Information on key species of interest to Ngai Tahu – Supplementary paper for Next Generation Project

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1.0 Introduction

Port Otago has carried out investigations for a proposed modification to the shipping channel to accommodate the next generation of container ships. As part of this process a considerable amount of information has been gathered and a number of surveys carried out to fill gaps in our knowledge of the hydrodynamics and ecology of the Harbour and offshore regions. This information is contained in a number of reports prepared for Port Otago Ltd and available on their website.

Port Otago commissioned a Cultural Impact Assessment (CIA) to be prepared by KTKO Consultancy and received a draft for review in January 2010. This draft CIA and a supporting report by Dr Terry Broad commissioned for KTKO acknowledged that a significant amount of information had been collected by Port Otago Ltd. However, it was agreed that the information relating to species and areas of particular concern to Ngai Tahu was spread over a number of sources and needed to be collated into one document.

The scope of this supplementary paper is to collate information covering the habitats, tolerances and potential effects and losses of populations of shellfish and fish. Species of particular interest that have been identified in discussions and the draft CIA included cockles (tuaki), pipi, tuatua, flatfish species, blue cod, various coastal fishes, rock lobster (crayfish) and paua.

2.0 Habitat, diet and tolerances - Shellfish

2.1 Habitats and diet - Shellfish

A variety of shellfish are gathered in the harbour for recreational and customary uses. Locations important for recreational users (and customary uses) were identified by Bell (1999) and important areas are identified in Figure 1 below. Based on anecdotal information a map showing where different benthic, shellfish and fish communities have been found was drawn up and presented in James et al. (2007) (Figure 2). Additional information that has been collected is summarised below.

Cockles (tuaki)

Cockles (*Austrovenus stutchburyi*) are found throughout New Zealand on sheltered shallow softshores particularly in harbours, inlets and estuaries. Some of the largest populations are found on the sand flats of Otago Harbour, Waitati Inlet and Papanui Inlet. Extensive surveys of these beds have been carried out in the past and maps showing the estimated biomass in different regions are provided in Breen et al. (1999) and Wing et al. (2002). Recent data has also been collected by Southern Clams Ltd.

Figure 1. Otago-Map showing location and intensity of hand gathering effort. (From Bell 1999)

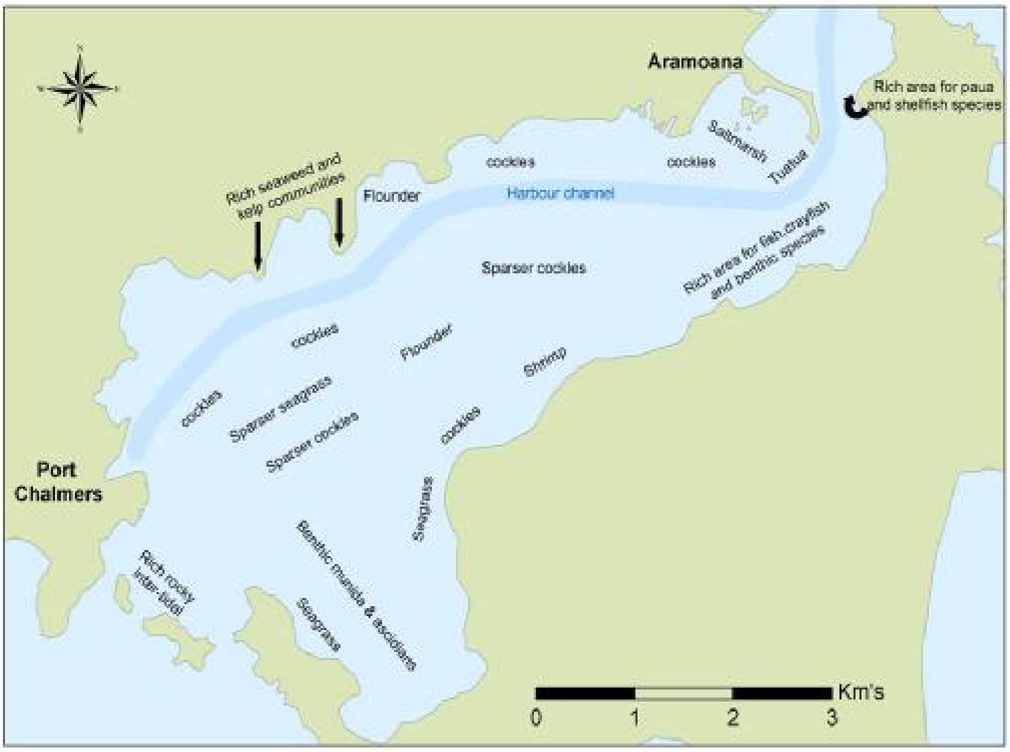

Figure 2. Areas where different benthic communities and habitats have been identified in the outer Otago Harbour (drawn from information and data collected by Otago University – K Probert pers comm., James et al. 2007).

Significant cockle beds are found in the Lower Harbour with up to 8091 tonnes estimated to have been present in the bed on sandbanks opposite Acheron Point, 2231 tonnes in the bed near Harwood and 3200 tonnes in the bed at Aramoana (Breen et al. 1999). Southern Clams Ltd have approval for an experimental commercial harvest of cockles in the beds opposite Acheron Point. In the recent surveys undertaken for Port Otago Ltd Paavo et al. (2008) also found cockles to be abundant opposite Acheron Point but greatest abundance was found southwest of Harwood (up to 625/m^2). The recreational survey by Bell (1999) identified several important areas for gathering shellfish, including cockles, on the southern side of the main shipping channel opposite Pulling Point and Tayler Point, and at Aramoana (Figure 1). The highest numbers were collected in beds from Careys Bay to Aramoana (Bell 1999).

In addition to these major beds smaller beds of cockles are known to be scattered around the harbour. Cockle beds are also important for cultural and recreational harvest in Waitati Inlet which is part of the East Otago Taiapure and Southern Clams Ltd have a license for a commercial harvest in the Inlet. Beds in the Harbour, inlets and coastline are recognised as an important source of kaimoana.

Looking at the whole of the lower harbour and the knowledge that the major populations of cockles are found in the intertidal area, the following drawing 11150/4 reproduced as Figure 3 shows the lower harbour areas interpreted to be between 0.0m and 1.0m in relation to chart datum. The total area in this depth range is estimated as 6,000,000m^2 and indicates potential cockle habitats.

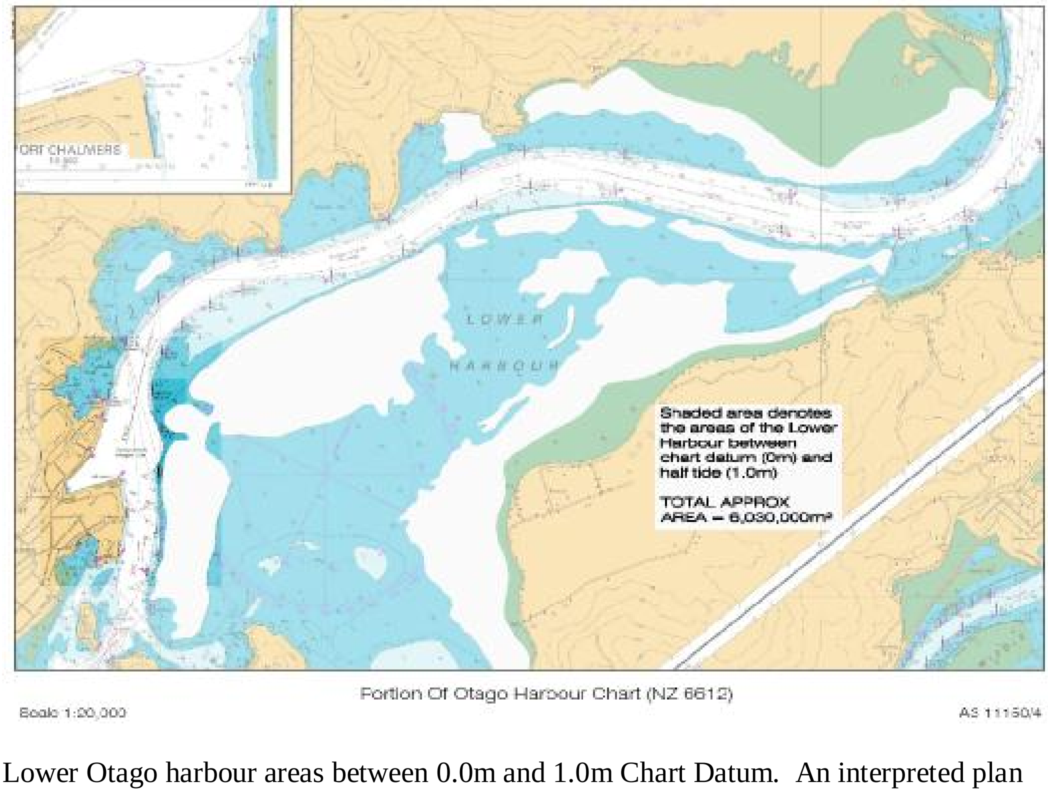

Figure 3: Lower Otago harbour areas between 0.0m and 1.0m Chart Datum. An interpreted plan by Port Otago Ltd.

While cockles flourish between low and mid-tide levels they can be found in muddy sand from 10 cm water depth down to 6-8 m below littoral zone. Individuals tend to be larger in deeper waters (Dobinson et al. 1989, Kainamu 2008). Because they have relatively short siphons they tend to live mostly within 5 mm of the sediment surface (Hewitt and Norkko 2006).

Like many bivalves, cockles are suspension feeders feeding on organic matter which they filter out of the water. Using stable isotope analysis of cockles and potential food sources in Blueskin Bay and at Harwood in Otago Harbour, Leduc et al. (2006) found that cockles in these habitats fed on seston from a range of sources including microphytobenthos, red algae and *Ulva* or sealettuce. Seagrass did not appear to be an important component of the diet for cockles in the Harwood area. Growth of cockles has been found to be higher where there is good water movement and thus a constant supply of organic seston eg the mouths of inlets and estuaries (Kainamu 2008, Owen 1992).

Pipi

The pipi (*Paphies australis*) is found throughout New Zealand but mostly on sandbanks of sheltered or protected beaches, bays and estuaries as well as harbours. It generally occurs from the mid-intertidal to the shallow sub-tidal down to 10-12 m (Cook 2010). They are strong burrowers but have relatively short siphons and prefer the top 8-10 cm of sandy flats with coarse shell/sand habitats, good water movement and little silt. Juvenile pipi are often found high on intertidal shores while mature adults are usually found in greater abundance in sub tidal beds in harbour channels (Hooker 1995).

Rainer (1981) recorded pipi as part of his fine sand community, but only at 4 sites and with a mean density of 3.5 individuals/0.2 m^2. It was more abundant at sites with low organic detritus content (< 1%) of the sediment, which tended to be on open sandbanks of the mid and outer Harbour. No pipi were recorded in recent grab and photo surveys of the Lower Otago Harbour but Paavo (2009a) did record a few individuals towards the bottom of transects of rocky shore habitats off Quarantine Island and Acheron Point.

Pipi are suspension feeders consuming microscopic algae (diatoms, flagellates) and organic material.

Tuatua

Southern tuatua *(Paphies donacina)* or surf clams are found throughout the South Island and Stewart Island, and around much of North Island (Cook 2010). They can be abundant in the low intertidal and shallow sub tidal off sandy beaches of the eastern South Island such as in the Otago region (Miller 1999). Spat can settle in the intertidal area but most large tuatua are found subtidally between 1 and 4 m depth. They are most abundant in the fine, well-sorted sand regions in the surf zone of open beaches where they are well adapted to a dynamic surf environment with shifting sands. Populations have been recorded in the Harbour near Aramoana, and Paavo et al. (2008) recorded a few individuals on the northern side of the main channel off Acheron Point and Tayler Point and subtidally on the edge of the channel near the Port (south of Beacon 28 and the area to be widened). The location of populations near Aramoana is still being investigated.

Tuatua have long siphons that can extend up to 3 cm through overlying sediment. They use these siphons to feed on suspended matter found in the overlying water including microscopic algae, organic material and detritus from a range of sources.

2.2 Tolerances to suspended and settled sediments - Shellfish

Cockles can be found in habitats with a range of sediment types. Owen (1992) noted they were present in the Avon-Heathcote Estuary in sediments composed of 10-85% fine silt (Owen 1992). Gibbs and Hewitt (2004) noted their optimum range was 5-10% mud content but that they can be found in sediments with 0-85% mud. Their ability to tolerate burial however depends very much on the type of sediment. While they can survive burial under several cms of sand Norkko et al. (1999) found they could survive up to 3 cm of clay sediment but could not survive burial in 6 or 9 cm of clay. No mortality was found in field and laboratory experiments with layers up to 1.5 cm of terrigenous clay (Norkko et al. 2001).

Pipi are less tolerant of fine sediment as they have relatively short siphons and lack the ability to clear their feeding apparatus of fine sediment. Pipi have a strong preference for sand (Gibbs and Hewitt 2004). They are not found in habitats with high concentrations of mud (>67%, Cummings et al. 2002) or silt/clay (>60%, Norkko et al. 2001) and the optimum sediment contains less than 5% mud. Pipi however, are active burrowers and all sizes of pipi have been found to be able to tolerate sediment depths, disturbance and inundation at depths of up to 10 cm with larger ones able to tolerate burial up to 40 cm of sand and continued burial in up to 15 cm of sand over four days (Creese 1998).

Estuaries, harbours and inlets are dynamic environments subject to episodic events and relatively high suspended sediment concentrations during heavy rain events or storms (up to 1000 mg/l TSS or more). Cockles, oysters and mussels are well adapted to this type of environment. For example, Hawkins et al. (1999) found the greenshell mussel did not reduce its filtering rate in field experiments until concentrations reached 1000 mg/l.

Suspension feeders such as cockles, pipi and tuatua all feed on small particles (<20um) they extract from overlying water. While they are able to tolerate relatively high concentrations of suspended sediments, which can occur naturally, continuous exposure to high concentrations can impact on their feeding ability and thus growth and condition (Norkko et al. 2006). Based on a series of field experiments, Hewitt et al. (2001) and Hewitt and Norkko (2006) found cockles initially benefit from higher suspended sediment concentrations and the extra food available but this benefit reduced when TSS concentrations reached 400 mg/l and persisted for 14 days. Recently derived terrigenous clay was found to affect bivalves more than resuspended marine sediments.

In laboratory experiments the condition of pipi was found to decrease at suspended sediment concentrations over 75 mg/l for periods exceeding 13 days (Hewitt et al. 2001). These results were backed up by field observations which also showed that high concentrations for over 25% of the time resulted in decreased condition (Hewitt and Norrko 2006).

There is little published information on tuatua and their environmental requirements and we are not aware of studies on their tolerances to suspended sediment and sediment deposition.

3.0 Habitat, diet and tolerances – Fish, rock lobster and paua

3.1 Introduction

Fishes are highly mobile and most New Zealand fish species are widely distributed throughout the country. None of the known fish species are endemic to the Otago coast. Demersal fishes found on the Otago coast, including fishes in Otago Harbour are typical of the fish assemblages found elsewhere on the east coast of the South Island (Anderson et al. 1998, Bagley et al. 2000, Beentjes et al. 2002, Hurst et al. 2000a).

Otago Harbour is a large tidal basin with substantial areas exposed at low tide. Most fishes therefore migrate in and out of the harbour with each tidal exchange and are not permanently resident. The occurrence of many adult and juvenile fishes found within the harbour is seasonal.

3.2 Habitat and diet – Fish

Flatfish species (Pleuronectidae – righteyed flounders)

Habitat

The distributions of the different New Zealand righteyed flounder species (Family Pleuronectidae) all overlap to some degree (Anderson et al. 1998, Ayling & Cox 1982) strongly suggesting that all of the species share at least some of their habitat requirements. New Zealand’s flatfish species are distributed from the north of the North Island to the bottom of the South Island, indicating they have a broad tolerance to water temperatures. There have been no research studies directed specifically at identifying the specific habitat requirements of New Zealand flatfishes – almost all of the available information indicates only where species are present (e.g. Manikam 1969). However, a review of the literature and known biology of the New Zealand Pleuronectidae, (Ministry of Fisheries website, Ayling & Cox 1982, Colman 1973, Colman 1974, Graham 1938, Graham 1939, Jellyman et al. 1997, Livingston 1987, Manikiam 1969, Roper & Jillett 1983) which includes some research in Otago waters, indicates the following distributional features and habitat differences between the species:

- Sand flounders are most abundant as adults on the open coast where there are sand sea beds but appear to utilise protected shallow waters (including harbours) and the shallow margins of protected coastal waters as nursery areas, moving progressively into deeper waters as they mature.

- Lemon and common soles are found in open coastal waters, mainly where there are sandy sea beds.

- Greenback flounder are primarily found on the open coast but may enter estuaries and river mouths.

- Black flounder are mainly found in lagoons, lakes and rivers with fresh waters and mainly muddy substrates and are not common outside these areas.

- Yellow-belly flounder are most abundant as adults in shallow harbours and estuaries with sand to mud seabeds where the waters have an estuarine influence although they also can be found in shallow open coastal waters.

- All of the flatfish species studied make a seasonal migration to (deeper) open coastal waters to spawn.

- Juvenile flatfishes are most abundant in shallow waters.

In Otago waters, sand flounder, lemon sole and common sole are the most commonly found species (Graham 1938, Roper & Jillett 1983) but all of the above flatfish species are known to be present.

Food and diet

The food of flatfishes is mostly comprised of benthic species, including polychaete worms, small crustaceans, small echinoderms and small molluscs, although small fishes and other organisms also form part of their diet (Gibson, 2005). The mouths of flatfishes are small and suited to foraging for small benthic organisms. Internationally, flatfishes are considered to be opportunistic feeders. The wide distribution of New Zealand's flatfish species from the far north to the deep south – waters which have a range of different benthic species – indicates New Zealand flatfish species are likely also to be opportunistic feeders. In a study of trophic niche overlap between flatfishes in a nursery area on the Portuguese coast, Cabral et al. (2002) found that niche overlap between species is probably minimised by dimensions other than food, namely time and space, and that the main food items of flatfishes were probably the most abundant in the area.

There has been limited research on the food or diet of New Zealand's flatfish species. Graham (1939) recorded the different food items in the gut contents of the Otago flatfish species from market samples over a number of years, but the locations where individual fish samples came from is not documented and there are no details of the numbers, occurrence, volume or weight of food items. Livingston (1987) analysed gut contents of five species of flatfishes from Wellington Harbour and found that they had a different diet than recorded in flatfishes from other areas of New Zealand. Although the major taxonomic groups contributing to the diet of the five flatfish species studied differed from species to species, there was dietary overlap between species. The research also found that the diet of each flatfish species varied according to the particular area of Wellington Harbour from which the samples were taken. This finding is consistent with the overseas literature indicating that flatfishes are opportunistic feeders and that they tend to feed on the most abundant organisms present.

Barracouta

Habitat

Barracouta are a schooling species that is abundant all along the middle and outer east coast of the South Island including Otago (Anderson et al. 1998, Graham 1938) where there is a major fishery. Barracouta spawn mainly in late-winter/spring (August–September). Juveniles have been recorded in inshore waters all around New Zealand (Hurst 1988, Hurst et al. 2000a).

Food and diet

Barracouta are predatory, feeding on any suitable food items that are readily available. Studies in New Zealand show fishes (including sprats, hoki, and red cod) and crustaceans were the main food items found in the stomachs of barracouta (Phillipps 1926, Graham 1939, Mehl 1969).

Blue cod

Habitat

Blue cod are found New Zealand wide (Anderson et al. 1998) but are most abundant around the South Island and Chatham Islands (Ayling & Cox 1982). The blue cod is common on or near rocky bottoms at all depths to 150 m. Adults appear to be home-ranging or territorial (Ayling & Cox 1982). Blue cod have an annual reproductive cycle with an extended spawning season during late winter and spring. Spawning aggregations have been reported within inshore and mid shelf waters. It is also likely that spawning occurs in outer shelf waters. Eggs are pelagic for about five days after spawning, and the larvae are pelagic for about five more days before settling onto the seabed.

Food and diet

Voracious predator that feeds mostly on small fishes and crustaceans, but also known to eat small bivalves and echinoderms (Thomson 1891, Thomson & Anderton 1921, Graham 1939, Ayling & Cox 1982, Russell 1983). Feeds mostly by stalking its prey and eating it whole (Russell 1983).

Blue moki

Habitat

Adults are found New Zealand wide but more common on the east coasts of the North and South Islands (Ayling & Cox, 1982, Anderson et al. 1998). Occurs in schools offshore over open seabeds although some adults remain around rocky reefs. Juvenile blue moki are found inshore, usually around rocky reefs (Russell 1983).

Food and diet

Blue moki feed on a wide variety of small benthic animals, with amphipods and small crabs predominating in the diet of those specimens examined (Thomson 1891, Graham 1939, Phillipps 1926, Russell 1983).

Butterfish

Habitat

The butterfish is an endemic species of kelpfish found in shallow waters around the New Zealand coast, especially in Cook Strait and around the South Island (Ayling & Cox 1982, Anderson et al. 1998). This species inhabits rocky coastlines and is commonly found among seaweed beds in moderately turbulent water. The main depth range is 0–20 m.

Food and diet

Butterfish are almost exclusively herbivorous, feeding on several of the larger seaweeds. Other organisms found in stomach contents are believed to be incidentally ingested. The diet of butterfish varies regionally and is largely determined by the species composition of the local seaweed beds. Brown seaweeds seem to be preferred (Ayling & Cox 1982, Russell 1983).

Hapuku (groper)

Habitat

Hapuku live on and around rocky reefs, pinnacles and seabeds throughout New Zealand waters to 800 m depth (Ayling & Cox 1982, Anderson et al. 1998). They seem to prefer areas where there are crevices and caves. In southern New Zealand, hapuku move into shallower waters in summer and deeper waters in winter (Ayling & Cox 1982).

Food and diet

Hapuku prey on a wide variety of fish and invertebrates, including red cod, tarakihi, blue cod, hoki and squid (Graham 1939, Ayling & Cox 1982).

Ling

Habitat

Ling are relatively abundant along the continental slope to 1000 m depth throughout New Zealand fisheries waters. Juveniles are found in shallower shelf waters (Ayling & Cox 1982, Anderson et al. 1998).

Food and diet

Ling is an active predator, feeding on crustaceans such as Munida and scampi and also on fish. Although a bottom dwelling species, ling have been caught in mid waters when feeding on fishes such as hoki. Small ling feed largely on crustaceans, whereas large ling prey mainly on fishes (Graham 1939, Mitchell 1984, Clark 1985).

Red cod

Habitat

Red cod are most abundant in depths of 200-300 m along the east coast of the South Island (Ayling & Cox 1982, Anderson et al. 1998). Red cod are seasonally abundant, with schools appearing in the Canterbury Bight and Banks Peninsula area around November. These schools are feeding aggregations and are not found in these waters after about June. Catch data indicates that they move into deeper water after this time. In the Canterbury Bight, spawning occurs from August to October. No definite spawning grounds have been identified on the southeast coast, but there is some evidence that red cod spawn in deeper water (>300–750 m).

Food and diet

Red cod have been found to feed on a wide variety of organisms in waters around New Zealand, with a diet largely comprised of small fishes, crabs, other crustaceans, squid and molluscs (Graham 1939, Ayling & Cox 1982).

Red gurnard

Habitat

Red gurnard are common in coastal waters all around New Zealand in depths from 20-150 m (Ayling & Cox 1982, Anderson et al. 1998). They spawn over an extended period in spring and summer. Spawning is widespread although localised over the inner and central continental shelf. Egg and larval development occurs in surface waters over a week or more. Small juveniles have been found in shallow harbours.

Food and diet

Studies have shown that red gurnard feed on a wide variety of polychaetes, crustaceans and molluscs and other marine animals including small fishes (Thompson 1891, Graham 1939, Phillipps 1926, Godfriaux 1970).

Tarakihi

Habitat

Tarakihi are most abundant over the middle and outer continental shelf (Ayling & Cox 1982, Anderson et al. 1998), showing seasonal movement from shallower waters 50-100 m deep in summer to 100-200 m deep in winter. Tarakihi spawn in several areas around New Zealand including the east coast of the North Island, Kaikoura to Pegasus Bay and the west coast of the South Island. Several juvenile nursery areas have been identified in a number of shallower, inshore waters, including the waters of Otago (Hurst et al. 2000b).

Food and diet

Benthic polychaetes, crustaceans, echinoderms and molluscs were the main food found in the stomachs of tarakihi (Graham 1939, Ayling & Cox 1982, (Godfriaux 1974). In a study of tarakihi gut contents in Tasman Bay and Bay of Plenty, crustaceans are dominant in the stomachs of small tarakihi and polychaetes the dominant organism in the stomach of large tarakihi (Godfriaux 1974). The diet of tarakihi also varied according to the area samples were taken from.

Trumpeter

Habitat

Found New Zealand wide Anderson et al. 1998 and generally in association with rocky reefs and seabeds down to 100 m depth, but sometimes occur in schools in association with blue moki (Ayling & Cox 1982,). Trumpeter are believed to spawn in winter in deeper waters of the outer continental shelf.

Food and diet

Trumpeter feed on a wide range of molluscs, crustaceans, and fish (Graham 1939, Ayling & Cox 1982).

Rock Lobster (Crayfish)

Habitat

Rock lobster are present all around New Zealand on or near rocky shores and reefs with structures that provide ledges, caves and crevices for shelter and around large algae that provide cover. Rock lobster show seasonal movement into shallow water for moulting and mating. Seasonally, females move to the edges of reefs to spawn their eggs. They are known to migrate long distances along the coast. Although they are generally found in depths of less than 100 m they occur to 200 m depth.

Rock lobster have an extended pelagic larval phase of 12-24 months duration. Larvae settle mainly in small crevices along the coastline with the most widespread settlement occurring during winter months (Booth et al. 1998).

Food and diet

Rock lobster feed on a wide variety of small crustaceans, shellfish, echinoderms fishes and seaweeds. They are also opportunist feeders and scavenge on any dead or decaying biological matter. In captivity, they grow well on manufactured diets of food pellets and fresh minced mussels (Bryars & Geddes 2005)

Paua

Habitat

Paua are found in the sublittoral and are distributed along the rocky coasts of both main islands of New Zealand and of the Chatham Islands, Stewart Island, and the Snares Islands. Paua can form large aggregations on reefs in shallow sub tidal coastal habitats. Movement is over a sufficiently small spatial scale that the species may be considered sedentary. Paua are broadcast spawners and spawning is thought to be annual. Habitat related factors are an important source of variation in the postsettlement survival of paua. Growth, morphometrics, and recruitment can vary over short distances and may be influenced by factors such as wave exposure.

Food and diet

Paua graze on brown and red algae. Tunbridge (1967) studied the feeding habit of small *Haliotis iris* in three localities at Wellington finding that the diet varied with the location, various brown and red algae being eaten. In a study of the food of paua, Poore (1972) concluded that floral composition has a major effect on the diet of paua which may vary markedly from place to place even within a small geographical area. Based on laboratory experiments, Cornwall et al. (2009) concluded that the paua feeds primarily on drift algae rather than attached plants. While some preferences for brown algae were apparent, Cornwall et al. (2009) found that paua consumed the most abundant algae present.

3.3 Fish eggs in Otago waters

Very little research has been conducted to determine spawning locations of fishes in Otago waters. Robertson (1980) undertook an extensive research project aimed at determining the seasonality, geographical distribution and vertical distribution of the planktonic eggs of fishes occurring in Otago waters. This summary relies on Robertson's (1980) report which should be referred to for the many maps and diagrams showing the results.

Three sampling areas were studied seasonally, Otago Harbour, Blueskin Bay and east of the Otago Peninsula. A much wider area from Moeraki to Nugget Point was studied non-seasonally.

Overall, Robertson (1980) found that the eggs of most species were very widely distributed along the coastline of Otago. The general areas of spawning of Otago fishes can be determined from the many maps showing the geographical distribution of fish eggs in the report. The following list reproduces Table 21 in Robertson (1980) indicating the areas of spawning of some fish species (using their common names rather than the Latin names in the original table) on the Otago coast.

Shallow shelf (0-40m)	Mid to deep shelf (40-200m)	Oceanic (>200m)
Sprat	Smooth rattail	Pearlside
Ahuru	Rugnose rattail	
Southern pigfish	Red gurnard	
Spotty (Paketi)	Telescope fish	
Banded wrasse	Blue cod	
Sand flounder	Common warehou	
Common sole	Witch flounder	
Slender sole		
Lemon sole		

Although the presence of fish eggs indicated that some spawning activity occurred year round in most areas of Otago sampled, there was a seasonal fluctuation with highest egg numbers in spring. No major spawning of sand flounders was detected in the study, but some sand flounder eggs were taken in samples from Blueskin Bay (Nov-Dec) and in Otago Harbour (Sept-Nov). Sole (Peltorhamphus spp.) eggs were abundant in Blueskin Bay (Jul-Oct). Sole eggs were also very abundant along the inshore Otago coast from Nugget Point northward. Lemon sole eggs were mainly concentrated between Nugget Point and Otago Peninsula. Yellowbelly flounder eggs were rare.

From vertical samples, the eggs of most species were found to be concentrated near the water surface, although sole eggs were evenly distributed throughout the water column.

3.4 Tolerances to suspended and settled sediments – Fish

The main environmental effects arising from dredging and disposal potentially affecting fish species are associated with suspended sediments and increases in turbidity. Dredging releases suspended sediments during the excavation and disposal. The locally increased suspended sediments and turbidity associated with dredging and disposal is obvious from the turbidity plumes which may be seen trailing behind dredge vessels and at disposal sites.

Otago Harbour is a naturally turbid environment as local sediments are frequently suspended due to wind, wave and tidal flows. Fish and shellfish that live or visit this environment are already tolerant of the naturally relatively high levels of suspended sediments. Outside Otago Harbour, waters are much less turbid, although storm events can flush large quantities of suspended sediments from rivers into shallow coastal waters during storm events. Marine species living in waters that are normally clear are less likely to be tolerant of very high levels of suspended sediments.

There has been very little research directed at determining the tolerance of New Zealand’s marine fish species to increased levels of turbidity and suspended sediments. One of the few studies was feeding trials on juvenile snapper using suspended silt/clay. These trials found only 8% success rate for foraging on mysid shrimps with NTUs of 160 (equivalent to increased turbidity during rain events) compared with 77% in controls (Mark Morrison, NIWA, pers comm.).

In the Port of Melbourne assessment it was suggested that 100 mg/l of SS and 70 NTU was necessary to protect fish eggs and larvae. Appleby and Scarratt (1989) summarised a number of studies that have assessed the effects of suspended sediments on fish. Most fish eggs and larvae do not show a significant effect until concentrations get above 500 mg/l and adult fish can tolerate at least 2000 mg/l for extended periods before mortality occurs. Most tidal reaches of Otago Harbour that flatfishes utilise as a nursery area will receive <10 mg/l of suspended sediments, well below the level that fish eggs, larvae and adult fishes are known to tolerate.

A detailed literature review (Anchor Environmental 2003) from studies in the last 30 to 40 years of the effects of suspended sediments on the various life stages of finfish, molluscs and crustaceans indicates that acute lethal effects are very low at suspended sediment levels below 500 mg/l for all species combined. Acute sub-lethal effects are very low at suspended sediment levels below 22 mg/l. Although the Anchor Environmental (2003) literature review is of data compiled from species found elsewhere throughout the world, many of those species are related to Otago species or are species inhabiting similar ecological niches to those found in Otago.

4.0 Exposure to dredging

Comprehensive modelling has been carried out for Port Otago Ltd to identify the extent and fate of the turbid plume that would result from the dredging operation. Most of the discharge is at depth thus highest suspended sediment concentrations will be higher towards the seabed and lower at the surface. The plume will be mostly confined to the channel but at high tide the plume will be able to spread onto the intertidal flats. Full results of the modelling are reported in Bell et al. (2009) and are summarised in James et al. (2009).

Suspended sediments

As can be seen in the example in Figure 4 below most of the tidal flats in the Lower Harbour will be subject to concentrations under 10 mg/l. However during dredging, concentrations in the plume could reach 100-200 mg/l for short periods in areas such as Latham Bay and the flats near Quarantine Island. The largest cockle beds in the Lower Harbour, opposite Acheron and Pulling Points, would be subject to concentrations over 1 mg/l but for less than 10% of the time, except when dredging Taylers Point and Cross Channel areas when it could be up to 30% of the time. Concentrations would only reach a potential threshold for cockles (400 mg/l) for 5-7% of the time and only while dredging in that immediate area.

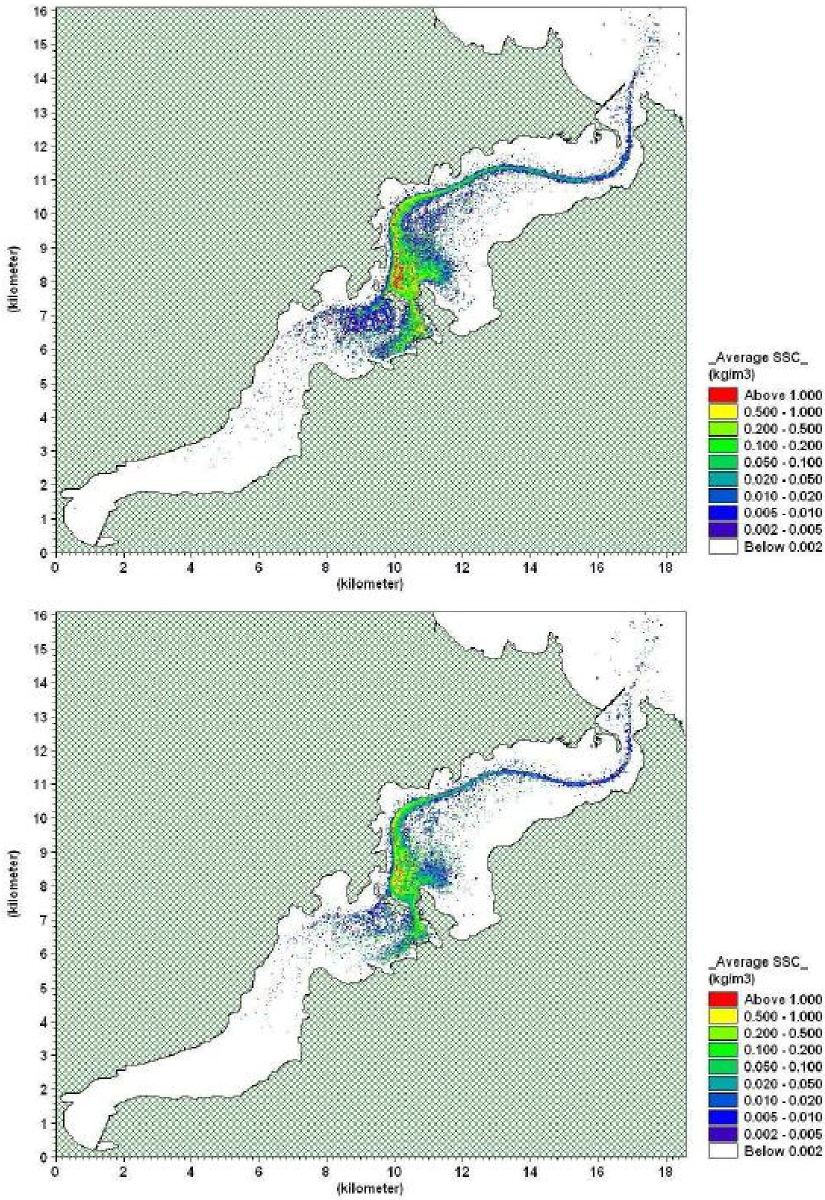

Figure 4: 14-day average SSC in kg/m^3 for a <u>Basin–east discharge source</u> for predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM) – from Bell et al. 2009).

Most of the flats from Te Rauone Beach to Harwood and at Aramoana would be largely unaffected (i.e <1 mg/l) and for less than 5% of the time, except for areas close to the channel for brief periods when dredging the Cross-channel section (>1 mg/l for up to 10% of the time and over 100 mg/l for up to 5% of the time).

It should be noted that these predictions are based on the large capital dredging programme. If Port Otago Ltd was to use smaller dredges the concentrations of suspended sediments would be lower than those predicted here but over a longer time period.

Deposition

During dredging sediments will settle out although most will subsequently be resuspended and dispersed. Modelling has predicted that the average deposition of sediment could be over 0.2 mm/d in some areas but this would be confined to the main channel. The highest average deposition outside the main channel is predicted to be on the intertidal flats opposite the Port where deposition could be 9.2 mm over the whole capital dredging programme (Bell et al. 2009). The maximum deposition which could affect 1% of this area or 1.1ha would be 82 mm or 0.8 mm/d.

Harwood, Aramoana and Te Rauone Beach sections would receive an average deposition of 1 mm or less over the dredging period. There would be patches subject to higher deposition but less than 10% of these areas would receive over 1.5 mm and very small areas (<1% of the areas at Aramoana and Te Rauone, 3.6 ha) over 4 mm, over the whole dredging period. Less than 1% of the intertidal area around Harwood would receive over 24 mm in total over the dredging programme (0.2-0.3 mm/d). The inter-tidal section opposite Pulling and Tayler Points would also be subject to some deposition as they are close to the Port and main channel. These areas are predicted to receive an average of 2.2 and 1.8 mm respectively over the dredging period. Small areas in these sections of the Harbour (<1% of the areas being <3.8a) are predicted to receive less than 15 and 13 mm respectively over the whole dredging period, this exposure being less than 0.2mm/day. (Table 7.6, Bell et al. 2009).

Concern has been raised that suspended sediments and deposition of sediment could reach the coastline to the north of Otago Peninsula, and in particular the kelp/seaweed forests which support diverse and abundant fish and other marine life. These forests are vulnerable to light changes and experiments have shown that thin coverings of sediment can reduce zygote attachment. The edge of the plume from capital dredging may reach the northern coastline on occasions but concentrations of suspended sediments would be less than 3 mg/l. Deposition along the coastline would be very small and when the plume did come in contact with the coast modelling indicates this would be less than 0.5 mm deposition of sediment over the dredging period. Much of this would be rapidly mobilised and dispersed.

5.0 Effects of dredging - Shellfish

The potential effects of dredging have been assessed and reported in James et al. (2009). The major effects have been identified as direct impacts through removal and disturbance, smothering of benthic communities and increased levels of suspended sediments leading to increases in turbidity and reduced light levels.

The most severe impact on shellfish beds will be losses during the widening of the swing basin and to a lesser extent at Aramoana. The largest area is at the swing basin opposite Port Chalmers which will result in loss of some intertidal and sub tidal habitat. It has been estimated that up to 8,000 m^2 of the intertidal area would be lost in this area. This represents less than 0.15% of the area of the Lower Harbour between 0.0 m and 1.0 m above chart datum (approximately 6,000,000m2). This affected area is predominantly below 0.25m chart datum therefore is only exposed on low spring tides and less than 6% of the time. The channel margins opposite the Port contain few cockles with the larger populations further up on the sandflats. Assuming there were 10 m^{-2} in the area to be widened and an average whole weight of 30 gm for an average individual (Breen et al. 1999) then this represents 2.4 tonnes which is less than 0.03% of the major bed nearby, opposite Acheron Point. Port Otago Drawings 11150/1-4 are included as Appendix A show this estimated area of intertidal zone that will be lost as a result of the dredging works, and puts this in context of the wider area of the lower harbour.

Figure 5: Area of intertdal zone adjacent to the Port Chalmers basin lost as a result of dredging.

Most of the area that will be lost during widening at Aramoana is sub tidal. No tuatua or pipi were recorded from Aramoana in the recent surveys but there are reputed to be significant beds in the area (James et al. 2007, anecdotal evidence) and the area has been identified as important for recreational gathering (Bell 1999). The recent surveys used grab samples or photo images in the sub tidal and small cores on the Aramoana flats so these shellfish could have easily been missed. The presence of tuatua and pipi beds in this region needs to be confirmed. The widening of the channel in the Aramoana region would disrupt and remove some of these populations if they were present in the strip to be widened. However, following the dredging operation these beds would be expected to recolonise the newly created sub tidal area and batter slopes in the short-medium term (2-3 years).

Increases in sedimentation can alter the physical benthic habitat and smother benthic biota. Harbours such as Otago are naturally subject to episodic events which can result in some sedimentation of fine material. Most suspension feeding bivalves found in these systems can tolerate these events but repeated sedimentation over several months can have impacts in the short to medium term. Most of the fine material that will be released during the proposed dredging operation will be dispersed over the following weeks to months and is unlikely to change the sediment characteristics significantly.

Cockles

Cockles have a preference for sediments with less than 10% mud/silt content but can tolerate up to 85% mud thus would be unlikely to be excluded from intertidal areas as a result of the dredging operation.

Sediment deposition in intertidal areas that have been identified as important for gathering of cockles (Aramoana and intertidal banks opposite Pulling and Tayler Points) or where significant beds occur (Harwood) would be unlikely to have a significant impact based on the following:

- Deposition will be less than 0.3 mm/day or 24 mm over the whole dredging programme. These depositions are below the critical levels which have been found to have a significant impact on cockles (20-30 mm in an event).
- Cockles are mobile and can burrow through the small layers of fine sediment that would deposit in intertidal areas during dredging.
- Deposited sediment will be resuspended and mobilised by tidal movement and wave activity, much of it eventually being flushed out of the harbour.
- Large areas with substantial cockle beds will receive negligible deposition.
- Recruitment would occur in the short to medium-term if unexpected losses were to occur in some regions.

The major cockle beds would be largely unaffected by increases in suspended sediments (SS) because:

- Cockles can tolerate high levels of SS and condition has been found to only decrease at levels above 300-400 mg/l.
- These concentrations would only be experienced by the major cockle beds for short periods eg opposite Acheron Point for 5-7% of the time when dredging in the Cross Channel and Tayler Bend sections.
- Most areas where large cockle beds occur would be largely unaffected and experience concentrations under 100 mg/l (Harwood, Te Rauone, Aramaona).

- Cockles would be expected to survive several days at high concentrations and concentrations would return to lower levels when the dredge moves on to other areas.

Pipi

Pipi are less tolerant of fine sediments and tend to be excluded if mud content is over 67%, preferring sediments with less than 5% mud. Populations have been recorded in the Aramoana area but as they tend to be found in the likes of sub tidal channels and marginal areas where there is significant water movement then fine sediments are unlikely to settle for long and will be resuspended and dispersed. Because of their ability to burrow through several cms of fine sediment they would be unlikely to be impacted by the depositions predicted.

The major pipi beds that have been identified to date are in the Aramoana area where suspended sediment concentrations are predicted to be under the 75 mg/l threshold at which pipi are likely to be impacted. Only parts of the main channel and marginal and intertidal areas between the Port, Quarantine Island and Latham Bay would experience concentrations over 100 mg/l and mostly when dredging close to the Port.

Tuatua

Tuatua are generally considered a surf species and only small populations have been recorded in the harbour with more significant populations towards the entrance. There is no information on the sediment tolerances of tuatua but they tend to be more of a sub tidal species and again significant water movement will ensure that effects on these populations if they were to occur were short-term. If some of the beds in areas around Aramoana were affected in the short term then recruitment would occur from other populations nearby and along the open beaches and the population re-establish.

Major beds of shellfish important to Ngai Tahu are expected to persist and if there were unexpected losses then they would recover in the short- to medium-term through recruitment and recolonisation.

6.0 Effects of dredging – Fish

Exposure of fishes to dredging and disposal will occur in pulses over the duration of the dredging programme. Fish are mobile and well able to take flight from the disturbance and noise and high suspended sediment levels caused by dredging and by disposal events. As soon as the dredge ceases operation, fishes can be expected to return to dredged areas to forage for benthic organisms exposed during dredging. After each disposal event fishes will be attracted to the disposal site to forage for biota exposed in the dredged material as soon as suspended sediment levels drop to levels they can tolerate.

Along the rocky shorelines of the open coast, suspended sediment levels are expected to be very low at <3 mg/l and deposition of sediments <0.5mm. These levels are much lower than occur during typical episodic storm events. Overall, the exposure of fishes to dredging and disposal effects of suspended sediments over the full duration of the dredging and disposal programme will be short term compared to the longevity of the fish species of the area. Typical life spans of fishes, rock lobster and paua are from several years to decades.

Most fishes have egg and larval phases that last for up to several weeks. These larval stages, along with permanent zooplankton are generally adapted to episodic high levels of suspended sediments that occur in estuaries and harbours such as Otago Harbour. Experiments over two weeks with different zooplankton have shown that mortality is high at levels over 10,000 mg/l but generally studies have not shown any significant impact at the levels experienced from dredging and disposal (Clarke & Wilbur 2000). Egg distributions of Otago fish species (Robertson 1980) summarised earlier in this paper shows that eggs of most species, including the main flatfish species are widely distributed along the coast. The proposed dredging and disposal activity would affect a very small area of the overall egg distributions of these species.

7.0 Summary Tables

The major points above are summarised in the tables below.

Table 1. Distribution, habitat and diet of key shellfish species of interest to Ngai Tahu.

Species	Distribution	Main locations (Otago)	Habitat	Diet
Tuaki	Throughout New Zealand on sheltered shallow softshores particularly in harbours, inlets and estuaries.	Large populations on sandflats of Otago Harbour, Waitati Inlet and Papanui Inlet. Largest populations in harbour found in intertidal area opposite Acheron and Tayler Points, around Aramoana and Harwood.	Mostly found in muddy sand from 10 cm water depth down to 6-8 m below littoral zone. Flourish between low and mid-tide levels. Can tolerate 0-85% fine mud/silt but prefers <10%. Condition reduces at SS of 3-400 mg/l. Can survive deposition of at least 3 cm.	Lives close to sediment surface and uses short siphons to feed on microphytobenthos and particulate red algae and *Ulva* or sealettuce in Otago region. Growth found to be higher where there is good water movement eg mouths of inlets/harbours.
Pipi	Throughout New Zealand but mostly on protected beaches, bays and estuaries as well as harbours	Pipi recorded as part of fine sand community in Otago Harbour, especially in areas of low organic detritus. Populations known to exist at Aramoana and other scattered locations.	Found below the surface on sandy flats, prefers areas with coarse shell/sand habitats with good water movement and little silt (<5%). Found intertidally and subtidally down to 10-12 m. Condition and feeding reduces at SS above 75 mg/l. Strong burrowers and can survive deposition of over 10 cm.	Pipi have longer siphons than cockles. They extract microscopic algae (diatoms, flagellates) and organic material from a range of sources in the overlying water.

Species	Distribution	Main locations (Otago)	Habitat	Diet
Tuatua	Throughout New Zealand, but *P. donacina* on sandy beaches of eastern South Island such as Otago region. Generally considered a surf species.	Populations recorded near Aramoana and occasionally in recent surveys on northern side of channel from Acheron Point to Tayler Point and subtidally south-east of Port.	Below the surface on open beaches. Mostly found subtidally on open beaches in the surf zone. Little information on effects of sediments available for this species.	Tuatua have long siphons that can extend up to 3 cm through sediment. Like other suspension feeders they feed on microscopic algae and organic material in the overlying water.

Table 2. Distribution, habitat and diet of key fish species, rock lobster and paua.

Species	Distribution and Habitat	Diet	Locations
Sand flounder *Rhombosolea plebeia*	NZ wide. Sandy seabeds in coastal waters out to about 100 m depth.	Benthic invertebrates (e.g. polychaetes, crustaceans, echinoderms).	Abundant in the northern harbours, Hauraki Gulf, Firth of Thames, Tasman Bay and on the east coast of the South Island including Blueskin Bay and south of Otago Peninsula.
Common (NZ) sole *Peltorhamphus novaezeelandiae*	NZ wide. Demersal. Sand and muddy seabeds out to about 100 m depth.	Benthic invertebrates (e.g. polychaetes, crustaceans, echinoderms).	Abundant in open coastal waters around the West and East coasts of the South Island, including Blueskin Bay and south of Otago Peninsula.
Lemon sole *Pelotretis flavilatus*	NZ wide. Demersal. Sand and muddy seabeds out to about 100 m depth.	Benthic invertebrates (e.g. polychaetes, crustaceans, echinoderms).	Abundant in open coastal waters around the West and East coasts of the South Island, including Blueskin Bay and south of Otago Peninsula.
Greenback flounder *Rhobosolea tapirina*	NZ wide and Australia. Demersal. Silty sand substrates from estuaries and inshore waters down to 100 m depth. Juveniles occasionally entering rivers.	Benthic invertebrates (e.g. polychaetes, crustaceans, echinoderms).	Mainly found on east coast of South Island including Otago coastal waters but not abundant anywhere in its distribution.
Black flounder *Rhombosolea retiaria*	NZ wide. Demersal. Mud to sand seabeds, mainly coastal lakes, brackish or fresh waters with access to the sea. Also recorded from coastal waters to 50m.	Benthic invertebrates (e.g. polychaetes, crustaceans, echinoderms).	Not abundant but most common in fresh water lakes and lagoons NZ wide (e.g. Lakes Ellesmere and Onoke) but also found in small numbers in rivers and estuaries, including rivers such as the Kakanui in Otago.
Yellow belly flounder *Rhombosolea leporina*	NZ wide. Demersal. Especially protected harbours and estuaries with sand to mud seabeds but also shallow coastal waters down to about 50 m.	Benthic invertebrates (e.g. polychaetes, crustaceans, echinoderms).	Most abundant in the northern North Island harbours with some freshwater influence. Not abundant in the South Island but found in many estuaries and harbours such as Taieri mouth.
Barracouta *Thyrsites atun*	All oceans worldwide. Pelagic, schooling. Inhabits waters on continental shelves or around islands.	Predator. Feeds on pelagic crustaceans cephalopods and small fishes like anchovy and pilchard	Abundant and widespread throughout New Zealand including the continental shelf along the Otago coast.
Blue cod *Parapercis colias*	NZ wide. Demersal. On or near rocky seabeds to 150 m depth.	Small fish and crabs.	Most abundant in Southland and Chatham Islands but also an important species in Otago.

Species	Distribution and Habitat	Diet	Locations
Blue moki *Latridopsis ciliaris*	New Zealand wide and southern Australia. Demersal. Over rocky and sand seabeds to 100 m.	Small benthic animals including polychaetes, crustaceans, echinoderms, molluscs.	Migrate annually to the upper east coast of the North Island to spawn. Found along the east coast of the South Island, including Otago
Butterfish *Odax pullus*	SW Pacific waters. Shallow inshore waters along the coastal fringe where rocks and brown algae are abundant.	Herbivore, preferentially feeding on brown algae. Animals in stomach contents are probably incidentally ingested with the algae.	Widely distributed throughout New Zealand but more abundant from Cook Strait south including Otago.
Hapuku *Polyprion oxygenios*	Circumpolar in southern hemisphere waters. Deepwater species. Adults demersal on rough ground from the central shelf to deeper waters. Juveniles are pelagic and occur in surface waters.	Predator. Feeds on barracouta and pilchards, in addition to various bottom-dwelling fish.	Widely distributed throughout New Zealand including Otago.
Ling *Genypterus blacodes*	Southern hemisphere. Demersal. Adults over mud and rocky seabeds in deeper waters of continental shelf and slope to 1000 m depth, juveniles in shallower coastal waters.	Predator. Feeds mainly on crustaceans such as Munida and scampi and also on fish.	Widely distributed in deep waters on the shelf edge throughout New Zealand including Otago.
Red cod *Pseudophycis bacchus*	SW Pacific waters. Demersal. Mainly over soft muddy or sandy bottoms, most abundant in 200-300 along the continental shelf but may also be found in shallower waters.	Feeds primarily on small fishes, cephalopods, crabs and other crustaceans.	Abundant and widely distributed throughout New Zealand but most abundant on the South Island east coast including Otago.
Red gurnard *Chelidonichthys umu*	Indo West Pacific. Coastal waters over sandy seabeds.	Crustaceans, cephalopods, small fishes.	Widely distributed throughout New Zealand. Abundant on the east coast of the South Island, including Otago.
Tarakihi *Nemadactylus macropterus*	Indo Pacific. Adults demersal on the continental shelf and upper slope to depths of 450 m. Juveniles tend to live near shallow reefs.	Polychaete worms, crustaceans, molluscs and echinoderms.	Tarakihi spawn in summer and autumn in several areas around New Zealand. The three main spawning grounds identified are Cape Runaway to East Cape, Kaikoura to Pegasus Bay, and the west coast of the South Island. Present along the Otago coast
Trumpeter *Latridopsis lineata*	Southern hemisphere. Over rocky reefs and seabeds.	Crustaceans, cephalopods, small fishes.	Most common around the southern half of the South Island including Otago but found as far north as the Bay of Plenty.
Red rock lobster (crayfish) *Jasus edwardsii*	NZ wide and southern Australia to 200 m depth. Widespread around all rocky coastlines.	Diet consists of small organisms with a preference for shellfish, crabs, seaweeds, small fish and sea urchins. Also a scavenger.	Abundant on all rocky coastlines around New Zealand. In Otago, found on all rocky shores but most abundant along rocky shorelines north of Blueskin Bay and south of Taiaroa Head.
Paua *Haliotis iris*	NZ wide. Rocky shores and reefs to 15 m depth.	An herbivore that feeds exclusively on unattached (drift) and attached macroalgae.	Widespread around all rocky shores but most abundant south of the middle of the North Island. Abundant along rocky shorelines and headlands of Otago.

8.0 Monitoring and Dredging Management

A monitoring and mitigation programme is outlined in the Assessment of Environmental Effects and broadly covers the following aspects:

- Plume tracking during dredging
- Monitoring of turbidity at key representative or sensitive sites (eg significant seagrass beds).
- Contaminant levels in dredged sediment.
- Benthic communities and habitats at selected sites in the harbour and offshore at the disposal site.
- Monitoring at a few key/representative coastal sites eg kelp beds on northern coasts.
- Observations of dead or dying fish during dredging.

Mitigation measures outlined in the AEE include :

- Managing dredging to avoid sensitive areas eg during bird breeding and peak fish spawning.
- Setting limits of turbidity near sensitive areas at which dredging would move to a different section.

9.0 Acknowledgements

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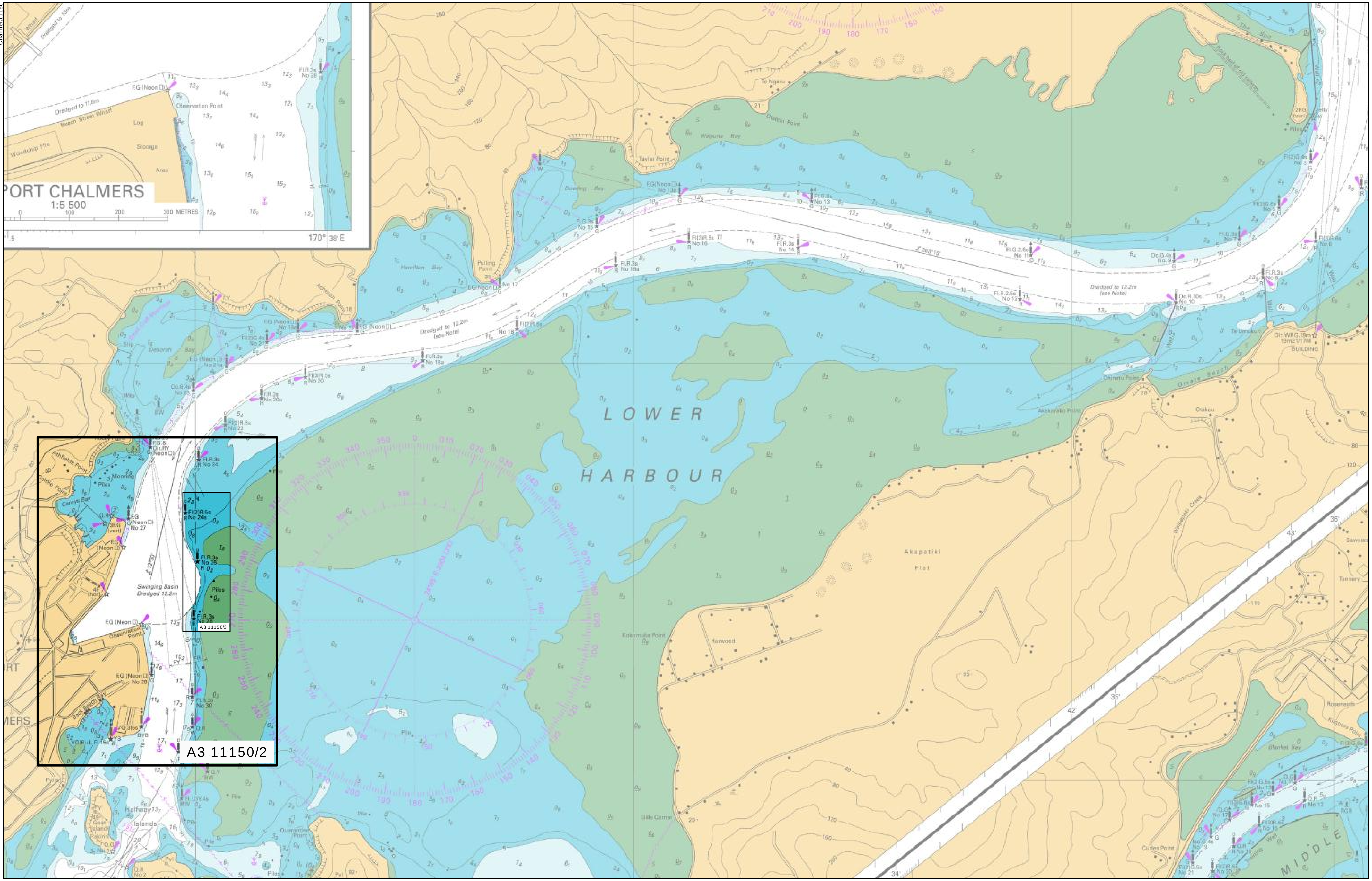
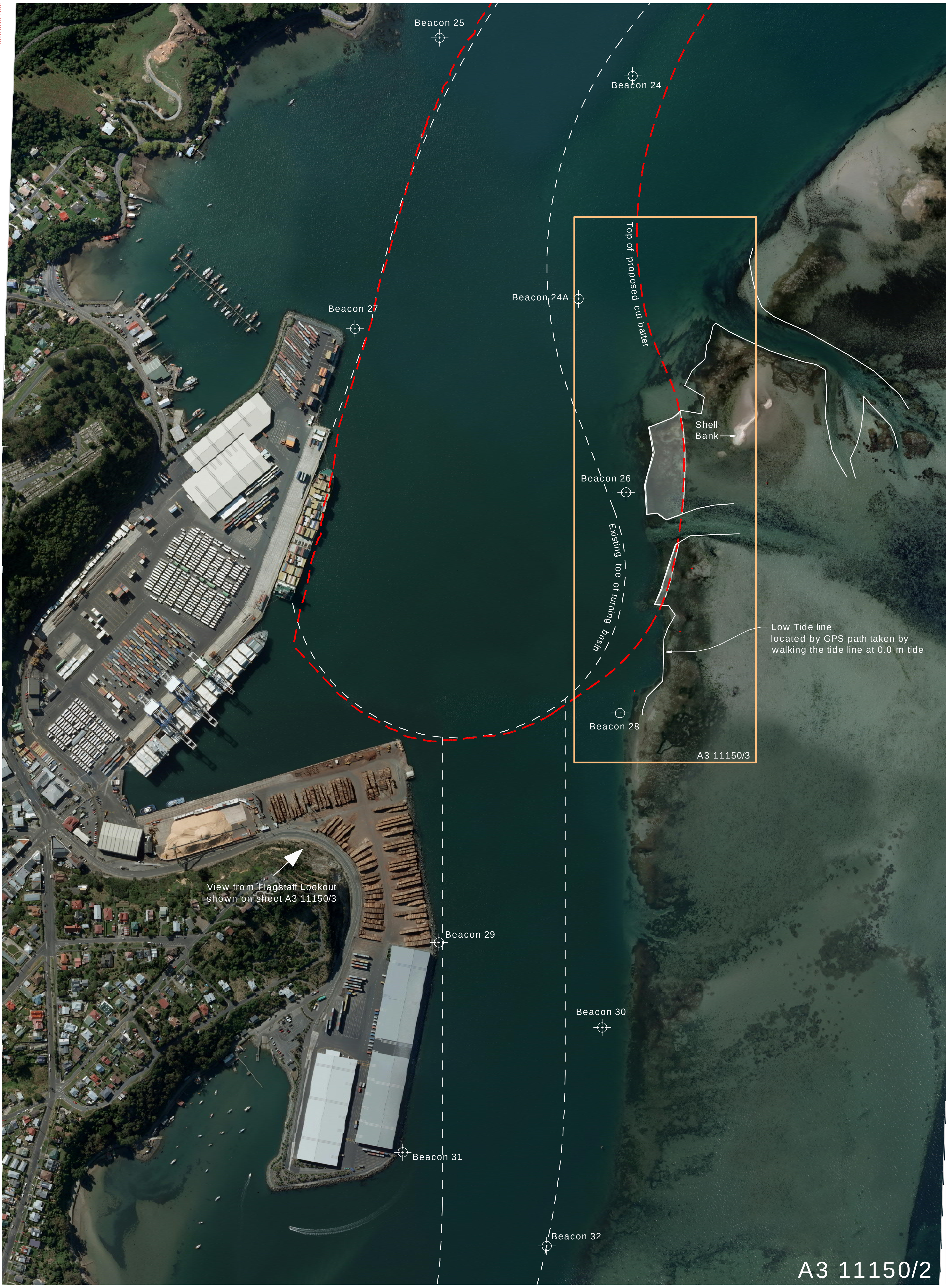
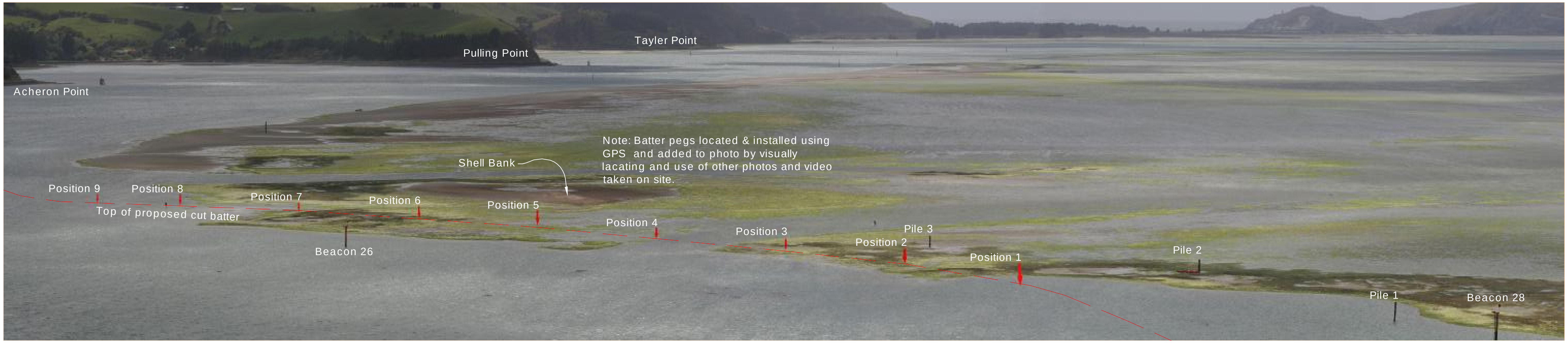


Portion Of Otago Harbour Chart (NZ 6612)

Scale 1:20,000

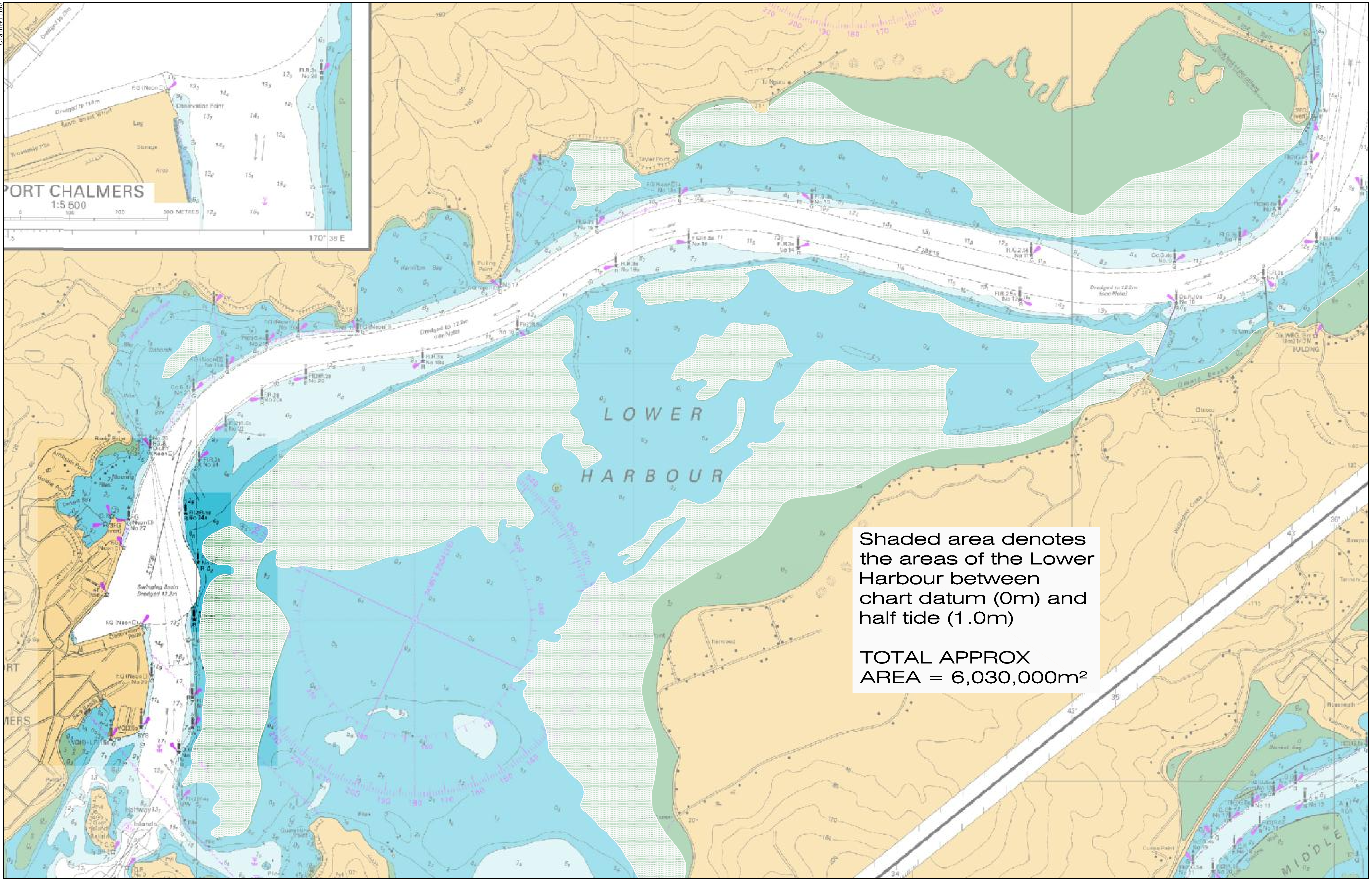

Beacon 25
Beacon 24
Beacon 27
Beacon 24A
Top of proposed cut batter
Shell Bank
Beacon 26
Existing toe of turning basin
Low Tide line located by GPS path taken by walking the tide line at 0.0 m tide
Beacon 28
A3 11150/3
View from Flagstaff Lookout shown on sheet A3 11150/3
Beacon 29
Beacon 30
Beacon 31
Beacon 32
A3 11150/2

Channel11150



As Viewed From Flagstaff Lookout

A3 11150/3



Portion Of Otago Harbour Chart (NZ 6612)

Scale 1:20,000

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