straight section similar to Option 4-2, this option was least favoured as it effectively reduced the sea room available in the approach to the rocky outcrop at Home Point from the north; Pilots generally avoid navigating in close proximity to Home Point on departures by staying as far west as possible within the existing channel when executing the turn around Buoy 14.

Therefore Option 4-2 was deemed the preferred channel alignment from a navigational perspective, followed by Option 2 and with Option 5 being the least preferred.

The Option 2, Option 4-2 and Option 5 channel alignments are documented on drawings: **PA1028-MA-1201 Revision D, PA1028-MA-1121 Revision M** and **PA1028-MA-1301 Revision A** respectively.

Following completion of the Desktop Simulation Study, some minor refinement of the channel design was undertaken that included the following:

- addition of lead lights along the N-S aligned sections of the Option 4-2 channel;
- minor revision of channel widths and bend geometry to accommodate a revised Suezmax design vessel with length overall (L_{OA}) = 276m and beam (B) = 50m;
- addition of a 'dolphin pocket' behind the eastern end of the proposed berth pocket for lineboat access; and
- minor adjustments to buoy locations.

The above refinements are incorporated within the final drawings presented with this report (**PA1028-MA-1121 Revision M** and **PA1028-MA-1123 Revision C**).

This was followed by a full bridge simulation study undertaken at the Marine Simulation Centre of the New Zealand Maritime School (Auckland). The study was required to validate the Desktop Simulation Study for the proposed expansion of the port to receive deeper draft Suezmax Oil Tankers having a length overall (L_{OA}) of 276m, beam of 50m, and draft of 16.6m.

The full bridge simulation study focussed on the two preferred channel designs, namely Option 2 and Option 4-2. The key findings from the study were as follows:

- The results of the two earlier portable and remote link simulation studies were validated;
- The Option 4-2 channel design is preferred by the pilots due to providing safer manoeuvring through critical sections of the approach channel;
- Minimal realignment of existing navigational buoys is considered necessary;
- An improvement in the existing leading sector light and buoy lights will be necessary to properly indicate navigable water in the approach channel from the fairway buoy to buoys 3/6;
- Existing tugs provide adequate towage under normal operations and we understand emergency capability is to be further reviewed given increased ship displacement; and
- The proposed channel design alignments will potentially assist in an emergency scenario by providing more sea room.

The aids to navigation (AtoN) have been assessed as part of this channel design process and the following modifications proposed:

- Eight (8) of the existing buoys will need to be relocated to accommodate the reconfigured channel alignment;
- Two (2) additional channel marker buoys (being one (1) starboard buoy and one (1) port buoy) will be installed at -17.7m RL;
- The fairway buoy will be moved to be aligned with the starboard channel markers and installed at -25.0m RL;
- Due to the rock outcrop, and therefore potential navigational hazard in the vicinity of Home Point, it is proposed that a West Cardinal Beacon be installed 175m north of buoy no. 7 at -15.8m RL;
- An improved Port Entry Light (PEL) is proposed. The proposed improvement is to remove the upper portion of the day shape on the forward lead light and to install a day and night light. The proposed changes to the PEL will be addressed by Northport;
- The existing (rear) lead light marking the offshore approach channel was considered to be too insensitive by the pilots and this was demonstrated in all the simulations. The sectors of the main lead should adequately show the navigation limits of the new channel and be bright enough to support operations in adverse environmental conditions; and
- A set of lead lights is to be established in Taurikura Bay to assist with the night time navigation of arriving Suezmax Tankers and other vessels.

1 INTRODUCTION

Refining NZ (RNZ) is exploring the possibility of undertaking dredging of the Whangarei Harbour entrance to enable fully laden Suezmax vessels to access and berth at the Crude Jetty, located at the RNZ refinery at Marsden Point.

Navigation of vessels to the RNZ refinery is currently facilitated through a completely buoyed and lit channel, 5 nautical miles long, and leading from the Fairway Buoy offshore to Marsden Point within Whangarei Harbour. The approach to Marsden Point has a shallowest depth of 14.7 metres below Chart Datum between the Fairway Buoy and No 1 buoy.

From a navigational perspective, the most important buoys are as illustrated on **Figure 1**, those being:

- Fairway Buoy: The outermost buoy for approaching and departing ships; approach alignment marked by leading beacons;
- Buoy No. 6: Adjacent to Busby Head which forms the outermost land extent; change in channel alignment;
- Buoy No. 7: Adjacent to Home Point, which is considered a 'pinch point' in the channel; change in channel alignment;
- Buoy No. 14: Adjacent to Mair Bank area; change in channel alignment; and,
- Snake Bank Beacon: Adjacent to Marsden Point; alignment marked by leading beacons.

Between Fairway Buoy and Snake Bank Beacon, there are currently five (5) channel alignments with two of those alignments (the inner and outer-most of the above) marked by leading beacons.

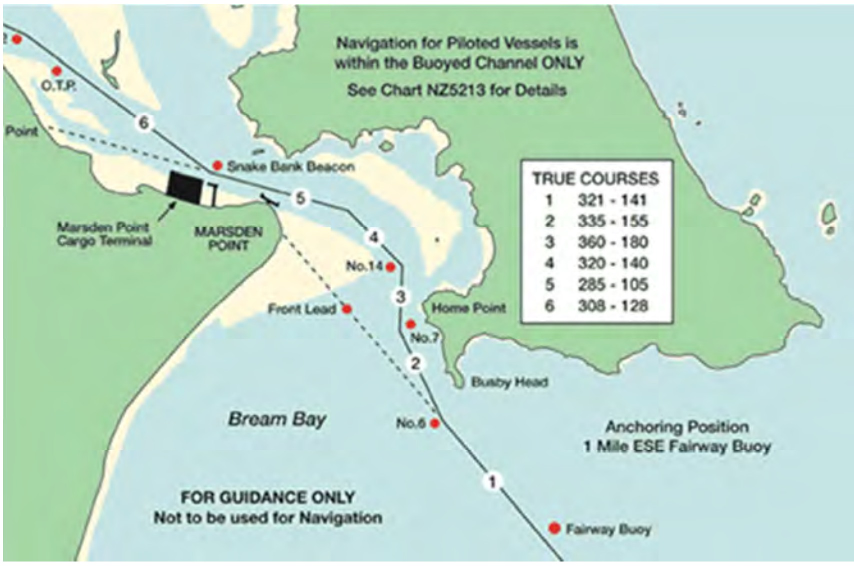


Figure 1: Existing navigation channel alignments

Royal HaskoningDHV (RHDHV) has been engaged by RNZ to investigate the design of a navigation channel (and associated dredging requirements) to provide high water access for fully laden Suezmax tankers to the Crude Jetty. This investigation involved the following key tasks:

- preliminary assessment of required channel widths based on international best practice guidelines (PIANC, 2014);
- facilitation of a Channel Design Workshop with representatives from RNZ, Northport, NorthTugz and the Whangarei Harbour Master;
- development and documentation of concept design alignment options for testing in a Desktop Simulation Study;
- completion of two rounds of a Desktop Simulation Study;
- assessment of channel design options in close consultation with key stakeholders;
- selection of a preferred channel design option(s);
- full bridge simulation study; and
- proposed installation of new, and reconfiguration of some existing, aids to navigation.

This report documents the channel design development and outcomes of the above tasks and comprises the following sections:

- Introduction (**Section 1**);
- Basis of Design (**Section 2**);
- Options Assessment (**Section 3**);
- Desktop Simulation Study (**Section 4**);
- Further Design Refinement (**Section 5**);
- Full Bridge Simulation Study (**Section 6**);
- Aids to Navigation (**Section 7**);
- Summary and Recommendations (**Section 8**); and,
- References (**Section 9**).

Design alignments, considered as part of the investigation, are attached in the Drawings section of the report and the following information is contained within Appendices:

- Preliminary Channel Width Assessment – Technical Memorandum (**Appendix A**);
- PIANC Channel Design Calculations (**Appendix B**);
- Desktop Simulation Study Report (**Appendix C**);
- Taurikura Bay Leads Report (**Appendix D**);
- Revised PIANC Channel Design Calculations (**Appendix E**); and
- Full Bridge Simulation Study Report (**Appendix F**).

2 BASIS OF DESIGN

2.1 Approach

The PIANC guidelines are an industry recognised standard for the design of navigational channels, as documented within *Harbour Approach Channels – Design Guidelines* (PIANC, 2014). For channel width, the PIANC procedure involves the determination of the vessel beam multiplier factor for each channel reach, taking into consideration a range of navigation, metocean and channel conditions.

PIANC also provides guidance on channel lengths and alignments, including the following:

- where possible, the recommended distance between successive bends should be greater than five (5) times the overall ship length (L_{OA}) of the design vessel;
- where possible, the recommended bend radius for a Tanker vessel should be five (5) times the L_{OA} of the design vessel (PIANC recommend the same multiplier for a Very Large Crude Carrier (VLCC) or a Small Tanker); and,
- additional channel width should be provided around bends to accommodate the Drift Angle (dependent on the bend radius and ship length) and response time of the ship handler (i.e. pilot).

It should be noted that the PIANC approach is suitable for the concept design phase of a project and is subject to refinement by fast-time and/or real-time ship manoeuvring simulation ('full-bridge' simulation) to ground truth the proposed channel geometry and layout of navigation aids. A desktop simulation has been used to compare various channel design options and a 'full bridge' simulation to assess the preferred channel design.

2.2 Input Data

The main inputs into the PIANC assessment are summarised below and comprise:

- channel design reaches;
- channel alignment;
- channel design levels;
- design vessel;
- vessel speed profile;
- wind data;
- wave data;
- tidal current data;
- water level;
- aids to navigation;
- bottom surface condition;
- channel slope; and,
- vessel passing (i.e. one-way or two-way).

2.2.1 Channel Design Reaches

For the purposes of the PIANC assessment, the existing channel was divided into six (6) reaches that correspond to changes in the alignment of the channel and degree of exposure. These are shown below (refer **Figure 2**) and comprise:

- Reach 1 – Fairway Buoy to Buoy 1/2;
- Reach 2 – Buoy 1/2 to Buoy 3/6;
- Reach 3 – Buoy 3/6 to Buoy 7;
- Reach 4 – Buoy 7 to Buoy 14;
- Reach 5 – Buoy 14 to Buoy 16; and,
- Reach 6 – Buoy 16 to Buoy 17.

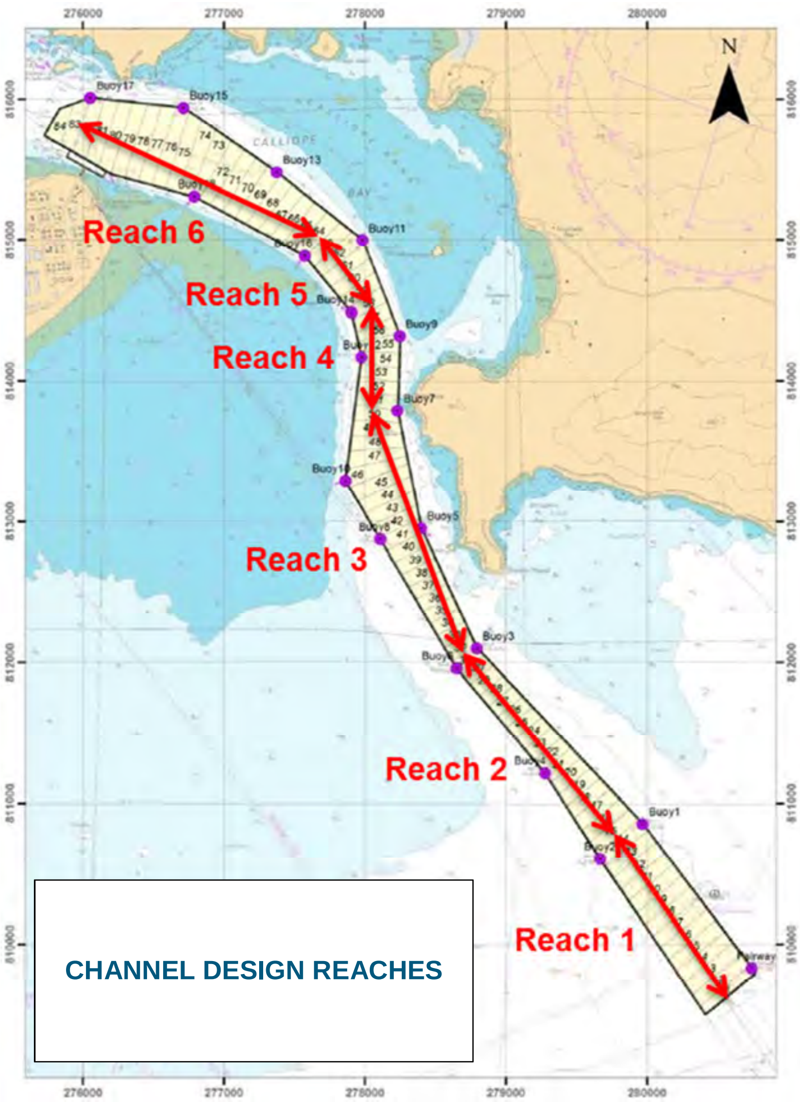


Figure 2: Channel Design Reaches

2.2.2 Channel Alignment

Several alternate channel alignment concepts were identified as part of the Channel Design Workshop held on 17th April 2015 and are denoted as Option 1, 2, 3 and 4. Channel alignment Option 5 was identified as part of a subsequent options assessment process. The features of these alignments and those that were selected for further conceptual design and assessment in the Desktop Simulation Study (refer **Section 4**) are discussed in **Section 3**.

2.2.3 Channel Design Levels

OMC developed vertical profiles at 100m spacing for different accessibility levels as part of their channel optimisation assessment (OMC, 2015a). This study considered the design for two channel access options (95% accessibility and 98% accessibility). The 98% access channel design for a 16.8m draft was used as a basis to prepare a stepped profile which may represent how the channel would be dredged in practice (refer **Figure 3**).

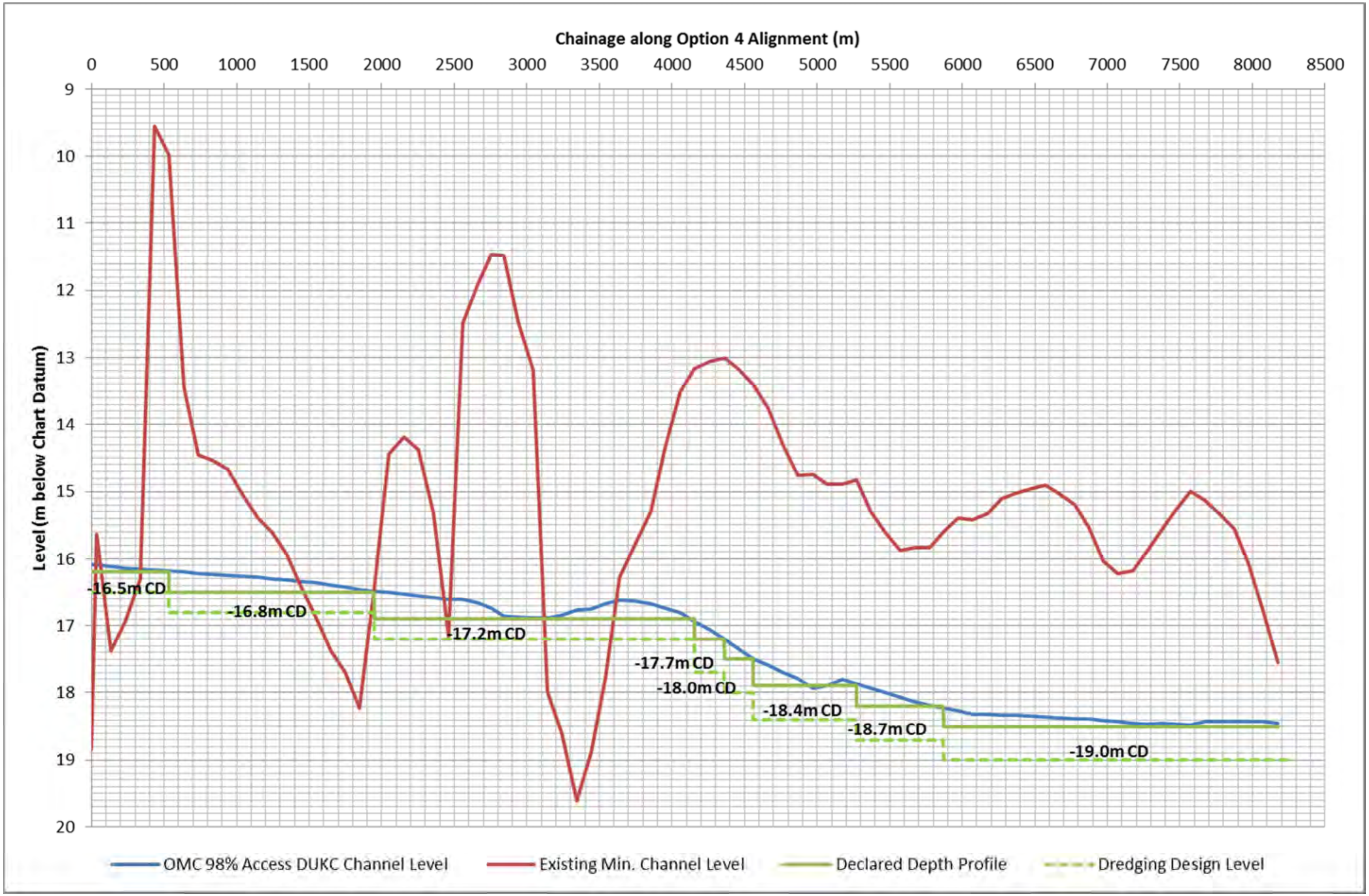


Figure 3: 16.8m Vessel Draft Channel Design Profile

The 'OMC 98% Dynamic Under Keel Clearance (DUKC) Access Channel Level' represents the minimum depth required to safely accommodate the proposed design ship draft under operational conditions. The OMC profile has been approximated with a series of steps referred to as the 'Declared Depth Profile' and would typically be referred to as the channel 'Declared Depth' (e.g. as shown on nautical charts).

However, an additional allowance is required to account for the potential future siltation of the channel between planned maintenance dredging campaigns. For relatively well protected and low siltation environments, an allowance of 0.2-0.3m is normally allowed. For very exposed and high siltation environments, an allowance of 0.5-1.0m+ may be more applicable. If specific sections of a channel are subject to siltation, then some localised measures may also be appropriate (e.g. greater siltation allowance at those sections, flatter batter slopes, dredging a 'hole' or 'trench' that the siltation can fall into, etc.) to ensure that any particular section of a channel does not become a future channel 'bottleneck'.

Siltation to a level that is above the declared depth of one particular section of a channel can lead to the entire channel being restricted (de-rated) to a lesser draft vessel (with operational and economic consequences); hence this is a significant consideration for all shipping channels.

For the purposes of the concept channel design (and the estimation of dredging volumes) a siltation allowance of 0.5m and 0.3m has been added to the declared depths for the outer and inner harbour areas respectively. The outer harbour is defined as the area offshore of Buoy 5 / Buoy 8. Generally, it would be expected that the outer channel will be subject to greater rates of sedimentation due to being located in a more exposed climate and for the inner channel, visa versa. The declared depth plus siltation allowance would normally be referred to as the 'Dredging Design Level'. The 'Dredging Design Level' is the target (or minimum) level for dredging.

The sedimentation allowances of 0.5m and 0.3m have subsequently been compared against the results of hydrodynamic and morphological numerical modelling undertaken by MetOcean Solutions (2016) and found to be suitable in terms of annual sedimentation allowance.

Finally, an allowance needs to be made for potential over-dredging, which is dredging below the required Dredging Design Level. Again, this can vary depending on a number of factors, including: type of dredging plant used, type of material being dredged, and metocean conditions during dredging. For the dredging of sand materials (as expected at this site), a typical allowance of 0.3m is allowed and has been used for this study. Typically, a dredging contractor would not be paid for over-dredged quantities (in order to discourage and minimise any over-dredging). However, this additional dredging volume would need to be taken into consideration in, for example, determining capacity of spoil grounds.

It should be noted that later Under Keel Clearance (UKC) design refinements by OMC (2015b) resulted in:

1. a slight reduction of the design vessel draft from 16.8m to 16.6m based on an understanding of the fleet of vessels that would be most likely to call at the port; and
2. the requirement to adopt the 'OMC 98% DUKC Access Channel Level' as the basis for the vertical design profile to avoid excessive delays by vessels accessing the port due to adverse weather conditions.

These minor modifications affected the design depths but did not have any impact on the PIANC design requirements for the channel and bend sizing, geometry and channel alignments.

2.2.4 Design Vessel

The adopted design vessel initially corresponded to that used for the OMC channel optimisation assessment for a '16.8m vessel draft' (OMC, 2015a). Relevant specifications of this design vessel comprised:

- Vessel type: Suezmax Tanker;
- 159,057 Dead Weight Tonnage (DWT);
- Beam (B) = 48m;
- Length overall (L_{OA}) = 274m;
- Length between perpendiculars (L_{BP}) = 264m; and
- Summer Draft (T) = 17.02m.

[Note: further into the channel design process, the design vessel draft was reduced to 16.6m, the beam increased to 50m and the LOA increased to 276m, at the request of RNZ, on the basis of their data base of Suezmax vessels. This is addressed in **Section 5**.

2.2.5 Vessel Speed Profile

The vessel speed profile (refer **Figure 4**) was provided by OMC and was used in their channel optimisation assessment (OMC, 2015a). The 'average' speed profile was adopted for use in the channel width assessment.

Figure 4: Vessel Speed Profiles (OMC, 2015a)

2.2.6 Wind Data

Wind data was obtained from MetOcean Solutions who provided an annual wind rose and seasonal/annual wind speed exceedance probabilities (refer **Figure 5** and **Table 1** respectively) based on measured wind speeds at Marsden Point from 2nd September 2009 to 1st May 2015.

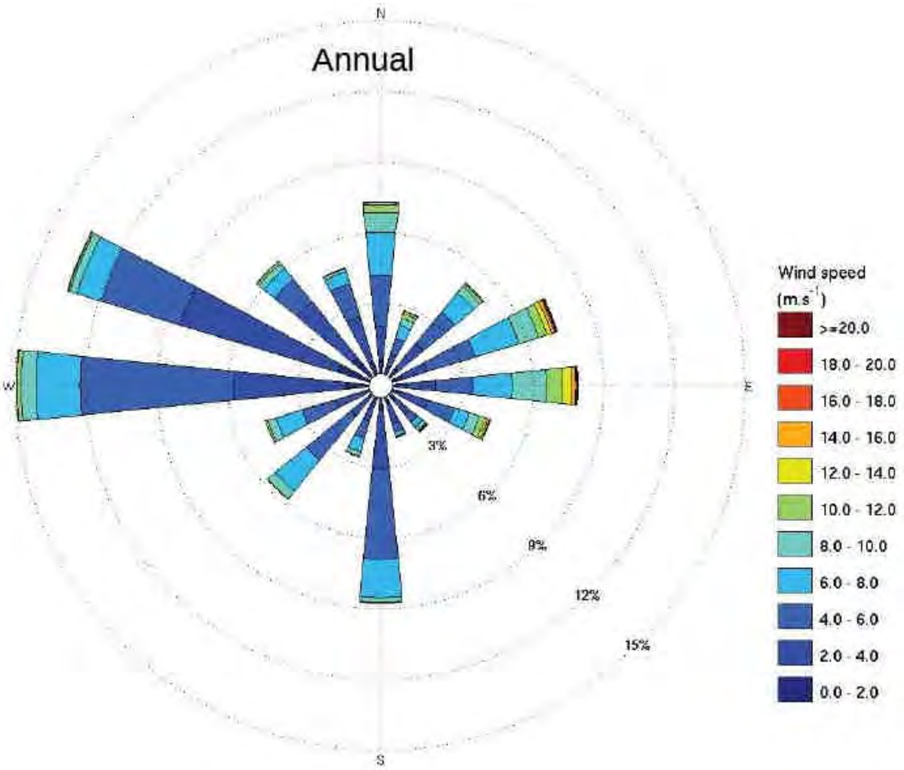


Figure 5: Annual Wind Rose at Marsden Point (MetOcean Solutions, 2015)

Table 1: Seasonal/annual Wind Speed Exceedance Probabilities for Marsden Point (MetOcean Solutions, 2015)

MARSDEN POINT (LOCATION: 174.50 E, -35.84 S)

Seasonal and annual wind speed exceedance probabilities (from 2nd of Septemper 2009 to 1st of May 2015)

U (m/s)	Exceedence (%)				
	Summer	Autumn	Winter	Spring	Year
>2	90.44	89.73	91.27	93.61	91.30
>4	60.23	56.96	58.41	65.06	60.30
>6	30.14	26.53	27.36	31.05	28.86
>8	11.56	10.60	13.19	10.88	11.51
>10	3.68	4.68	6.68	2.99	4.43
>12	1.32	2.23	3.30	0.62	1.81
>14	0.61	0.86	1.63	0.12	0.77
>16	0.10	0.28	0.75	0.02	0.27
>18	0.04	0.13	0.48	0.01	0.16
>20	0.00	0.03	0.21	0.00	0.06
>22	0.00	0.02	0.05	0.00	0.02
>24	0.00	0.00	0.02	0.00	0.00

2.2.7 Wave Data

Wave data was provided by OMC from the 'Alpha' Waverider buoy located near the centre of Reach 1 (refer **Figure 2** for location). The 1% exceedance probability swell and sea height was transformed to the centre of each channel Design Reach using the wave attenuation factors provided by OMC, which are summarised in **Table 2**. The 1% exceedance probability wave period for swell and sea was reported by OMC to be 22.22 seconds and 6.9 seconds respectively.

Table 2: 1% Exceedance Probability Wave Conditions

Location	Wave Attenuation Factor	Swell Height (H_s, m)	Sea Height (H_s, m)
Reach 1 (centre)	1	2.4	1.55
Reach 2 (centre)	0.8	1.9	1.2
Reach 3 (centre)	0.36	0.9	0.6
Reach 4 (centre)	0.24	0.6	0.4
Reach 5 (centre)	0.24	0.6	0.4
Reach 6 (centre)	0.24	0.6	0.4

It is noted that wave modelling has been undertaken by MetOcean Solutions (2016) to assess the impact of the dredged channel on coastal/estuary processes. The anticipated effects of the channel deepening on the wave climate are reported to be as follows:

- *"The effect on the mean significant wave height fields is likely to be very subtle and does not exceed 2 cm. During storm events, these changes in the significant wave height fields may reach 20 cm in discrete locations.*
- *The offshore extent of the deepened channel modifies the refraction pattern of waves at the delta entrance. Enhanced refraction occurring along the eastern margin of the deepened channel is predicted to increase wave height at Busby Head and offshore of Smugglers Bay up to a maximum of 10 and 15 cm respectively.*
- *Conversely, a minor decrease of wave height (1 – 2 cm on average) is expected along sections of Ruakaka Beach, while the maximum increase is 2 cm. Note that modifications of the wave refraction at the distal margin of the channel may generate a zone to the north of the river mouth characterised by a slight increase of the wave height (up to a 5 cm maximum).*
- *Changes in wave height over Mair Bank are not expected to exceed 2 cm".*

Any changes in wave characteristics as a result of dredging associated with the Crude Shipping Project are not expected to materially impact on the conclusions of this report.

2.2.8 Tidal Current Data

ADCP tidal current data was collected and analysed by Ross Vennell (Department of Marine Science, University of Otago). This analysed data was used to characterise the longitudinal and cross currents within each channel Design Reach. The data was collected over a spring tide period with a 2.5m range from 18th May to 21st May 2015. The plots of current velocity vectors were reviewed to determine the maximum current velocities (and corresponding directions) for a period of 1 hour either side of high water, which corresponds to the proposed transit window for the Suezmax design vessel. The magnitude of longitudinal and cross currents was determined from the heading of the proposed Option 4 and Option 2 channel alignments (refer **Section 3**) relative to the direction of the current vectors.

The longitudinal and cross current velocities determined for each Design Reach along the Option 4 channel alignment are summarised in **Table 3** and **Table 4**, which correspond to ebb tide (1 hour after high water) and flood tide (1 hour before high water) respectively. The maximum ebb or flood tide longitudinal and cross currents were selected for the PIANC channel width assessment.

Table 3: Option 4 Ebb Current Velocities at High Water +1 hour

Location	Channel Alignment (deg. from N)	Maximum Current Velocity (knots)	Worst Direction Cross Currents (deg. from N)	Cross Current (knots)	Worst Direction Longitudinal Currents (deg. from N)	Longitudinal Current (knots)
Reach 1	141	0.4	141	0.0	141	0.4
Reach 2	141	0.4	125	0.1	141	0.4
Reach 3	180	0.8	155	0.3	180	0.8
Reach 4	180	1.0	160	0.3	180	1.0
Reach 5	121 to 180	1.0	155	0.4	135	1.0
Reach 6	121	1.4	135	0.3	121	1.4

Table 4: Option 4 Flood Current Velocities at High Water -1 hour

Location	Channel Alignment (deg. from N)	Maximum Current Velocity (knots)	Worst Direction Cross Currents (deg. from N)	Cross Current (knots)	Worst Direction Longitudinal Currents (deg. from N)	Longitudinal Current (knots)
Reach 1	321	0.4	275	0.3	280	0.3
Reach 2	321	0.4	280	0.3	290	0.3
Reach 3	0	1.3	325	0.7	0	1.3
Reach 4	0	1.5	10	0.3	0	1.5
Reach 5	301 to 0	1.5	345	0.7	330	1.5
Reach 6	301	1.5	330	301	301	1.5

The longitudinal and cross currents determined for the Option 2 channel alignment are summarised in **Table 5** and **Table 6**.

Table 5: Option 2 Ebb Current Velocities at High Water +1 hour

Location	Channel Alignment (deg. from N)	Maximum Current Velocity (knots)	Worst Direction Cross Currents (deg. from N)	Cross Current (knots)	Worst Direction Longitudinal Currents (deg. from N)	Longitudinal Current (knots)
Reach 1	141	0.4	141	0.0	141	0.4
Reach 2	141	0.4	125	0.1	141	0.4
Reach 3	165	0.8	180	0.2	165	0.8
Reach 4	189	1.0	160	0.5	189	1.0
Reach 5	121 to 189	1.0	155	0.6	135	1.0
Reach 6	121	1.4	135	0.3	121	1.4

Table 6: Option 2 Flood Current Velocities at High Water -1 hour

Location	Channel Alignment (deg. from N)	Maximum Current Velocity (knots)	Worst Direction Cross Currents (deg. from N)	Cross Current (knots)	Worst Direction Longitudinal Currents (deg. from N)	Longitudinal Current (knots)
Reach 1	321	0.4	275	0.3	280	0.3
Reach 2	321	0.4	280	0.3	290	0.3
Reach 3	345	1.3	0	0.3	345	1.3
Reach 4	9	1.5	0	0.2	9	1.5
Reach 5	301 to 9	1.5	345	0.7	330	1.5
Reach 6	301	1.5	330	0.7	301	1.5

2.2.9 Water Level

Tidal levels at Marsden Point, based on the Northport Operational Handbook, are as follows (Northport, 2015):

Mean High Water Spring (MHWS)	2.7m
Mean High Water Neap (MHWN)	2.3m
Mean Low Water Neap (MLWN)	0.8m
Mean Low Water Spring (MLWS)	0.4m

All water levels are relative to Chart Datum (CD).

The water level adopted for the PIANC width assessment was MHWN. This was considered to represent an average 'high water' access condition for vessels entering the port.

2.2.10 Aids to Navigation

Aids to navigation (AtoN) were characterised as "good" in accordance with the PIANC design procedure, which corresponds to the provision and availability of paired lighted buoys/lighted leading lines, availability of pilots and DGPS (Differential Global Positioning System).

Proposed additional AtoN, and reconfiguring of some existing AtoN, is presented is **Section 7**.

2.2.11 Bottom Surface Condition

The bottom surface condition was characterised as "smooth and soft" in accordance with the PIANC design procedure.

2.2.12 Channel Slope

The channel slope was characterised as having "sloping channel edges and shoals" in accordance with the PIANC design procedure, which corresponds to channel batters that are not flatter than 1V:10H.

2.2.13 Vessel Passing

A 'one-way' channel was adopted for navigation of the design vessel. This follows current practice where the passing of tankers (and other large vessels) is not permitted.

2.3 Bend Geometry

The bend geometry for each alignment was determined using PIANC guidance as summarised in **Section 2.1**. The PIANC guidelines note that when transiting a bend in an approach channel the width of the 'swept path' of a vessel will increase. The additional channel width required to accommodate this effect comprises two components:

- the additional with due to drift angle; and
- the additional width due to response time (of the ship-handler).

The additional width due to the drift angle of the vessel can be determined by using the following formula:

$$\Delta W_{DA} = \frac{{L_{oa}}^2}{aR_C}$$

Where:

ΔW_{DA} = additional width of the vessel's swept path due to drift angle in a curved channel section
R_C = bend radius
L_{oa} = vessel length overall
a = factor depending on the ship type: a=4.5 for larger displacement ships (tankers, bulk carriers etc.)

The following width allowance is recommended to compensate for the time delay of the ship handler in responding to a required alteration in course:

$$\Delta W_{RT} \quad = 0.4B$$

Where:

B = vessel beam

Both of the allowances for additional bend width (i.e. ΔW_{DA} and ΔW_{RT}) were added to the largest channel width approaching each bend to determine the maximum width applied at the apex of each channel bend.

2.4 Berth Area Geometry

The plan geometry of the berth pocket at the Crude Jetty was determined using guidance provided within literature (Thoresen, 2014). This recommends that the berth pocket should have a length of 1.25 times the length overall (LOA) and a width of 1.5 times the beam of the design vessel. This corresponds to a berth pocket 345m long and 75m wide.

3 OPTIONS ASSESSMENT

3.1 General

A Channel Design Workshop was held on 17th April 2015, during which preliminary PIANC channel design widths and several alternate channel alignments were presented by RHDHV and discussed with representatives from Refining NZ, NorthTugz, Northport and the Harbour Master. A technical memorandum documenting the preliminary channel width assessment and the discussions during the Channel Design Workshop was prepared by RHDHV and is provided within **Appendix A** for reference.

The results of the preliminary channel width assessment (based on available metocean information at the time) indicated that the PIANC channel widths were generally less than the navigation widths currently defined by the existing buoy positions. Several alternate alignments for the access channel were presented and further developed based on discussions held during the Channel Design Workshop. These alignments are denoted as Option 1, 2, 3 and 4. Channel alignment Option 5 was identified as part of a subsequent options assessment process. The features of these channel alignments are discussed below and selected channel alignments were further refined and tested in the Desktop Simulation Study (refer **Section 4**).

The Channel Design Workshop also helped to identify some gaps in the available measured data, which would improve further analysis, including tidal currents and wind speeds. As a result, additional tidal current data was collected in May 2015 using an Acoustic Doppler Current Profiler (ADCP) mounted to a survey vessel (refer **Section 2.2.8**). Longer records of measured wind data at Marsden Point were also accessed (refer **Section 2.2.6**). This data was used to refine the channel designs ahead of the Desktop Simulation Study, which was undertaken by Be-Software (under the management of RHDHV) in July and September 2015 (refer **Section 4**).

3.2 Option 1

Channel design Option 1 is shown schematically on **Figure 6** and comprises the preliminary determined PIANC channel width (nominally 200 metres wide) along an alignment that keeps within the existing buoyed navigation area ("fairway") and closely follows the current shipping channel centreline. This design includes five (5) changes in alignment and a 900m length between changes in alignment through the critical Home Point stretch. It is noted that this distance is less than five (5) times the length overall (L_{OA}) of the design vessel (i.e. 5 x 274m = 1,370m) as recommended by PIANC. Furthermore, after curved bend geometry is taken into account for both bends, this distance would reduce further.

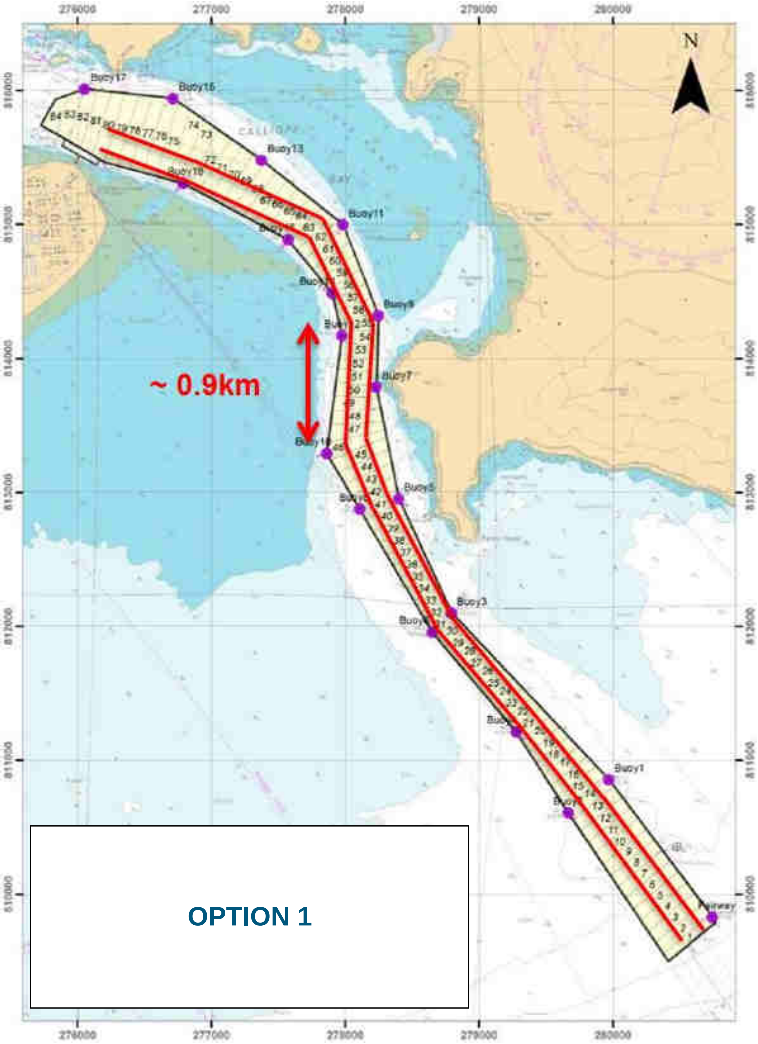


Figure 6: Channel Design 'Option 1' (delineated in red)

3.3 Option 2

Channel design Option 2 is shown schematically on **Figure 7** and aimed to increase the distance between changes in channel alignment through the critical Home Point stretch to 1.3km (although this would be reduced after curved bend geometry is taken into account) within the existing fairway. This alignment follows the existing channel route and requires the same number of changes in heading and bends to navigate as channel design Option 1. However, due to the potential increase in distance between bends through the Home Point stretch, Option 2 was selected over Option 1 for further refinement and desktop simulation.

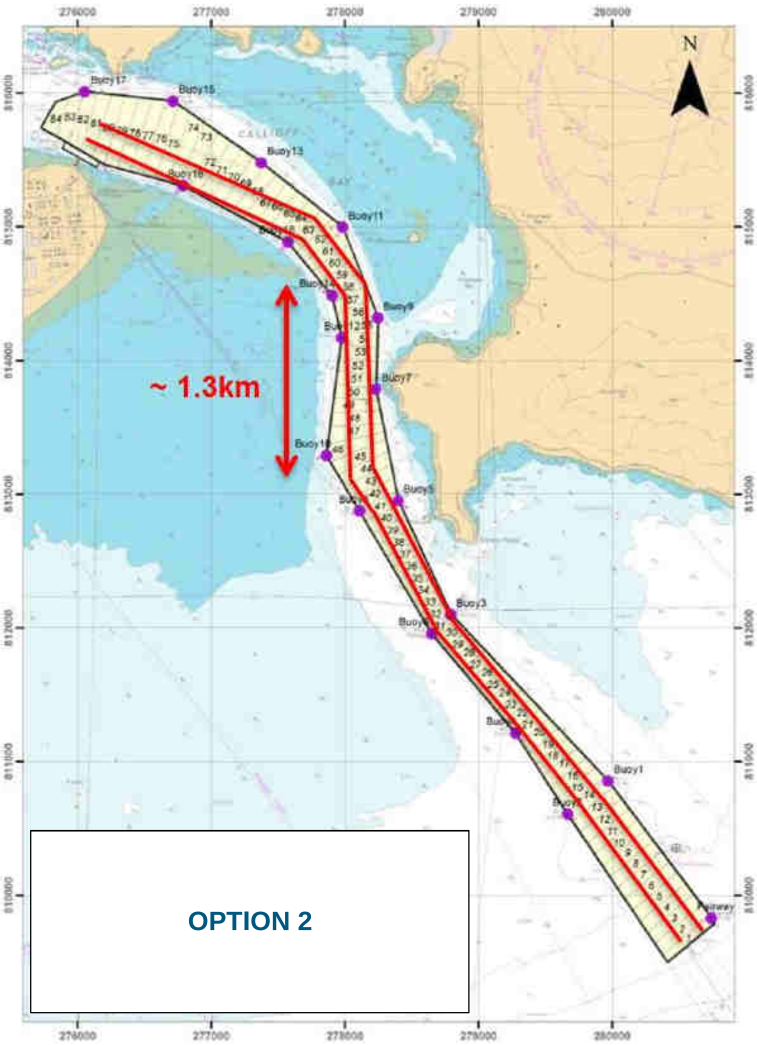


Figure 7: Channel Design 'Option 2' (delineated in red)

The results of the more detailed PIANC channel width assessment for the Option 2 alignment are summarised in **Table 7**. Detailed calculation sheets are provided within **Appendix B**.

Table 7: Option 2 PIANC Channel Width Assessment Results

Location	Description	Beam Multiplier	PIANC Width (m)
Reach 1	Fairway Buoy to Buoy 1/2	4.3	210
Reach 2	Buoy 1/2 to Buoy 3/6	4.3	210
Reach 3	Buoy 3/6 to Buoy 7	4.0	190
Reach 4	Buoy 7 to Buoy 14	4.2	200
Reach 5	Buoy 14 to Buoy 16	4.7	230
Reach 6	Buoy 16 to Buoy 17	4.7	230

The bend geometry for the Option 2 alignment was determined using PIANC guidance as summarised in **Section 2.1** and **Section 2.3**. **Table 8** summarises the calculation of the additional width allowances for Drift Angle and Response Time to determine the bend widths for Option 2.

Table 8: Option 2 Bend Geometry

Bend No.	Bend Radius (m)	Drift Angle Width (m)	Response Time Width (m)	Maximum Approach Channel Width (m)	Bend Width (m)
1	1370	12.2	19.2	210	240
2	1370	12.2	19.2	200	230
3	800	20.9	19.2	230	270

The refined Option 2 design alignment was documented on a concept design drawing ahead of the Desktop Simulation Study (refer to drawing PA1028-MA-1201 Revision D in the **Drawings**).

3.4 Option 3

Channel design Option 3 is shown schematically on **Figure 8** and provides a further increase in the distance between changes in channel alignment through the Home Point stretch to 1.6km (although this would be reduced after curved bend geometry is taken into account) by extending the channel alignment outside the existing buoyed navigation area in the vicinity of Buoy 8. This alignment also reduces the number of changes in heading to a total of four (4) when compared to five (5) changes in heading for Option 1 and Option 2. Option 3 was considered to potentially improve navigational conditions by participants at the Channel Design Workshop and was subsequently refined in further discussions to develop channel design Option 4 (refer **Section 3.5**).

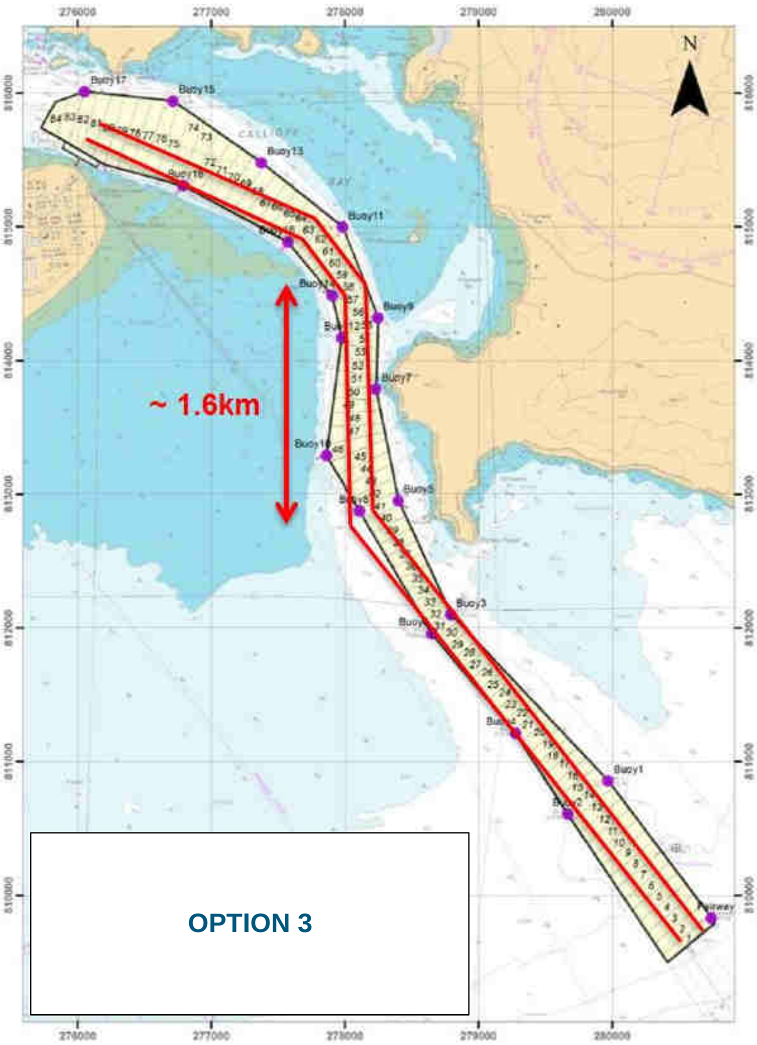


Figure 8: Channel Design 'Option 3' (delineated in red)

3.5 Option 4

As discussed, channel design Option 4 was identified as a refinement to Option 3 during the Channel Design Workshop and is shown schematically on **Figure 9**. The principal benefits achieved by the Option 4 alignment are:

- the simplification of the channel route into three (3) main headings (from five (5) heading changes in Option 1 and Option 2), by creating a single bend from Buoy 14 to Buoy 16 as a refinement to Option 3;
- the reduction of the number of bends (to two only) that need to be navigated by vessels;
- increasing the distance between changes in channel alignment, particularly through the critical Home Point stretch (from ~0.9km to ~1.6km taken from centre to centre of the bends); and,
- maximising the use of the existing leads on the fairway approach channel (which required the channel to lie outside the existing fairway around Buoy No 8).

As an outcome of the Channel Design Workshop, Option 4 was selected for further refinement and desktop simulation.

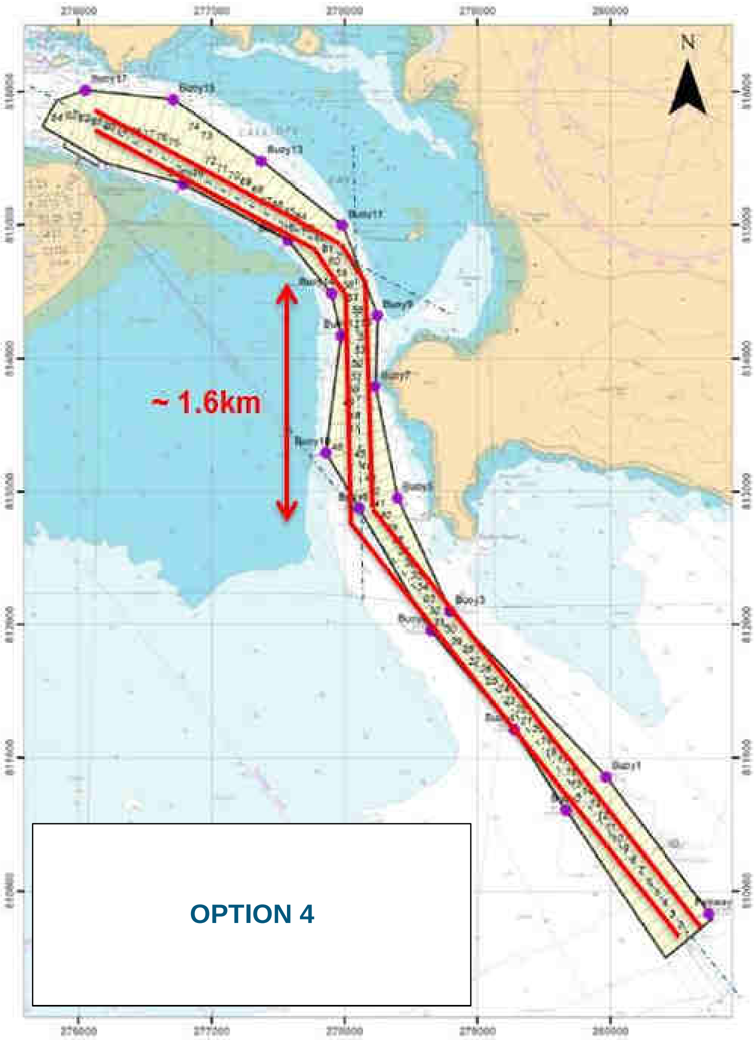


Figure 9: Channel Design 'Option 4' (delineated in red)

The results of the detailed PIANC channel width assessment for the Option 4 alignment are summarised in **Table 9**. Detailed calculation sheets are provided within **Appendix B**.

Table 9: Option 4 PIANC Channel Width Assessment Results

Location	Description	Beam Multiplier	PIANC Width (m)
Reach 1	Fairway Buoy to Buoy 1/2	4.3	210
Reach 2	Buoy 1/2 to Buoy 3/6	4.3	210
Reach 3	Buoy 3/6 to Buoy 7	4.5	220
Reach 4	Buoy 7 to Buoy 14	4.2	200
Reach 5	Buoy 14 to Buoy 16	4.7	230
Reach 6	Buoy 16 to Buoy 17	4.7	230

The bend geometry for the Option 4 alignment was determined using PIANC guidance as summarised in **Section 2.1** and **Section 2.3**. **Table 10** summarises the calculation of the additional width allowances for Drift Angle and Response Time to determine the bend widths for Option 4.

Table 10: Option 4 Bend Geometry

Bend No.	Bend Radius (m)	Drift Angle Width (m)	Response Time Width (m)	Maximum Approach Channel Width (m)	Bend Width (m)
1	1370	12.2	19.2	220	250
2	530	31.5	19.2	230	280

The Option 4 design alignment was documented on a concept design drawing ahead of the Desktop Simulation Study (refer to drawing PA1028-MA-1101 Revision B in the **Drawings**).

3.5.1 Option 4-1

During the final stages of the first round of the Desktop Simulation Study (refer **Section 4.1**), discussions were held between the simulation team and the NorthTugz pilots, Tugmasters and the Harbour Master. As a result, some further refinements were made to Option 4, following the immediate outcomes of the simulation. These amendments are discussed further in the Desktop Simulation Study (refer **Section 4**).

The Option 4 PIANC channel width assessment results were not amended; however, the adjustments affected Bend No. 2 geometry, as shown in **Table 11** (modified bend radius shown in bold).

Table 11: Option 4-1 Bend Geometry

Bend No.	Bend Radius (m)	Drift Angle Width (m)	Response Time Width (m)	Maximum Approach Channel Width (m)	Bend Width (m)
1	1370	12.2	19.2	220	250
2	**580**	28.8	19.2	230	280

The Option 4-1 design alignment was documented on a concept design drawing, representing the modified design for Option 4 following the first round of the Desktop Simulation Study (refer to drawing PA1028-MA-1111 Revision A in the **Drawings**). The drawing shows the proposed channel toe lines as a 'black' dashed lines, the PIANC channel toe lines as a 'green' dashed line (generally within the envelope of the 'buoy to buoy' navigation area beyond Buoy 3/6) and details of shifted and new navigation markers.

3.5.2 Option 4-2

Following the first round of the Desktop Simulation Study (refer **Section 4.1**), Bend No. 2 within the Option 4-1 alignment appeared to remain of some concern for the pilots for ship handling purposes, particularly as its radius of 580m was less than the PIANC recommendation of 1370m. Although the PIANC recommendation is for a radius of 5 x L_{OA}, a smaller radius can be adopted if tested through suitable simulation studies under varying conditions and vessel manoeuvring can be undertaken safely.

To address this issue more effectively, a minor modification to Option 4-1 was developed prior to the second round of the Desktop Simulation Study (refer **Section 4.2**) in order to accommodate a gentler bend with an 800m radius at this location. This was achieved in Option 4-2 through the slight re-adjustment of the existing buoys, specifically Buoy 14 which was moved to the north-west. In addition, the north-south (N-S) channel alignment was moved (32m) to the east so that the eastern toe line of the channel lined up with the existing position of Buoy 7.

This provided the additional bend width required to accommodate the 800m radius bend alignment, which was the maximum radius that could be achieved without further encroachment into the adjacent shallow areas of Mair Bank (west, Buoy 12/14) and Calliope Bank (east, Buoy 11). The second round of Desktop Simulation Study was used to assess the navigability of this revised bend alignment (refer **Section 4.2**).

Whilst it was not possible to achieve the PIANC recommended 1370m bend radius due to natural channel restrictions, Option 4-2 did provide for additional sea room before and after the bend (refer **Figure 10)**. This proved useful in the simulations, especially at Buoy 9 which provided additional manoeuvring space prior to the vessel passing Home Point.

Figure 10: Option 4-2 showing PIANC width and R=800m bend (green shading) and additional sea room (yellow shading)

Table 12 summarises the calculation of the additional width allowances for Drift Angle and Response Time to determine the bend widths for Option 4-2 (modified bend radius shown in bold). The PIANC channel width assessment remained the same as for Option 4.

Table 12: Option 4-2 Bend Geometry

Bend No.	Bend Radius (m)	Drift Angle Width (m)	Response Time Width (m)	Maximum Approach Channel Width (m)	Bend Width (m)
1	1370	12.2	19.2	220	250
2	**800**	20.9	19.2	230	270

The Option 4-2 design alignment was documented on a concept design drawing ahead of the second round of the Desktop Simulation Study (refer to drawing PA1028-MA-1121 Revision M in the **Drawings**).

3.6 Option 5

Option 5 was developed following the first round of the Desktop Simulation Study as an alternative to Option 4 and aimed to avoid any dredging adjacent to Buoy 12/14.

In order to accommodate this, the Option 4-1 N-S channel alignment was moved a further 57m to the east relative to the Option 4-2 alignment. As a result, Buoy 7 also had to be moved a similar distance to the east and, as a consequence, this option would require dredging at Home Point, an area known to contain rock boulders and bedrock.

In comparison to Option 4-2, this option provided almost no sea room around Buoy 9 for departing vessels approaching Home Point, refer **Figure 11**. This proved to be less favourable and less safe, as further detailed in **Section 4.2,** as it effectively meant that the pilots had little room for manoeuvring correction on departure approaching Home Point.

The PIANC channel width assessment and bend geometry remained the same as for Option 4.

The Option 5 design alignment was documented on a concept design drawing ahead of the second round of the Desktop Simulation Study (refer to drawing PA1028-MA-1301 Revision A in the **Drawings**).

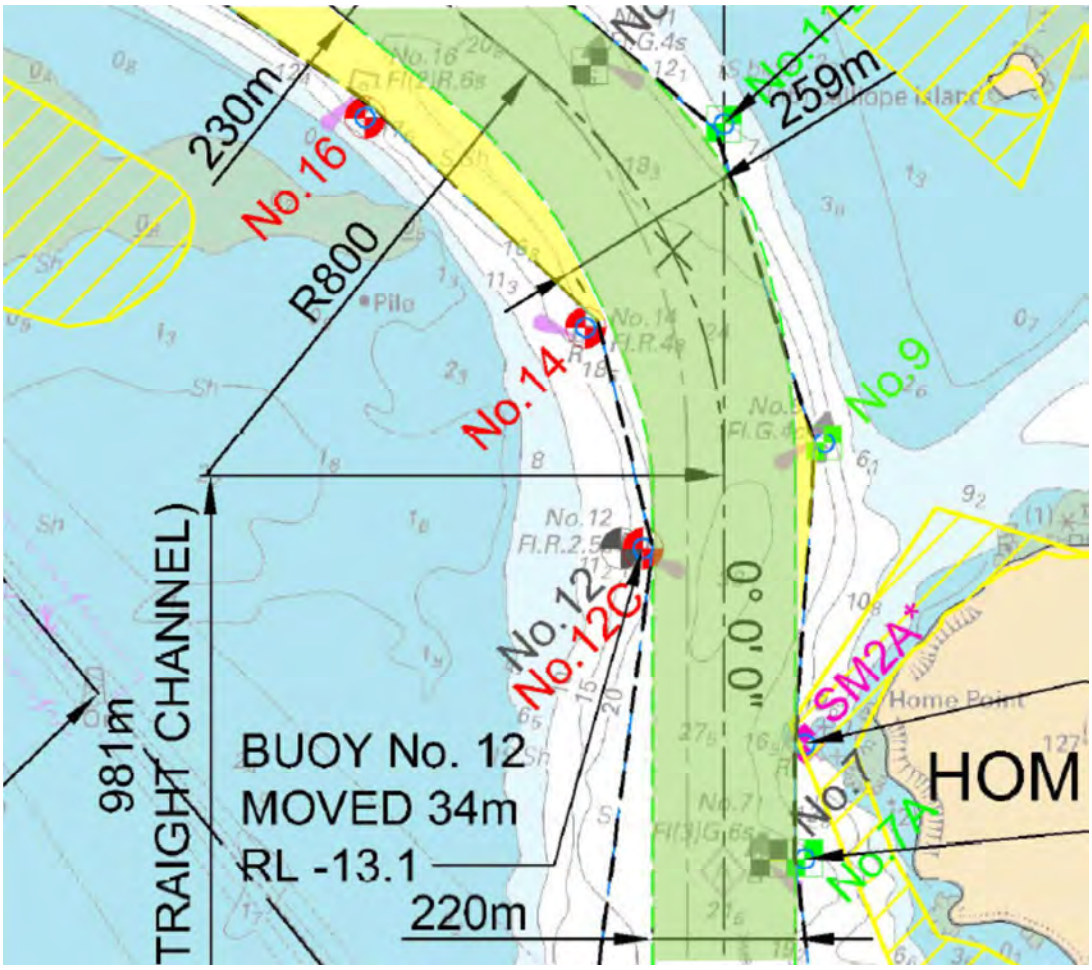


Figure 11: Option 5 showing PIANC width and R=800m bend (green shading) and additional sea room (yellow shading)

3.7 Navigation Buoys and Markers

In order to accommodate the changes (improvements) to navigation, a number of the existing buoys would require moving in order to reflect the revised channel geometry. Where possible, it was preferred to avoid any buoy movement and, where movement was necessary, it was preferred to limit this as much as possible. It should be noted that the modification of existing navigation aids would need to be approved through a formal process that involves stakeholders including the Harbour Master and Maritime New Zealand.

Table 13 summarises an early assessment of the required buoy movements for each channel alignment option discussed above. Note that in respect of Options 2 and 4-2, these buoy movements are now superseded by those in **Table 19** within **Section 5** of this report, which incorporate certain refinements.

Table 13: Required movement of existing buoys

Buoy No.	Option 2	Option 4-1	Option 4-2	Option 5	Reason	Justification
Drawing No.	PA1028-MA-1201 Rev B	PA1028-MA-1111 Rev A	PA1028-MA-1121 Rev A	PA1028-MA-1301 Rev A	-	-
1	-	-	-	-	-	-
2	-	-	-	-	-	-
3	20m NE	20m NE	20m NE	20m NE	Moved out to accommodate design channel along lead-line	PIANC channel width is wider than existing buoyed channel
4	-	-	-	-	-	-
5	-	105m NW	105m NW	105m NW	Moved in to avoid dredging near Busby Head	PIANC 5xLOA radius is achievable
6	-	-	-	-	-	-
7	-	-	-	55m E	Moved out to accommodate N-S centreline shift	N-S centreline shift to the east avoids dredging of Mair Bank
8	-	105m SW	75m SW	112m S	Moved out to align with N-S centreline, and accommodate PIANC bend	Provides visual guide for pilots to follow N-S centreline
9	-	-	-	-	-	-
10	-	-	-	-	-	-
11	130m E	120m E	150m SE	225m SE	Moved out to align with N-S centreline, and accommodate PIANC bend	Provides visual guide for pilots to follow N-S centreline and additional bend width
12	-	55m W	23m W	34m E	Moved in/out to accommodate N-S channel alignment	Reduce number of heading changes and avoid dredging of Mair Bank (Option 5)
13	-	-	-	-	-	-
14	-	-	53m NW	-	Moved out to accommodate increased bend radius	Improved navigability of critical Bend No.2
15	-	-	-	-	-	-
16	-	-	-	-	-	-
17	-	-	-	-	-	-
18	-	128m E	128m E	128m E	Moved East to avoid dredging Mair Bank and keep turning circle inside channel	PIANC channel width is wider than existing buoyed channel
Note that the above buoy movements are now superseded by those in Table 19 within Section 5 of this report.						

In addition, some new bouys/markers were added to the navigation system, in consultation with the NorthTugz pilots, Tugmasters and the Harbour Master, as summarised in **Table 14**.

Table 14: New buoys / markers required

Buoy No.	Option 2	Option 4-1	Option 4-2	Option 5	Reason	Justification
PB1	Yes	Yes	Yes	Yes	Port Buoy to mark end of deeper channel	Channel has been extended and Port Buoy marks entry point
SM2	Yes	Yes	Yes	Yes	Special Marker to mark expected rock outcrop at Home Point	Clearly marking danger

4 DESKTOP SIMULATION STUDY

4.1 Desktop (Portable) Simulation (July 2015)

The first round of the Desktop (Portable) Simulation Study was undertaken from 27th to 31st July 2015 at the NorthTugz offices at Marsden Point and was facilitated by Bruce Goodchild of Be-Software. The simulation set up comprised an instrument console, a manoeuvring display and five (5) 36" TV monitors providing a 200 degree horizontal field of view (refer **Figure 12**).

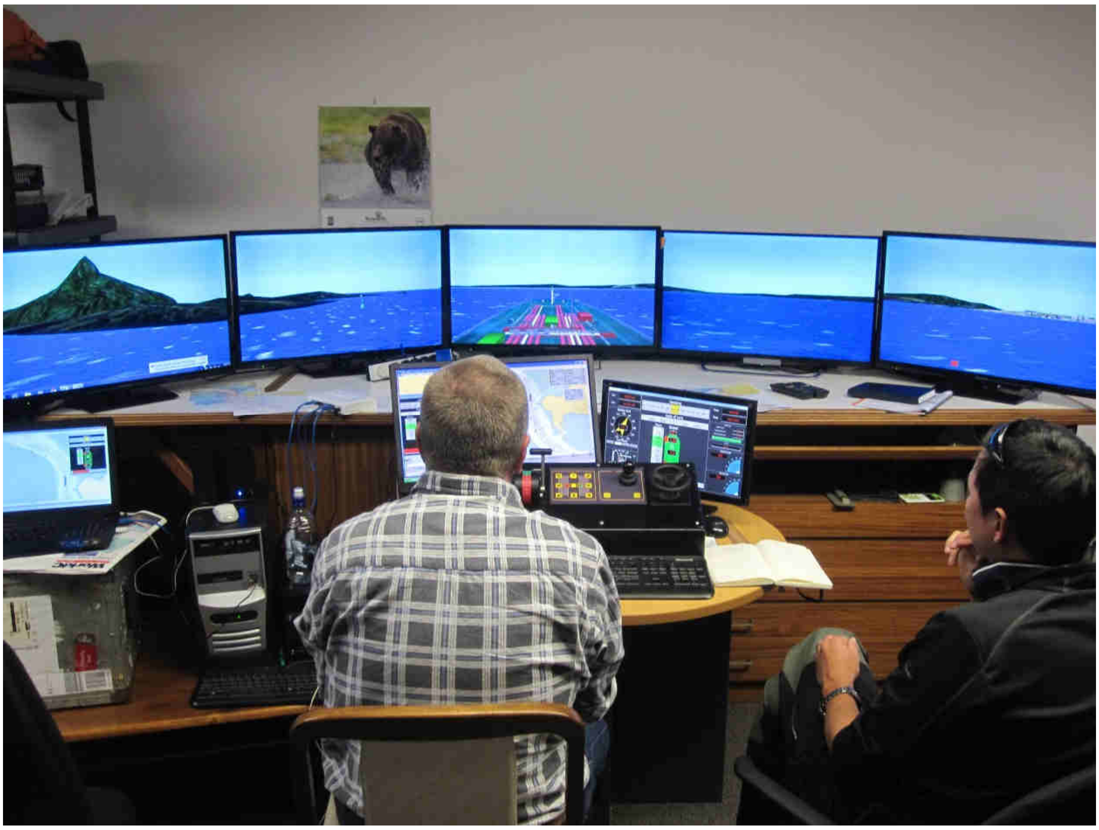


Figure 12: Desktop simulation set up

The simulation runs were completed by a range of participants including Bruce Goodchild, NorthTugz pilots and Tugmasters, and the Harbour Master. The simulation run program extended over a period of 5 days and involved the following main phases:

- calibration of ship models on the existing navigation channel;
- simulation runs on the Option 4 and Option 2 channel alignments under a range of environmental conditions ranging from average to limiting operational conditions and using the following vessels;
  - loaded Suezmax design vessel (17m draft) arrivals at High Water (slack tide);
  - ballast Suezmax design vessel (7.0-7.5m draft) departures on full ebb and flood tides;
  - partially loaded Suezmax design vessel (14.5m draft) at various states of the tide; and,
  - loaded Logship (12m draft) arrivals and departures on full ebb and flood tides.

- berthing of loaded Suezmax design vessel (17m draft) on to the Crude Jetty using the existing tugs, 'Bream Bay' and 'Takahiwai';
- swinging of ballast Suezmax design vessel (7.0-7.5m draft) on departure from the Crude Jetty using the existing tugs, 'Bream Bay' and 'Takahiwai' on full ebb tide; and,
- simulation of a range of emergency scenarios including loss of rudder control, loss of engine power and complete vessel blackout using the loaded Suezmax design vessel (17m draft) on arrivals, and ballast Suezmax design vessel (7.0-7.5m draft) and Logship (12m draft) on departures.

The desktop simulation study report prepared by Be-Software is provided within **Appendix C** and documents the feedback provided by pilots for each simulation run and the conclusions and recommendations of the study. Those relating to the first round of the Desktop Simulation Study are summarised below:

- the PIANC channel width of 210m nominated for the approach channel from the Fairway Buoy to Buoy 3/6 was considered to be adequate for the arrival (loaded) and departure (ballast) of the design vessel;
- the buoys between the Fairway Buoy and Buoy 3/6 should remain in their current positions, with the exception of Buoy 3 which needs to be moved outside the toe line of the proposed channel, and a new red port hand buoy should be installed abreast of the existing Fairway Buoy to mark the start of the proposed channel;
- beyond Buoy 3/6 it was considered that both the Option 4 and Option 2 channel would support the arrival and departure of the design vessel without tug assistance, however there was a clear preference amongst the pilots for the Option 4 channel alignment;
- the design Suezmax vessel was able to successfully execute the turn at Buoy 14 on arrivals and this was assisted by shifting Buoy 11 to the east;
- on departures the ballast Suezmax vessel was able to execute the turn at Buoy 14 and shifting Buoy 12 simplified the turn and enabled pilots to keep to the west to avoid the shallow water off Home Point. This was considered by the pilots to be particularly important for smaller vessels that can be underpowered and therefore affected more by peak ebb tidal currents;
- for the Option 4 channel alignment the following buoy positions were considered to improve navigation:
    - shifting of Buoy 12 to the west to accommodate the N-S alignment of the channel and to allow a single turn to be possible on departure and arrival in a critical area;
    - shifting of Buoy 11 further east to provide additional sea room in the event of a delayed turn around Buoy 14 on arrival and to provide additional area for correction of vessels in an emergency situation;
    - alignment of Buoy 11 and Buoy 8 to provide a N-S lead along the centreline of the central leg of the channel alignment;
    - inward shifting of Buoy 5 by a small undefined amount to minimise dredging; and
    - installation of an additional beacon directly off the Home Point rock outcrop.

- between Buoy 3/6 and Buoy 17 dredging of the channel should generally be undertaken from 'buoy to buoy';
- maintaining the existing positions of Buoy 13 and 15 was considered necessary to provide important navigation width for exiting the turn at Buoy 14 on arrival, a turning area off the Crude Jetty, and an area for vessel correction and safe anchorage in an emergency situation; and
- The longer distance between successive bends helped to avoid the need for a complex "S-Bend" manoeuvre at the higher risk Home Point location.

The channel alignment modifications described above resulted in the development of Option 4-1 and Option 4-2 (as described in **Section 3.5**).

In addition to the channel alignment Option 4 modifications, an additional channel alignment (Option 5) was developed as an alternative to avoid any dredging adjacent to Buoys 12/14 along Mair Bank (as described in **Section 3.6**). The Option 5 channel alignment involved a movement of the N-S channel alignment further to the east, but requires dredging in the vicinity of Home Point. This new channel alignment also requires the relocation of the existing No 7 and No 12 buoys.

4.2 Desktop Simulation Study (September 2015)

The second round of the Desktop Simulation Study was undertaken from 29th to 30th September 2015 and was facilitated by Bruce Goodchild of Be-Software. Simulations were conducted within the Melbourne office of Be-software and were accessed remotely via a real-time interactive link. This allowed participants to not only view the simulations, but also ask questions and get updates at any time during the simulation.

The simulation runs were completed by Bruce Goodchild acting as the pilot and Kirit Barot (Master Mariner Class 1 with 37 years of shipping experience and pilot within Whangarei Harbour) remotely observing and commenting, when he was available. Other observers during the simulation period included Richard Mocke and Matt Potter of RHDHV.

The simulation run program extended over a period of 2 days and involved the following main exercises:

- simulation runs with the loaded Suezmax design vessel (17m draft) arriving within the Option 4-2 and Option 5 channels under limiting environmental conditions (30 knot winds);
- simulation runs with the loaded Logship (12m draft) arriving within the Option 4-2 and Option 5 channels under limiting environmental conditions (30 knot winds) at the peak of ebb and flood tidal flows;
- simulation of berth approach and berthing manoeuvres with arrivals of the loaded Suezmax design vessel (17m draft);
- simulation of berth departures to clear Buoy 7 with the ballast Suezmax design vessel (7.0-7.5m draft) within the Option 4-2 and Option 5 channels under limiting environmental conditions (30 knot winds) at the peak of ebb and flood tidal flows;

- simulation runs with the loaded Logship (12m draft) departing within the Option 4-2 channel under limiting environmental conditions (30 knot winds) at the peak of the ebb and flood tidal flows;
- simulation of emergency scenarios (with and without tug assistance) with departures of the ballast Suezmax design vessel (7.0-7.5m draft) within the Option 4-2 channel under limiting environmental conditions (30 knot winds) at the peak of the ebb tidal flow and suffering a power blackout in the vicinity of Buoy 14 and Buoy 12 and a main engine failure passing Buoy 8;
- simulation of emergency scenarios (with tug assistance) with arrivals of the loaded Suezmax design vessel (17m draft) under limiting environmental conditions (30 knot winds) and suffering a power blackout in the vicinity of Buoy 12 with rudder jams;
- simulation of night time arrivals with the loaded Suezmax design vessel (17m draft) within offshore approach section of the Option 4-2 channel; and,
- simulation of night time departures with the ballast Suezmax design vessel (7.0-7.5m draft) within the Option 4-2 channel under limiting environmental conditions (30 knot winds) at the peak of the ebb tidal flow.

The desktop simulation study report prepared by Be-Software is provided within **Appendix C** and documents the overall conclusions and recommendations of the study. Those relating to the second round of the Desktop Simulation Study are summarised below:

- there was a clear preference amongst the pilots for the Option 4-2 channel as it simplified the arrival approach around the critical area at Buoy 14; and the combined effect of the westward movement of Buoy 12 and north-westward movement of Buoy 14 provided more sea room for the arriving ship in this area and increased the turning radius in comparison to Option 4;
- the Option 4-2 channel was considered to be superior to the existing and Option 2 channel, an improvement over the Option 4 channel, and provided significantly more sea room in the critical Buoy 14 area, in comparison to the Option 5 channel;
- the additional sea room provided by the Option 4-2 channel also improved clearance from the rocky outcrop off Home Point on departures; and,
- the set of fixed leads introduced within Taurikura Bay for the Option 4-2 channel to define the N-S centreline were effective, particularly at night.

5 FURTHER DESIGN REFINEMENT

5.1 General

Following completion of the second round of the Desktop Simulation Study, the Option 4-2 and Option 2 channel alignments were taken forward for further assessment. Further refinement was undertaken to address the following channel design aspects:

- addition of lead lights along the N-S aligned sections of the Option 4-2 channel;
- minor revision of channel widths and bend geometry to accommodate a revised Suezmax design vessel with L_{OA} = 276m and Beam = 50m;
- addition of a 'dolphin pocket' behind the eastern end of the proposed berth pocket for lineboat access; and,
- minor adjustments to buoy locations.

The further design refinement also included a minor reduction of the design vessel draft from 16.8m to 16.6m (OMC, 2015b). However, this change in design vessel draft did not affect the PIANC design requirements for the channel bend widths and alignments. Accordingly, this was not considered further.

In addition, a 98% access channel design was subsequently selected as the preferred vertical design profile (initially the 95% access profile was considered, as discussed in **Section 2.2.3**). This also was not considered to have a material impact on PIANC design requirements for the channel bend widths and alignments and was therefore also not considered further.

5.2 Additional Lead Lights

As part of the Desktop Simulation Study it was proposed to establish a set of lead lights in Taurikura Bay to assist with the night time navigation of arriving Suezmax Tankers and other vessels. These leads would define the north south centreline of the proposed Channel Option 4-2 between buoys 3/6 and buoy 14. The requirement for leads only applied to Channel Option 4-2.

These leads were trialled in the simulation study and found to be beneficial for the navigation of the proposed Channel 4-2 as they helped the pilots turning the ship into the approach to the centreline of the channel. The pilots commenced the turn after passing buoys 3\6 and used the leads to align themselves into the centreline of the channel.

The positioning of these leads was investigated further by Bruce Goodchild and is documented within the report provided in **Appendix D**. There are four possible options that have been considered:

- A PEL Sector Lead Light (PEL Option 1) established on Calliope Bank.
- Traditional Leads (Low Leads Option 2) established on Calliope Bank (Fore Lead) and Taurikura Bay Foreshore (Rear Lead).

- Traditional Leads (Water Leads Option 3) established on the Calliope Bank. Both Fore and Rear Lead on Calliope Bank.
- Traditional Leads (High Leads Option 4) established on Calliope Bank (Fore Lead) and on the lower southern slopes of Mania overlooking Taurikura Bay (Rear Lead).

Water Leads Option 3 was selected as the preferred option. The IALA Leading Line Design Program was used to determine that the minimum heights of each lead above Mean High Water are 6 metres for the Front Lead and 13 metres for the Rear Lead for an observer located no more than 4 meters above Mean High Water. Both leads are shown in their proposed positions on drawing PA1028-MA-1121 Revision M (refer **Drawings**).

The proposed leads in Taurikura Bay are described in further detail in **Section 7**.

5.3 Revised Design Vessel Specifications

A minor modification was made to the original design vessel specifications (refer **Section 2.2.4**), which was incorporated into the PIANC channel design procedure. This involved an increase in the vessel beam from 48m to 50m and an increase in the L_{OA} from 274m to 276m. The changes to the design vessel length and width had a minor effect on the PIANC channel and bend design widths, with increases of up to 5 metres in some channel reaches.

The revised PIANC channel design calculations are provided in **Appendix E** and the results for the Option 2 and Option 4-2 channel designs are summarised in **Table 15**, **Table 16**, **Table 17** and **Table 18**. The PIANC channel design alignment is shown as a 'green' dashed line on the revised design drawings (refer **Drawings**) for Option 2 (PA1028-MA-1201 Revision D) and Option 4-2 (PA1028-MA-1121 Revision M). This green dashed line was used as a guide to define the buoy to buoy toe lines that define the proposed navigation area for both channel alignments; particularly in space constrained areas such as the Home Point reach and the bend around Buoy 14.

Table 15: Revised Option 2 PIANC Channel Width Assessment Results

Location	Description	Beam Multiplier	PIANC Width (m)
Reach 1	Fairway Buoy to Buoy 1/2	4.3	215
Reach 2	Buoy 1/2 to Buoy 3/6	4.3	215
Reach 3	Buoy 3/6 to Buoy 7	4.0	200
Reach 4	Buoy 7 to Buoy 14	4.2	210
Reach 5	Buoy 14 to Buoy 16	4.7	235
Reach 6	Buoy 16 to Buoy 17	4.7	235

Table 16: Revised Option 2 Bend Geometry

Bend No.	Bend Radius (m)	Drift Angle Width (m)	Response Time Width (m)	Maximum Approach Channel Width (m)	Bend Width (m)
1	1400	12.1	20.0	215	245
2	1400	12.1	20.0	200	230
3	800	21.2	20.0	235	275

Table 17: Revised Option 4-2 PIANC Channel Width Assessment Results

Location	Description	Beam Multiplier	PIANC Width (m)
Reach 1	Fairway Buoy to Buoy 1/2	4.3	215
Reach 2	Buoy 1/2 to Buoy 3/6	4.3	215
Reach 3	Buoy 3/6 to Buoy 7	4.5	225
Reach 4	Buoy 7 to Buoy 14	4.2	210
Reach 5	Buoy 14 to Buoy 16	4.7	235
Reach 6	Buoy 16 to Buoy 17	4.7	235

Table 18: Revised Option 4-2 Bend Geometry

Bend No.	Bend Radius (m)	Drift Angle Width (m)	Response Time Width (m)	Maximum Approach Channel Width (m)	Bend Width (m)
1	1800	9.4	20.0	225	255
2	800	21.2	20.0	235	275

The changes in channel and bend widths also required a change in marker positions, as reflected in **Table 19** for the two preferred options. The requirement for the new markers (PB1 and SM2) remained, as previously noted (refer **Table 14**).

Table 19: Revised required movement of existing buoys – preferred options

Buoy No.	Option 2	Option 4-2	Reason	Justification
	PA1028-MA-1201 Rev D	PA1028-MA-1121 Rev M	-	-
Fairway	-17.7mRL to -25.5mRL	-17.7mRL to -25.5mRL	The deeper approach channel requires the Fairway buoy to be moved to deeper water.	-
1	-	-	-	-
2	17m NE	17m NE	Moved in to match buoy offset for design channel	Existing buoy out of alignment in relation to other port buoys (PB1A, 4 & 6)
3	20m NE	20m NE	Moved out to accommodate design channel along lead-line	PIANC channel width is wider than existing buoyed channel
4	-	-	-	-
5	-	105m NW	Moved in to avoid dredging near Busby Head	PIANC 5xLOA radius is achievable and width is significantly greater than minimum width required
6	-	-	-	-
7	-	-		
8	347m SSE	76m SW	Option 2: Moved to mark apex of bend Option 4-2: Moved out to align with N-S centreline, and accommodate PIANC bend	Option 2: Enables buoy-to-buoy dredging in this location Option 4-2: Provides visual guide for pilots to follow N-S centreline
9	-	-	-	-
10	-	-	-	-
11	290m E	153m SE	Moved out to align with N-S centreline (Option 4-2), accommodates PIANC bend and marks apex of bend (Option 2)	Provides visual guide for pilots to follow N-S centreline, additional bend width and bend apex defined
12	-	28m W	Moved in/out to accommodate N-S channel alignment	Reduce number of heading changes past Home Point (Option 4-2)
13	-	-	-	-
14	-	53m NW	Moved out to accommodate increased bend radius	Improved navigability of critical Bend No.2
15	-	-	-	-
16	-	-	-	-
17	-	-	-	-
18	128m E	128m E	Moved East to avoid dredging Mair Bank and keep turning circle inside channel	PIANC channel width wider than existing buoyed channel

5.4 Dolphin Pocket

Navigation access for workboats is required by Refining NZ around the four (4) mooring dolphins located behind the eastern end of the Crude Jetty. The design workboat has a draft of 3.4 metres and length (L_{OA}) of 17 metres. NorthTugz tugs advised that this vessel would require a water depth of 4 metres at the lowest tide and a manoeuvring area of 30 metres around each mooring dolphin. The dolphin pocket was designed as a squared-off berth pocket that enveloped the 30 metre manoeuvring area for each mooring dolphin and had a design depth of -4.3m CD (addition 300mm added to required water depth as a siltation allowance).

The dolphin pocket design was added to drawings for both the Option 2 and Option 4-2 channel alignments and is detailed as 'Inset A' on drawing PA1028-MA-1121 Revision M (refer **Drawings**).

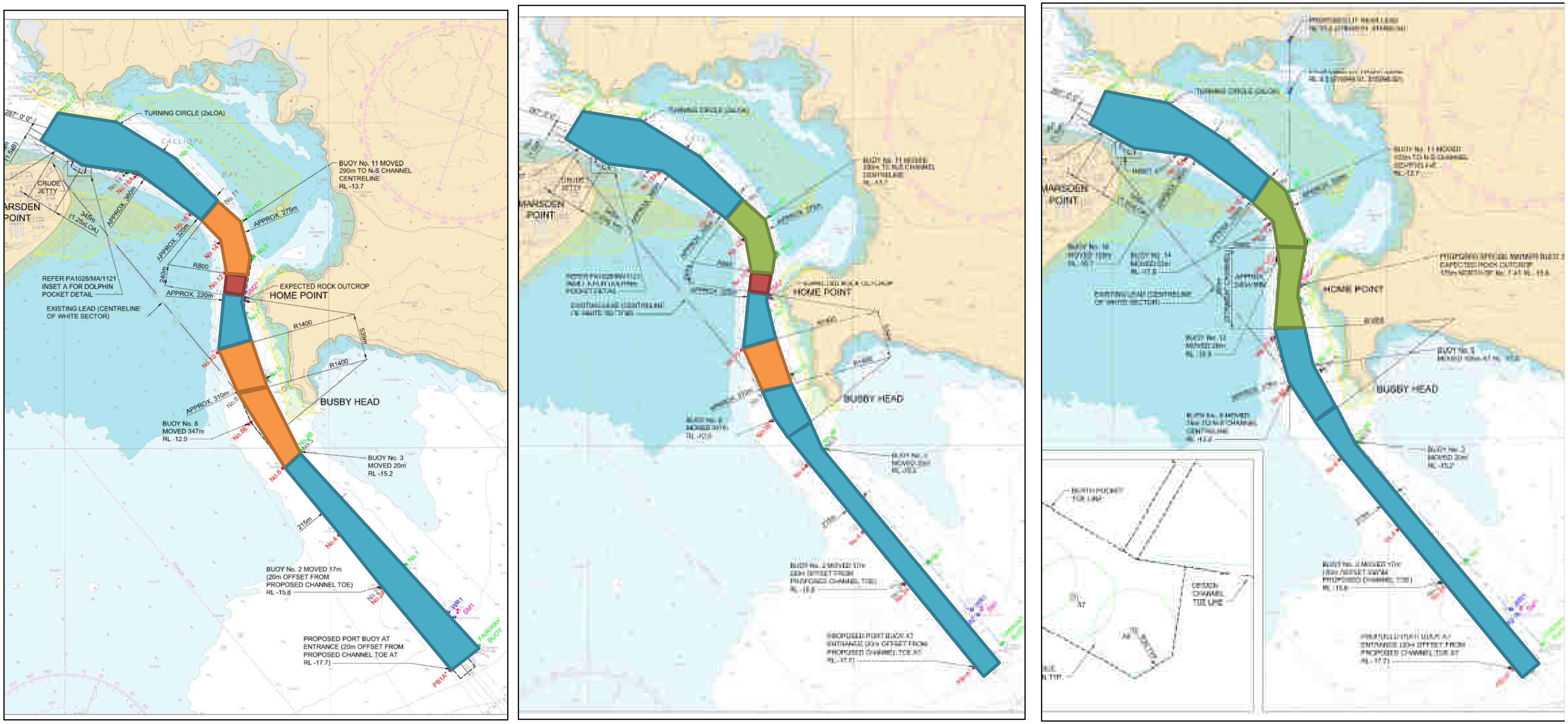
5.5 Channel Classification

The existing channel alignment and channel alignment Option 2 and Option 4-2 have been divided into subsections and each section classified with respect to navigational safety.

The classification has been developed based on the results of the Desktop Simulation Study and also consideration of PIANC criteria for safe navigation.

The results of the channel classification show that Option 4-2 can be classified as a mix of 'adequate' and 'optimum'. For both the existing channel alignment and Option 2, there are sections of the channel that have been classified as 'marginal' and 'inadequate'. See **Figure 13**.

It is noted that where sections of the channel are classified as 'marginal' or 'inadequate', this indicates the need for extensive navigational studies to assess under which conditions vessel manoeuvring can be undertaken safely. For the existing channel, the pilots would have developed experience over time as to which environmental conditions (i.e. wind, waves and currents) allow for safe navigation and under which conditions vessel manoeuvring should not be undertaken.



Existing Option 2 Option 4-2

	Classification	Definition from Simulation Report	Adopted PIANC Criteria
	Optimum	Ideal under both operating and extreme conditions, no issues encountered	> 5*LOA
	Adequate	Very good under operating conditions, manageable under extreme conditions	< 5*LOA, > 2.5*LOA
	Marginal	Adequate under operating conditions but poor under extreme conditions	< 2.5*LOA, > 1.25*LOA
	Inadequate	Poor under both operating and extreme conditions, may be considered unacceptable from a navigational risk perspective	< 1.25*LOA

Figure 13: Channel classification

6 Full Bridge Simulation

The full bridge simulation study was undertaken from 7th July to 13th July 2016 in the Marine Simulation Centre of the New Zealand Maritime School (Auckland).

The study was required to validate the two earlier simulation studies (see **Section 4**) for the proposed expansion of the port to receive deeper draft Suezmax Oil Tankers having a length overall (L_{OA}) of 276m, beam of 50m, and draft of 16.6m.

The full bridge simulation study focussed on the two preferred channel designs, namely Option 2 and Option 4-2.

The first two days of the full bridge simulation study were used to simulate manoeuvring within the two channel designs (denoted as Option 2 and Option 4-2), by a group of pilots which included the Marsden Point Harbour Master, the Northtugz Pilot Manager, and a senior Auckland Pilot.

The next three days utilized a different group of pilots including the senior pilots for Marsden Point and a senior Tugmaster. This second group were also used to simulate manoeuvring within the two different channel designs (Option 2 and Option 4-2) and in particular the emergency scenarios and the use of existing tug capability for the port.

The simulation set up comprised a full mission simulator with integrated tug simulator. The full mission simulator on the main bridge incorporated a number of instrument consoles and vision displays covering 300 degrees of horizontal field of view displayed on large projector screens. A separate tug bridge was available with 360 degrees of broken horizontal field of view on large 50 inch monitors. The main bridge instrument consoles incorporated ARPA radar, ECDIS, and manoeuvring displays showing speeds, engine RPM, rudder angle and rate of turn. Real instrumentation was provided for most of the bridge equipment. Similar real tug instrumentation was available on the tug bridge. A view of the full mission simulator and some typical displays from the simulation centre are presented in **Figure 14**.

Figure 14: Displays from the simulation centre, Auckland

The full bridge simulation study report prepared by Be-Software is provided within **Appendix F** and documents the overall conclusions and recommendations of the study. In summary, the findings were as follows:

- The results of the two earlier portable and remote link simulation studies were validated. This study used a different simulation system and different sets of mathematical equations but the results were the same as obtained from the previous simulation studies;
- Both channel designs were feasible with operational limitations up to a 30 knot wind and slack tide high water arrival of the design ship, following current operational procedures for the port;
- The Option 4-2 channel design is preferred by the pilots as it provides a simpler approach through the critical turn area in the vicinity of buoy 14. This allows the pilots to execute a constant radius turn which is easily monitored using a Portable Pilotage Unit (PPU). It also provides more sea room for all departing vessels to clear the rocky outcrop at Home Point safely, particularly during ebb tides and strong offshore winds. Simulated scenarios used current operational procedures with the design ship in ballast and loaded condition;
- The simulated design ship was considered to manoeuvre at below average capability for a normal vessel of this class so represented a conservative case. However, the pilots were able to use existing tug capability and PPU to consistently navigate safely within the confines of both channel designs. Of the two designs, Option 4-2 was considered optimum as it allows the most sea room for the arriving vessel and has a larger radius of turn in the channel alignment for both arrival and departure vessels. Greater sea room and improved bend radius significantly improves existing channel safety margins, especially under adverse weather conditions and with a difficult ship to manoeuvre;
- An alternative simulated design ship was used in the full bridge simulation study as an additional check to manoeuvring capability. The alternative design ship study was a Suezmax Class Oil Tanker having a length overall (L_{OA}) of 280m, beam of 50m, and draft of 16.6m. The alternative design ship was considered to be of average manoeuvring capability and this ship was consistently navigated safely in both channel designs;

- Minimal realignment of existing navigational buoys is necessary with both channel designs;
- An improvement in the existing leading sector light and buoy lights will be necessary to properly indicate navigable water in the approach channel from the fairway buoy to buoys 3/6 (see **Section 7**);
- Existing tugs are capable of handling the design ship under normal operational conditions;
- Existing tugs provide adequate towage under normal operations and we understand emergency capability is to be further reviewed given increased ship displacement; and
- The proposed channel design alignments will potentially assist in an emergency scenario by providing more sea room.

7 Aids to Navigation

The proposed aids to navigation (AtoN) are shown on drawing PA1028-MA-1121 Revision M (refer **Drawings**).

The existing channel demarcation is provided by a safe water mark (also referred to as the fairway buoy) and eighteen (18) channel markers consisting of nine (9) starboard buoys and nine (9) port buoys. As described in **Section 5**, eight (8) of the existing buoys will need to be relocated to accommodate the reconfigured channel alignment. The buoys that need to be moved, and the distance that each will need to be moved, are presented in **Table 19**.

Due to the proposed deepening of the access channel, the channel will also become longer as it now extends into deeper water. It is therefore proposed that two additional channel marker buoys, one (1) starboard buoy and one (1) port buoy, will be installed at -17.7m RL. This is the same water depth as the existing fairway buoy. The fairway buoy will be moved to be aligned with the starboard channel markers and installed at -25.0m RL.

Due to the rock outcrop, and therefore potential navigational hazard in the vicinity of Home Point, it is proposed that a West Cardinal Beacon be installed 175m north of buoy no. 7 at -15.8m RL. The West Cardinal Beacon indicates that there is a navigational hazard present and all vessels should keep to the west of the beacon. The West Cardinal Beacon will be approximately 4.5m in height at Chart Datum (1.8m at MHWS) and it is proposed that it will consist of a 250mm steel tube construction with a top mark and light as shown in **Figure 15**.

Figure 15: Example of the proposed West Cardinal Beacon

An outcome from the ship simulation study was to improve the Port Entry Light (PEL). The proposed improvement is to remove the upper portion of the day shape on the forward lead (see **Figure 16**) and to install a day and night light in its place. The proposed changes to the PEL will be addressed by Northport and light specifications (e.g. colour etc.) will be as per the Harbour Masters instructions.

Figure 16: Existing PEL front lead

The existing (rear) lead light marking the offshore approach channel was considered to be too insensitive by the pilots and this was demonstrated in all the simulations. The sectors of the main lead should adequately show the navigation limits of the new channel and be bright enough to support operations in adverse environmental conditions.

As mentioned in **Section 5.2**, it is proposed to establish a set of lead lights in Taurikura Bay to assist with the night time navigation of arriving Suezmax Tankers and other vessels. These leads would define the north south centreline of the proposed reconfigured channel between buoys 3/6 and buoy 14. Details of the proposed lead lights are as follows:

Basis of Design

- Water based
- No day shapes required
- Day and Night light required
- Light specifications: As per Harbour Masters instructions
- Minimal visual impact possible when viewed from the North, East and West

Taurikura Front Lead

Position:	35° 50.375 S, 174° 31.293 E
Height:	8.7m above chart datum, 6.0m above Mean High Water Spring
Width:	600mm diameter
Construction:	Tubular steel with steel ladder and basic 1.2m x 1.2m platform for equipment
Colour:	Rescue Orange front (2m x 500mm stripe) facing 180° S, remainder of the tower light cloud grey (BS5252 colour Y81-011-082)
Design:	As per **Figure 17**
Light:	Day/night range light VLB-91 of 3nm (or as per Harbour Masters instruction)
Power:	Solar and battery unit with automation system

Figure 17: Example of the proposed Taurikura Front Lead
Note: proposed colour differs from that shown in figure above.

It is noted that **Figure 17** shows one of 39 similar designs being used on the Whangarei Harbour. The beacons have a height of 5-6m above Chart Datum (2.3 - 3.3m above MHWS) and are of the same construction as the proposed Taurikura Front Lead.

Taurikura Rear Lead

Position:	35° 49.990 S, 174° 31.293 E
Height:	15.7m above chart datum, 13.0m above Mean High Water Spring
Width:	850mm diameter
Construction:	Tubular steel, two 6m enclosed ladders with platform at each level. Bottom platform 850mm x 850mm. Top platform 2m x 1.8m for equipment.
Colour:	Rescue Orange front (4m x 750mm stripe) facing 180° S, remainder of the tower light cloud grey (BS5252 colour Y81-011-082)
Design:	As per **Figure 18**
Light:	Day/night range light VLB-91 of 5nm (or as per Harbour Masters instruction).
Power:	Solar and battery unit with automation system

Figure 18: Example of the proposed Taurikura Rear Lead
Note: proposed colour differs from that shown in figure above.

Figure 18 is known as 'Skips Rocket' and is currently situated at Limestone Island in the Upper Whangarei Harbour and is used as the Shell Cut Inbound Rear Lead. The light on this structure is 19m above Chart Datum (16.3m above MHWS) and the total height of the structure is 21m above Chart Datum (18.3m above MHWS). It is of the same construction as the proposed Taurikura Rear Lead.

7.1 Typical Installation Methods

Northport have advised that the typical installation methods likely to be adopted, as based on previous experience, are as follows:

7.1.1 Taurikura Leads

Both leads will require the same process as outlined below:

- Installation equipment
  - Jack-up barge
  - Tug
  - Piling rig
  - Crane
  - Vibro Hammer or traditional hammer piling

- Process
  - Piles are pre painted on shore ready for installation
  - Piling rig positioned on site by tug
  - Barge legs lowered into place
  - Barge is jacked up above the MHWS tide (usually by 1m)
  - The first section of pile (usually pile length required below the seabed plus 1m above MHWS) is driven into place
  - Remaining sections of pile are welded into place
  - Ladder and platform are fixed into position
  - Lead paint is touched up at weld areas and for any surface damage caused during installing
  - Light assembly is the last part of the lead assembly
  - Barge will jack back to water level and will be recovered by tug

- Time frames
  - Process is heavily dependent on the weather, the following is based on benign weather conditions
  - Assuming benign weather conditions, the process will take a total of 6 days:
    - 1 day mobilisation
    - 2 days piling (includes allowance for minor delays)
    - 1 day ladder and platform assembly
    - 1 day light installation and paint touch-ups
    - 1 day demobilisation

7.1.2 Home Point

It is noted that this is a difficult environment to operate in due to fast running tidal flows and back eddies. Along with the water flows, the reef itself poses a challenge with respect to installing a beacon and a buoy may end up being the only practical and efficient method of marking the reef.

Method A – Beacon

To prevent the requirement to fix too or drill into the reef, the design would be a tripod base and a standard beacon viewed from the surface, utilising 2 MT blocks on each leg to hold in position.

- Installation equipment
    - Tug and barge
    - Crane
    - Commercial divers

- Process
    - Beacon is constructed and prepared on land and readied for installation
    - Beacon is loading onto the barge
    - Tug and barge move onto location and fix barge in place with spuds
    - Operation will be tidal dependant, operations to be conducted during neap tides and at slack water
    - Crane lifts beacon into the water and lowers in place
    - Divers will inspect positioning prior to disconnect
    - Crane disconnect
    - Diver final inspection

- Time frames
    - Process is heavily dependent on the weather, the following is based on benign weather conditions
        - 1 day total

Method B – Buoy

The critical element of the buoy system is the swing circle must be as small as possible to ensure that the safe water is marked at all times. The mooring system would therefore be unconventional, consisting of 3 separate mooring blocks and chain, connected to an equaliser plate (also referred to as a monkey plate) and then a chain and swivel assembly to the buoy.

- Installation equipment
    - Standard navigational Tug and barge
    - Commercial divers
    - Lift bags

- Process
    - Buoy is painted ashore and the mooring system prepared ready for installation
    - Buoy is loading onto the barge
    - Tug and barge move onto location and fix barge in place with spuds
    - Operation with be tidal dependant, operations to be conducted during neap tides and at slack water
    - Each mooring block and chain is lowered onto the seabed individually
    - Divers will connect the three chains to the equaliser plate on the seabed
    - Lift bags will be utilised to connect the equaliser plate to the buoy's chain and swivel assembly.
    - Buoy is released.
    - Divers will inspect positioning prior to departure

- Time frames

- Process is heavily dependent on the weather, the following is based on benign weather conditions
  - 1 day total

This estimate is based on Northport’s experience of a typical installation process and it is noted that the actually process adopted could vary from that described above.

8 SUMMARY

Several alternative navigation channel alignments were developed in accordance with the PIANC guidelines (PIANC, 2014) to provide high water access for fully laden Suezmax vessels and to ensure no issue for other vessels accessing the harbour/channel. These alignments were evaluated by key stakeholders including Refining NZ, NorthTugz, Northport and the Harbour Master and selected alignments were tested in two separate desktop simulation studies.

Participants in the simulations included Bruce Goodchild of Be-Software, RHDHV staff, NorthTugz pilots and Tugmasters and the Harbour Master. The desktop simulation studies facilitated the testing of alternative channel alignments and navigation marker configurations and refinements to channel designs under a wide range of different operating conditions, including:

- different design vessel types (Suezmax and Logships);
- loaded, partially loaded and ballasted vessels;
- average to limiting environmental conditions (e.g. wind, waves);
- day and night transits;
- different states of the tide;
- different tug configurations;
- arrivals, departures and berthing; and,
- emergency scenarios (e.g. loss of rudder control, loss of engine power and complete vessel blackout).

The outcomes of the Desktop Simulation Study indicated that the Option 4-2 channel alignment was the preferred channel alignment from a navigation perspective.

Transits through the Option 2 channel alignment were also completed successfully by the pilots. However the need to execute two bends in close succession either side of the Home Point area with this option resulted in the need for an “S-bend” manoeuvre. This introduced navigational difficulties which increased navigational risk with this option, in comparison to the preferred Option 4-2, which allowed for a simpler and straight run past the same location.

The Option 5 channel alignment was least favoured as this alignment effectively reduced the searoom available in the approach to the rocky outcrop at Home Point from the north, which is known as a navigation hazard amongst all pilots.

Following completion of the Desktop Simulation Study, some minor refinement of the channel design was undertaken that included the following:

- addition of lead lights along the N-S aligned sections of the Option 4-2 channel;
- minor revision of channel widths and bend geometry to accommodate a revised Suezmax design vessel with L_{OA} = 276m and Beam = 50m;

- addition of a 'dolphin pocket' behind the eastern end of the proposed berth pocket for lineboat access; and,
- minor adjustments to buoy locations.

This was followed by a full bridge simulation study undertaken at the Marine Simulation Centre of the New Zealand Maritime School (Auckland). The study was required to validate the Desktop Simulation Study for the proposed expansion of the port to receive deeper draft Suezmax Oil Tankers having a length overall (L_{OA}) of 276m, beam of 50m, and draft of 16.6m.

The full bridge simulation study focussed on the two preferred channel designs, namely Option 2 and Option 4-2. The key findings from the study were as follows:

- The results of the two earlier portable and remote link simulation studies were validated;
- The Option 4-2 channel design is preferred by the pilots due to providing safer manoeuvring through critical sections of the approach channel;
- Minimal realignment of existing navigational buoys is considered necessary;
- An improvement in the existing leading sector light and buoy lights will be necessary to properly indicate navigable water in the approach channel from the fairway buoy to buoys 3/6;
- Existing tugs provide adequate towage under normal operations and we understand emergency capability is to be further reviewed given increased ship displacement; and
- The proposed channel design alignments will potentially assist in an emergency scenario by providing more sea room.

The aids to navigation (AtoN) have been assessed as part of this channel design process and the following modifications proposed:

- Eight (8) of the existing buoys will need to be relocated to accommodate the reconfigured channel alignment;
- Two (2) additional channel marker buoys, one (1) starboard buoy and one (1) port buoy, will be installed at -17.7m RL;
- The fairway buoy will be moved to be aligned with the starboard channel markers and installed at -25.0m RL;
- Due to the rock outcrop, and therefore potential navigational hazard in the vicinity of Home Point, it is proposed that a West Cardinal Beacon be installed 175m north of buoy no. 7 at -15.8m RL;
- The Port Entry Light (PEL) was found to be inadequate with regard to defining the navigation limits and also inadequate for operations undertaken in adverse environmental conditions. The PEL light is therefore to be modified and a forward lead added to provide a traditional lead. The forward lead is to be lit with a day and night light;
- The existing (rear) lead light marking the offshore approach channel was considered to be too insensitive by the pilots and this was demonstrated in all the simulations. The sectors of the main lead should adequately show the navigation limits of the new channel and be bright enough to support operations in adverse environmental conditions; and
- A set of lead lights is to be established in Taurikura Bay to assist with the night time navigation of arriving Suezmax Tankers and other vessels.

9 REFERENCES

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OMC International [OMC] (2015b), *Marsden Point 2015 Channel Optimisation: 16.6m Vessel Draft*, prepared for Northport Ltd (Marsden Point), 30 November 2015.

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DRAWINGS

Drawing Number	Title	Rev	Status
PA1028-MA-1201	Channel Design Realignment – Option 2 Channel Alignment	D	Prelim. Concept Design
PA1028-MA-1101	Channel Design Realignment – Option 4 Channel Alignment	B	Prelim. Concept Design
PA1028-MA-1111	Channel Design Realignment – Option 4-1 Channel Alignment	A	Prelim. Concept Design
PA1028-MA-1121	**Channel Design Realignment – Option 4-2 Channel Alignment**	**M**	**Final Concept Design**
PA1028-MA-1301	Channel Design Realignment – Option 5 Channel Alignment	A	Prelim. Concept Design
PA1028-MA-1203	Channel Design – Option 2 Dredge Footprint	D	Prelim. Concept Design
PA1028-MA-1123	**Channel Design – Option 4-2 Dredge Footprint**	**C**	**Final Concept Design**
PA1028-MA-1301	Channel Design – Option 5 Dredge Footprint	A	Prelim. Concept Design

DRAWING No. PA1028/MA/1201

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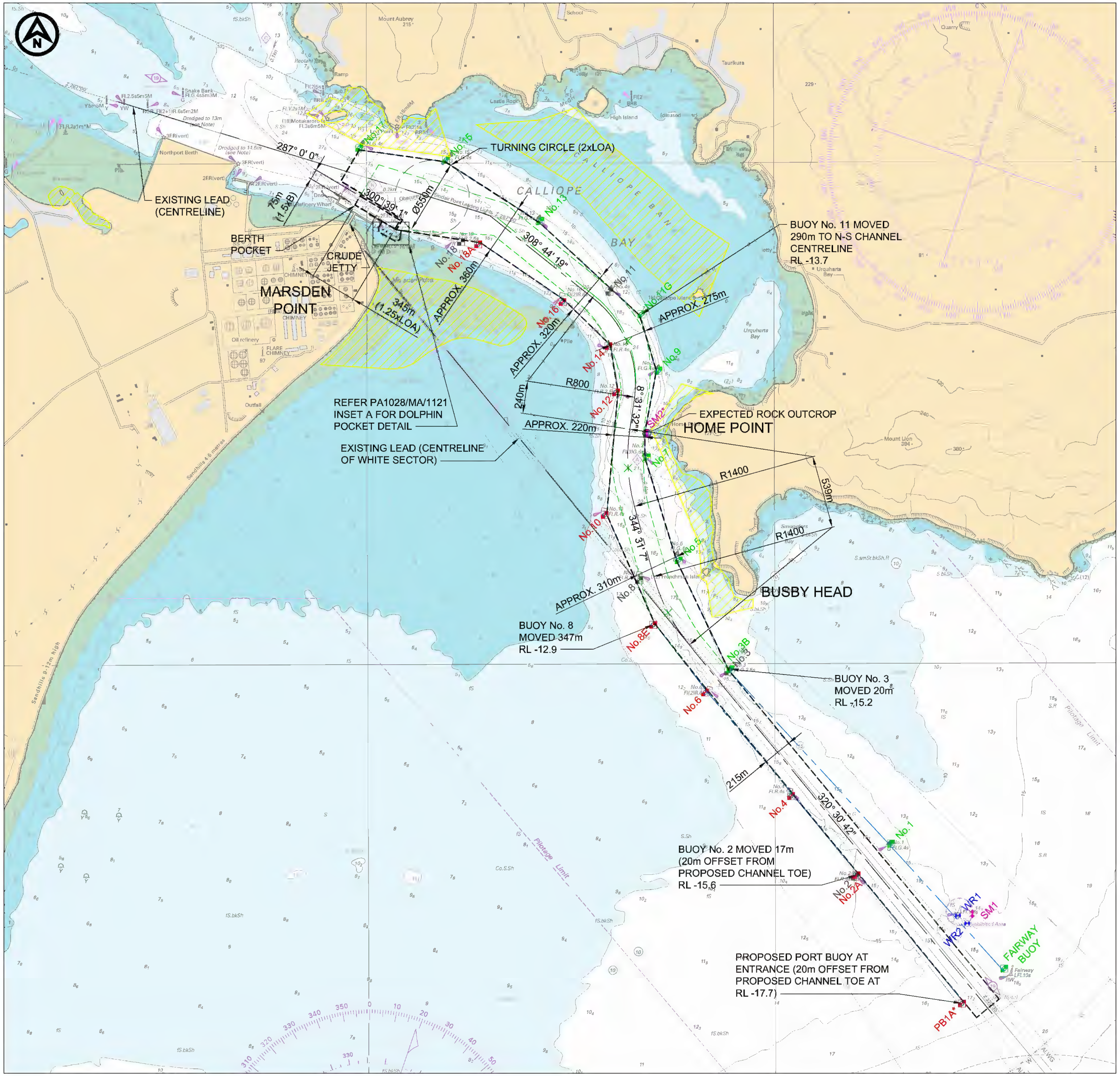

LEGEND:

- DESIGN TOE LINE
- DESIGN CHANNEL CENTRELINE
- THEORETICAL TOE LINE
- THEORETICAL CHANNEL CENTRELINE
- BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)
- PROPOSED RELOCATED BUOYS (e.g. No. 11A)
- STARBOARD BUOYS
- PORTSIDE BUOYS
- WAVERIDER BUOYS
- SPECIAL MARK BUOYS
- EXISTING BUOYS TO BE RELOCATED
- MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 276m AND BEAM (B) = 50m.

REV	DATE	DESCRIPTION	BY	CHK	APPD
D	02.12.15	BUOY No.8 MOVED	BAM	RM	
C	02.11.15	CHANGES CARRIED OVER FROM OPTION 4-2	BAM	RM	
B	22.07.15	RELOCATED BUOYS ADDED	BAM	MP	
A	20.07.15	DRAFT FOR REVIEW	BAM	MP	

REVISIONS

CHART DATUM

NOT FOR CONSTRUCTION

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CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ Your Energy Hive

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN OPTION 2 CHANNEL ALIGNMENT

HASKONING AUSTRALIA PTY LTD SYDNEY

Royal HaskoningDHV Enhancing Society Together

DRAWN BAM | DATE 02/12/2015 | JOB No. PA1028

AUTOCAD REF. PA1028-MA-OP2D-95%

SCALE AT A1 1:15000

DRAWING No. PA1028/MA/1201 | REVISION D

\\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1028 REFINING NZ CAD\E11 WORKING DRAWINGS\PA1028-MA-OP2D-95%.DWG 12/2/2015 4:37 PM

DRAWING No. PA1028–MA–1101

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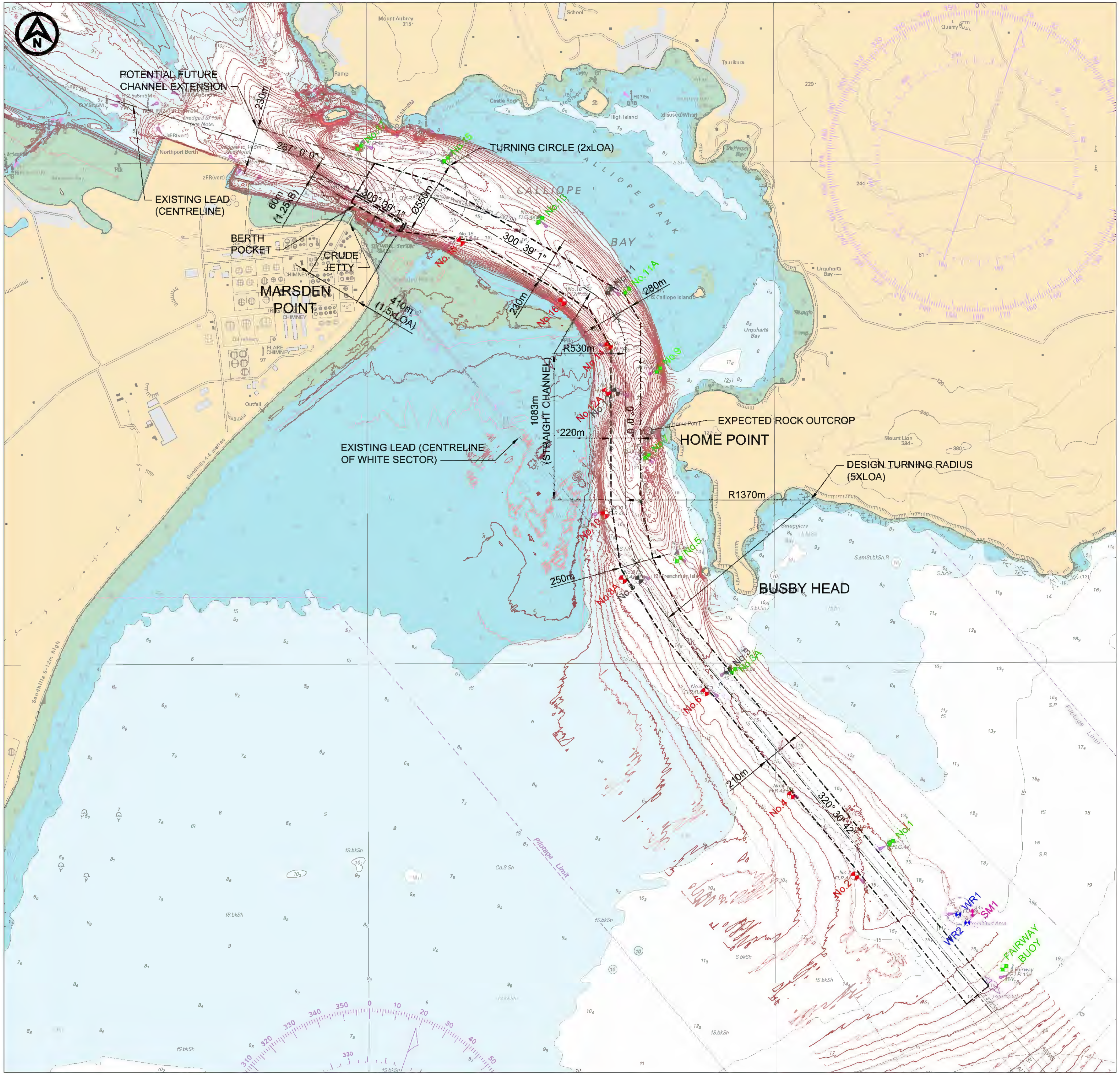

LEGEND:

- PROPOSED CHANNEL TOE LINE
- STARBOARD BUOYS
- PORTSIDE BUOYS
- WAVERIDER BUOYS
- SPECIAL MARK BUOYS
- EXISTING BUOYS TO BE RELOCATED
- RELOCATED BUOYS (e.g. No. 11A)

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 274m AND BEAM (B) = 48m.

CHART DATUM

NOT FOR CONSTRUCTION

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1:15000 (A1) 1:30000 (A3)

REV	DATE	DESCRIPTION	BY	CHK	APPD
B	22.07.15	RELOCATED BUOYS ADDED	BAM	MP	
A	20.07.15	DRAFT FOR REVIEW	BAM	MP	

REVISIONS

CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ Your Energy Hive

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN REALIGNMENT OPTION 4 CHANNEL ALIGNMENT

HASKONING AUSTRALIA PTY LTD SYDNEY
Royal HaskoningDHV Enhancing Society Together

DRAWN BAM	DATE 22/07/2015	JOB No. PA1028
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DRAWING No. PA1028–MA–1101		REVISION B

DRAWING No. PA1028/MA/1111

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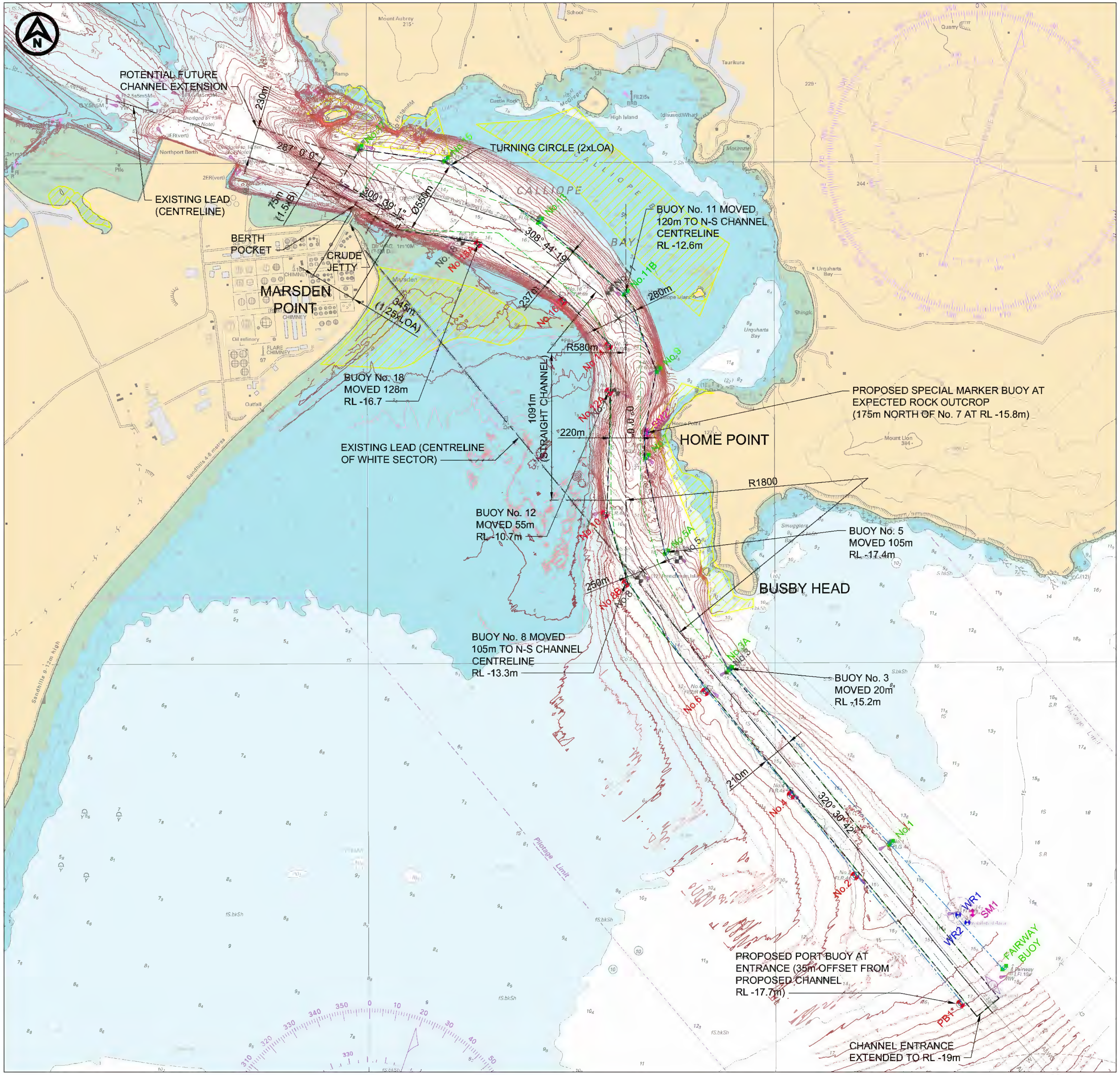

LEGEND:

– – –	PROPOSED CHANNEL TOE LINE
– – –	DESIGN CHANNEL TOE LINE
······	BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)
	STARBOARD BUOYS
	PORTSIDE BUOYS
	WAVERIDER BUOYS
	SPECIAL MARK BUOYS
	EXISTING BUOYS TO BE RELOCATED AND PREVIOUS REVISIONS
	RELOCATED BUOYS (e.g. No. 11A)
	MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 274m AND BEAM (B) = 48m.
5. PROPOSED CHANNEL TOE FOLLOWS DESIGN CHANNEL TOE SOUTH OF BUOY No. 3, AND FOLLOWS BUOY BOUNDARY NORTH OF BUOY No. 3.

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	10.09.15	REVISED FROM OPTION 4	BAM	MP	

REVISIONS

CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ Your Energy Hive

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN REALIGNMENT OPTION 4–1 CHANNEL ALIGNMENT

HASKONING AUSTRALIA PTY LTD SYDNEY

Royal HaskoningDHV Enhancing Society Together

CHART DATUM

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DRAWN BAM | DATE 21/09/2015 | JOB No. PA1028

AUTOCAD REF. PA1028–MA–OP4–1A–DESIGN LEVEL

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DRAWING No. PA1028/MA/1111 | REVISION A

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