# Chapter 12 Dredging and disposal in Aniva Bay

## 12.1 INTRODUCTION

This supplemental information on dredging activity in Aniva Bay is provided in order to address specific questions raised by stakeholders to the Project following publication of the international style Environmental Impact Assessment (EIA) in 2003, and as such forms a component of the EIA addendum (EIA-A). In addition, this addendum addresses modifications since the EIA was published. The information presented deals with aspects of the dredging campaign in Aniva Bay that may influence both commercial fisheries and benthic communities, which because of the commonality of potential impacts, are dealt with here rather than in the respective sections dealing with those interests.

## 12.2 DREDGING AND DISPOSAL REQUIREMENTS

The development of a Liquefied Natural Gas (LNG) plant and materials offloading facility (MOF) at Prigorodnoye in Aniva Bay requires the construction of two jetties for these facilities. In order to enable vessel access, allow the offloading of heavy equipment and ensure safety, capital dredging to deepen the approach channels and turning basin is required to obtain adequate water depths. In total, an estimated volume of 1.45 million $m^3$ of material needs to be dredged as detailed below:

- Dredging for LNG jetty, turning basin and berth = 1,300,000$m^3$ (20 % soft sediment and 80% rock);
- Dredging for MOF = 145,000$m^3$ (30 % soft sediment and 70 % rock (claystone).

Thus the majority of the material to be dredged and disposed of is rock (1,141,500$m^3$) as opposed to soft sediment (303,500$m^3$).

In comparison with many large-scale construction and infrastructure projects the dredging volumes for the LNG and MOF are relatively small as the following list of recent major capital dredging schemes demonstrates:

| No. | Project | Dredge volume (Million cubic metres: $Mm^3$) | Approximate distance(s) of disposal site(s) from reclamation or shore (km) [Source] |
|---|---|---|---|
| 1. | Hong Kong airport artificial island (Chek Lap Kok new airport) (1998) | 184 $Mm^3$ | From airport reclamation site: 38km (route of boat); 20km as the crow flies [Environmental Protection Department, The Government of the Special Administrative Region (Hong Kong). http://www.epd.gov.hk/epd/english/] |

| | | | |
|---|---|---|---|
| 2. | "The World" offshore islands' complex (reclamation project), Dubai, United Arab Emirates, Arabian Gulf | 300 $Mm^3$ | 5.75km offshore.<br>[[www.nakheel.com<br>www.vanoord.com] |
| 3. | (Proposed) Main Port of Rotterdam extension project | 12 $Mm^3$ | N/A – material to be removed to be mixed with incoming sand from borrow areas or other sources. The reclamation site is adjacent to the mainland.<br>[http://www.kvi.nl/~annrep/ar1999/kviar_1999_c7_2_2.html] |
| 4. | London Gateway (proposed port) | 30 $Mm^3$ | Material from dredging transported to Shell Haven and used for reclamation or other construction material (i.e. up to 200 metres from and adjacent to the mainland).<br>[P&O. 2002. The (London Gateway Port Limited) Harbour Empowerment Order 2002; Environmental Statement Part A: Context. Oscar Faber. Bristol.] |
| 5. | Harwich Haven Approach Channel deepening, UK | 19 $Mm^3$ | 10km from shore (closest point).<br>[www.dft.gov.uk/stellent/groups/dft_shipping/documents/page/dft_shipping_035830-03.hcsp] |
| 6. | Bharat Shell – Channel deepening for LNG receiving terminal, Hazira, India (2004) | 15 $Mm^3$ | Dredged material for the entrance channel will be partly reclaimed onshore, where suitable, at a distance up to 1.6km from the shore. Unsuitable material dumped in:<br>(i) deepwater channel 5km over high-water;<br>(ii) 15 nautical miles over low-water behind a sandbar.<br>[Royal Haskoning Oct. 2005.] |
| 7. | Channel deep-water port Muuga Estonia (1981-1984) | 6 $Mm^3$ | Assumed reclamation took place adjacent to mainland and probably within 1km.<br>[Various internet searches] |
| 8. | Felixstowe South, UK, jetty reconfiguration | 3.8 $Mm^3$ | Approximately 90km from the proposed reclamation site.<br>[Royal Haskoning] |
| 9. | Sakhalin LNG terminal | 1.5 $Mm^3$ | 25km due south of the dredging site near the shore. |

Although the scale of dredging does not necessarily equate to the potential magnitude of environmental effect and impact, the above figures do indicate that the volume of the dredging to be undertaken at the LNG site is on a scale that by modern day standards would not be considered out of the ordinary.

The timing for undertaking the dredging is significantly controlled by the prevailing climatic conditions within Aniva Bay and ecological sensitivities (namely salmon migration between May and September). Sea ice occurs in the Bay from the middle of January to end of March, effectively precluding any marine operations during this period. These factors, therefore, effectively restrict marine dredging works in the Bay to October-December and during suitable weather within this period. Due to vessel mobilisation and logistical considerations it is highly unlikely that dredging operations can be undertaken during the March-April period. Based on the amount of material to be dredged, it has been estimated that the dredging could be undertaken in a total period of six months (in aggregate) through optimal use of techniques and equipment.

## 12.3 DREDGING DISPOSAL SITE SELECTION

### 12.3.1 Introduction

Investigation for the selection of a marine disposal site for dredged material involves a number of steps that enable potential adverse impacts on the marine environment to either be avoided or minimised. Appropriate environmental matters considered in selecting a suitable site include:

- Water column – physical characteristics that may affect the dispersal of dumped material (e.g. water depth, stratification, surface and bottom currents, temperature profile, suspended solids, salinity). In shallow water depths, the potential for the remobilisation and dispersal of disposed sediment at the seabed through wave and current activity is potentially greater than in deeper water depths. In deeper water, fine sediment dispersion can be increased as material falls through the water column and, importantly, the monitoring of environmental effects may also be technically compromised in deeper water depths;
- Seabed – physical characteristics that may affect the dispersal of dumped material (e.g. topography, sediment grain size, sediment mobility and chemistry). Where feasible, sediment derived from dredging should be disposed of at a site where seabed sediment composition is similar and material is either retained in a discrete area (if of different composition to the receiving environment) or allowed to disperse to facilitate habitat recovery;
- Marine communities – characterisation of biota to assess potential effects of sediment disposal on marine life. Should include data on planktonic and benthic communities, demersal fish fauna and cetaceans and seabirds. Ideally, disposal should be undertaken in areas of lower marine productivity, biological diversity, sensitivity to potential effects, absence of protected/rare species and good potential for recovery;
- Other uses – As the effects of sediment disposal have the potential to adversely influence a number of environmental interests, it is important that areas of significance for commercial fishing (level of fishing activity, use as a spawning or feeding area by commercially valuable species), vessel navigation, recreational activity and protected marine areas are

avoided or that impacts in such areas are acceptable through the use of appropriate management.

Information on the characteristics of the disposal site is required to determine the probable fate and effects of the dumped material. The physical conditions in the vicinity of the disposal site will determine the transport and fate of the dredged material. The physiochemical conditions can be used to assess the mobility and bioavailability of the chemical constituents of the material. The nature and distribution of the biological community and the proximity of the disposal site to marine resources and amenities will, in turn, define the nature of the effects that are to be expected.

### 12.3.2 Site suitability

The main objective for the disposal of dredged material arising from the works at the LNG and the MOF was to select an area/site at which environmental impacts would be either avoided or minimised, but that also met economic and technical criteria. In respect of this, ensuring that disposed material could be confined to a relatively well-defined area (i.e. contained rather than dispersive) was an important factor in determining suitability. Additionally, transport distances for disposal of material had to be within limits that enabled the dredging works to be completed in a reasonable timeframe and which also minimised other environmental effects (e.g. air emissions and potential collision risk with whales). As such, disposal outside of Aniva Bay was not considered a project-viable option, as briefly discussed in more detail below.

On the basis of available environmental information and data collected during baseline studies for the Sakhalin II Project, the physical and environmental conditions characteristic of the central part of Aniva Bay indicated that it could be suitable for the disposal of some types of dredged material. In relation to the criteria listed above the following points can be made:

- Water column - Water depths in the area are in the range of 30-100m. At these water depths, potential remobilisation of material through wave activity may be reduced in comparison to shallower areas. The potential extent of fine sediment dispersion within the water column is also reduced in comparison with sites in deep water. Importantly, the monitoring of environmental effects at disposal sites in water depths of this range is technically realistic and easier in comparison with sites at greater water depths;
- Seabed – The sediment characteristics of the area reflect the lower energy conditions (i.e. below the reach of wave base) that prevail in comparison with the more dynamic nearshore coastal zone. Seabed sediments generally comprise fine sand and silt, spread over a large, undulating, gently southwards sloping shelf;
- Marine communities – the coastal zone of Aniva Bay is the most productive and diverse with respect to benthos and is also of key importance for commercial invertebrate species such as scallops, sea

cucumbers and *Laminaria*. The benthic communities of deeper water areas (approximately >30m) such as those of the central area of the Bay are reflective of the widespread soft sediment conditions and are not as diverse or productive as those of the coastal zone;

- Other activities – main commercial fish spawning and feeding areas are located in the coastal zone (e.g. spawning for herring and capelin) or outside of the main part of Aniva Bay (e.g. walleye pollack). Other species migrate to or are present in greater numbers in deeper waters (e.g. flatfish species). The distribution of selected commercial fish species is shown in Figure 12.2. Much of the central area of the Bay is also located out of main navigation paths to Korsakov and other port facilities. There are no protected areas in the Bay (see Fig. 12.1). Locating a disposal site away from the immediate coastal area also limits the possibility for disposed sediment to reach beaches and areas of recreational use.

Discussion and consultation with the relevant authorities regarding the selection of a suitable site for disposal of material arising from dredging at the LNG jetty and MOF centred around two proposed areas and sites, although a third site/area was also briefly considered (as discussed below). The two main locations as shown on Fig 12.1 were:

- Site 1: An existing disposal site for dredged material from the port of Korsakov, 46° 41 05" N, 142° 42 00" E, water depth; 10m; and
- Site 2: A new site outside the 12-mile zone in Aniva Bay, about 25 Km due south of the LNG construction site, 46° 25 00" N, 142° 55 00" E; water depth 63m.

The selection process to determine the suitability of these two sites was supported by a study undertaken by SakhNIRO (2001). A third site was suggested by Sakhrybvod in 2002, after baseline studies were completed. This third site was located outside of Aniva bay, at 46°00 00"N, 144°00 00"E, a distance of 110 km from the LNG site in a water depth of 900m (see Figure 12.1).

Based on a preliminary environmental and technical screening it was determined that site 3 was not advantageous or desirable from an environmental standpoint and infeasible from a technical standpoint. The location of the site, 110km from the dredge area, would have entailed significant additional transport of dredged material in comparison with any site located within Aniva Bay. The potential environmental effects associated with this distance to disposal would include increased fuel consumption leading to increased emissions to air (e.g. $SO_2$) and increased potential for risk of vessel collision with cetaceans. The additional journey time involved would also have significantly increased the time taken for the overall dredging-disposal operation, making the process unviable with regard to project timescales.

Consideration of the optimal depth for the disposal of material is also important. During disposal, dredged material behaves like a "density slug", in which fines and aggregates fall together at the same rate (i.e. the rate of fall is not a function of particle size during the initial stages of fall). The slug acts as a jet, entraining water around its periphery as it falls. During the descent, the edges of the slug start to break away and then behave as individual particles. Once the material reaches the seabed, it flattens out and comes to rest.

The degree to which the slug breaks up is dependent upon the time it takes for it to reach the seafloor. If the dredged material placement site is too deep, and the material is not sufficiently aggregate, the slug never effectively reaches the seafloor as it has had so much water entrained that it ends up as a strip of plume that then disperses. The water depth of Site 3 was considered to be too great for these reasons.

Finally, in the overwhelming majority of cases, the disposal of sediment arising from dredging is performed in coastal and continental shelf waters (<100m) where environmental data on biological and physical impacts is more readily available and technical measures to monitor and deal with potentially adverse environmental is more readily facilitated. The possibility for thorough assessment of impact and monitoring would not have been possible at Site 3 due to the depth of the site.

Having discounted site 3, a number of criteria were considered for determining which of the other two sites would be the preferred location, as set out below:

Environmental issues:

- Temporal and spatial impact;
- Effects on benthic invertebrates;
- Dispersion of disposed material;
- Air quality;
- Commercial fisheries.

Technical issues:

- Regulatory requirements for disposal;
- Equipment/vessel availability;
- Navigational interference;
- Compatibility with project schedule.

Table 12.1 provides a summary of the findings of a selection analysis (further information on key commercial fish and shellfish species present within Aniva Bay and pertinent to the selection process is provided in Section 12.3.3).

**Figure 12.1. Location of potential sites for disposal of dredged material arising from construction of the LNG and MOF facilities in Aniva Bay.**

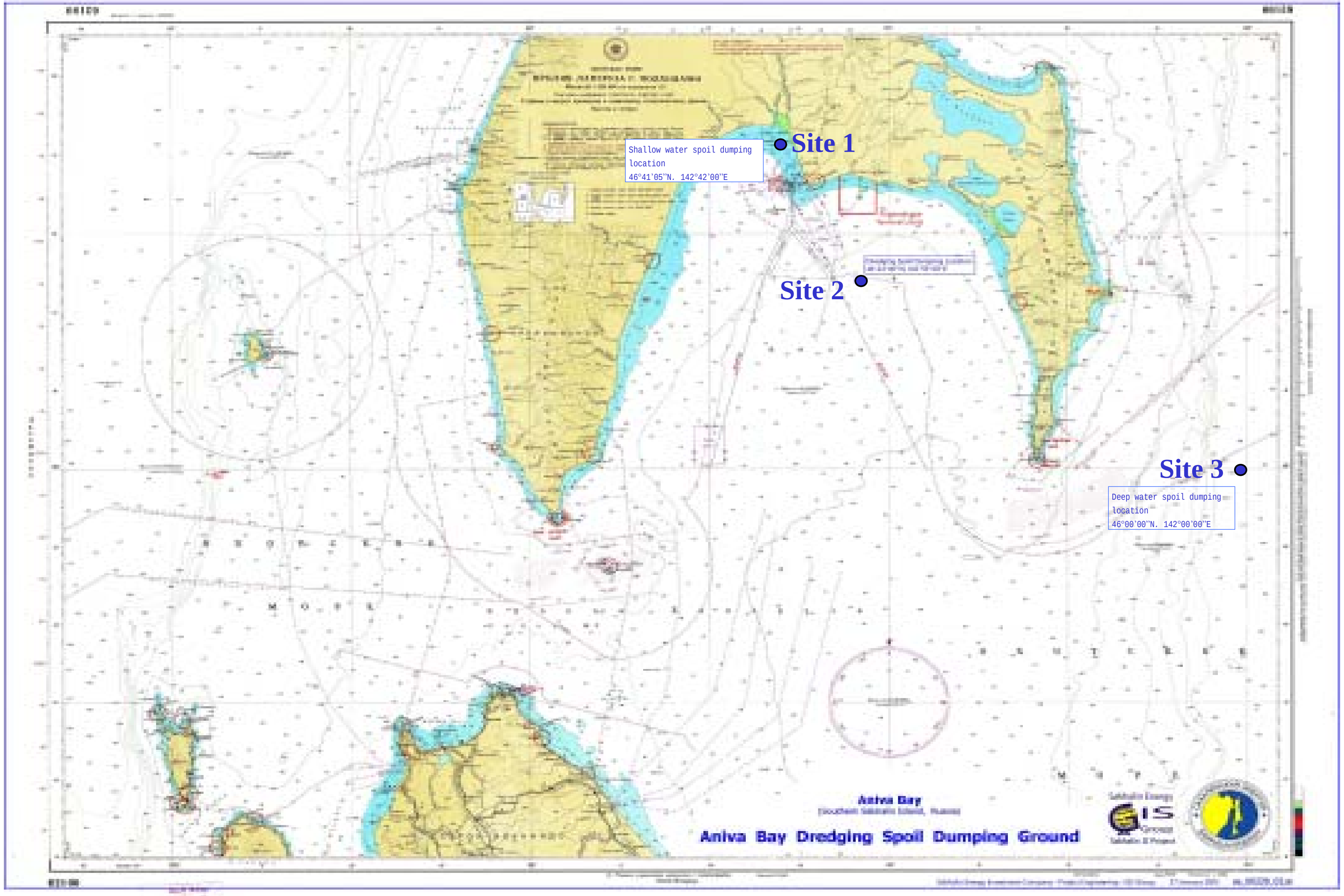


**Table 12.1. Comparative analysis of disposal sites for dredged material arising from the LNG and MOF works in Aniva Bay**

| **CRITERIA** | **SITE 1**<br>**10m water depth, north-west of Korsakov (The Salmon Bay), 22km north-west of LNG site** | **SITE 2**<br>**65 m water depth, 25km south of LNG site** |
|---|---|---|
| Legal Requirements for Disposal | Site previously used for the disposal of dredged material from Korsakov Port. Significant uncertainty regarding the legal position on the use of this site for disposal. | Located outside of the 12-mile Territorial Sea. International Maritime Organisation (IMO) regulations and guidance apply. |
| Equipment (vessels) | Available in the region. | Available in the region. |
| Project Schedule | Not compatible as work would be limited to between November to December. | Compatible with proposed project schedule |
| Navigational safety | Site relatively close to Korsakov Port. Frequent dredger movements into and out of the navigational approaches to the Port could interfere with commercial shipping traffic entering and leaving the area. | No Interference with existing shipping traffic movements or navigation. |
| Benthic communities | No specific benthic data on the site available.<br>However, shallow water (8-9m) sediments just offshore of Korsakov Port were sampled by Hydrotex (2002). The survey location is approximately 8km to the south-west of the disposal site and given the proximity, similar water depth and placement of sediment from the Port at this site, the benthic community is likely to be of similar character. Hydrotex (2002) recorded a community dominated by bivalves (4 species, including *Macoma calcarea*) and polychaetes (13 species; Cirratulid worms making up 17% of the biomass). Species diversity was recorded as 20 species with an average biomass of 48.5g/$m^2$.<br>SakhNIRO (2001a) state that the shallow water (0-13m) sediments in the north-western part of Aniva Bay, including the area occupied by Site 1, support the Sakhalin surf clam *Spisula sachalinensis*. | Soft sediment community dominated by polychaetes, amphipods and bivalves (*N.sakhalinica* and *Liocyma fluctuosa*). Survey data (DVNIGMI 2001) indicates that the communities of the area are characterised by a relatively low biomass and density. However, data from SakhNIRO (2004a) indicates that the disposal site had a higher biomass (53.7 g/$m^2$) than either the LNG dredge site (9.7 g/$m^2$) or the MOF site (6.3 g/$m^2$), which are characteristic of the shallower waters of Aniva Bay. Species diversity was similar to that found in the other areas (36 species, compared with 41 and 48 species respectively), while abundance was significantly lower (200 ind/$m^2$ compared with 1002 ind/$m^2$ and 945 ind/$m^2$ respectively). |

| **CRITERIA** | **SITE 1**<br>**10m water depth, north-west of Korsakov (The Salmon Bay), 22km north-west of LNG site** | **SITE 2**<br>**65 m water depth, 25km south of LNG site** |
|---|---|---|
| Existing suspended solid concentrations (SSC), sediment and dispersive characteristics of site | Existing SSC at seabed and in water column unknown. However, it is likely that SSC are generally higher than the rest of Aniva Bay due to the inflows of the Susuya and Tsunai rivers, which are the two main rivers flowing into the Bay.<br>Shallow water depth (<10m) at site suggests that dispersion through the water column of fine sediment would be confined to a smaller area than at Site 2, as the duration for settlement of sediment from out of the water column would be significantly less than for either of the other sites. However, current velocities likely to be greater than at Site 2 leading to entrainment of material and deposition in the coastal or littoral zone.<br>Existing sediments at the site have been tested and apart from cadmium (Cd) and mercury (Hg), all other contaminants (heavy metals, PCBs, PAHs, PHCs and organochlorines) were found to exist at concentrations significantly below maximum allowable levels under European legislation. The Cd content was considered high in relation to background levels found in marine sediments from undeveloped areas while the Hg content was considered average (Typhoon 2002). | SakhNIRO (2004a) report SSC of 3-7 mg/l prior to disposal of sediment at the site. Modelling undertaken (TEOC, volume 5, Book 9, Part 2, Appendix F2; as reported in the EIA Volume 5, Chapter 3) indicates dispersal of fine sediment from the site trending in a north-east to south-west direction, with predicted SSC of 10 mg/l occurring at least 1km either side of the site covering an area of approximately $2km^2$. |
| Air Pollution | Emissions from dredging vessels confined to trip frequency over the 45km round trip to the disposal site. | Emissions from dredging vessels confined to trip frequency over the 50km round trip to the disposal site. |

| **CRITERIA** | **SITE 1**<br>**10m water depth, north-west of Korsakov (The Salmon Bay), 22km north-west of LNG site** | **SITE 2**<br>**65 m water depth, 25km south of LNG site** |
|---|---|---|
| Commercial Fisheries and Shellfisheries | Local residents use the Korsakov coastal area for year-round fishing. In particular winter fishing attracts crowds of people. Many farming residents from the nearby villages are dependent on fishing in wintertime. No intensive commercial fishing activity within the actual disposal area occurs (SakhNIRO 2001a).<br>On the basis of trawl data, SakhNIRO (2001b) have classified the fish fauna of Aniva Bay into a number of complexes. The fish assemblage of the north-western part of Aniva Bay (also known as Salmon Bay) belongs to Complex B). Pacific stout sand lance and a number of species of sculpin dominate along with walleye pollack. The area is of particular importance for spawning herring and as a habitat for juvenile salmonids, capelin, smelts, saffron cod and herring.<br>From spring to late autumn large numbers of smelt occur at the mouth of the Salmon Bay. Capelin is mainly concentrated in the south–west part Bay. Starry flounder, Sakhalin flounder, brown flounder and banded flounder are the most frequently met species in the coastal zone. Saffron cod also occurs in the coastal zone during its winter spawning period (see Figure 12.2 a, b and c). Key invertebrate species include four cornered bearded crab, Japanese sea cucumber and red king crab. | Data from SakhNIRO (2001b) indicates that the fisheries resource of the area is limited, with the fish fauna being dominated by species of bottom-dwelling sculpins, particularly plain sculpin (*Myoxocephalus jaok*).<br>Site 2 lies within the area of the Bay occupied by species belonging to Complex A, which covers the central area where silty bottom sediments predominate (SakhNIRO 2001b). The epibenthic fish fauna comprises flathead sole, eelpout and seasnail. Rainbow smelt and walleye pollack dominate the pelagic fauna. Pacific herring and capelin are relatively uncommon (see Figure 12.2 a, b and c). Benthic invertebrates are represented by basket stars, snow crab (*Opilio*), four-cornered bearded crab and sponges.<br>The snow crab is commercially important, particularly for the Japanese market.<br>Trawl data for *Opilio* indicates that this species is present within the central part of Aniva Bay. Available data (SakhNIRO 1999 and 2001) indicates that numbers of individuals fluctuate significantly within the Bay (see Figure 12.2g and h). Non-commercial sized individuals and immature females predominated in the trawl catches (99% immature specimens in 1998 and 88-97% respectively in 2000). The few commercial specimens recorded in 1998 were found below 100m water depth. |

Analysis of the two sites using the above criteria, as set out in Table 12.1, concluded that Site 2 is the most suitable for disposal of the dredged material. The location of Site 2 outside of the more dynamic and productive coastal zone, in deeper less productive waters, reduces the potential for adverse effects on marine productivity and fisheries interests. A location towards the central area of the bay at such a depth also practically eliminates the potential for sediment dispersal once deposition has taken place on the seabed due to the lower velocity bottom currents in comparison to a more dynamic coastal site. This, together with the fact that the disposed material is largely aggregate and therefore sinks quickly to the seafloor, reduces the area of seabed over which adverse effects on benthic communities outside of the immediate area of disposal could occur.

However, the introduction of dredged sediment with significantly different properties (grain size and composition) to existing seabed sediment in the area would constitute a significant change for the benthos in the disposal area. The potential environmental impacts associated with these aspects of disposal at the selected site and the dredging process in general are discussed in greater detail in the following sections.

A more centrally located site is also further away from public beaches and fishing areas, does not interfere with nearshore navigation and is still within reasonable distance of the dredging location.

### 12.3.3 Commercially important fish and shellfish species in Aniva Bay

The complex hydrologic regime in Aniva Bay, resulting from the mixing of both warm and cold-water currents, gives rise to a diverse fish fauna, where elements of both southern and temperate communities occur. Fish belonging to a number of different ecological groupings are present: nerito-pelagic and demersal-pelagic (e.g. herring (*Clupea pallasi*) and arabesque greenling (*Pleurogrammus azonus)* among others), near-bottom and bottom species (flounders, sculpins cottids and saffron cod (*Eleginus gracilis*) and others) and diadromous fishes (pink salmon *Oncorhynchus*, smelt of the genus *Salvelinus* and Pacific redfins from the genus *Tribolodon*). Species from this last group enter the rivers flowing into the bay for spawning and then migrate into the Bay where they feed in the coastal zone or pass through to offshore, marine feeding areas.

Pelagic juveniles of some marine commercial fishes stay in the bay, including herring, walleye pollock (*Theragra chalcogramma*) and arabesque greenling and others. At relatively shallow depths (10-15 m) these species are distributed throughout the water column. Some commercially important near-bottom fishes (saffron cod, starry flounder *Platichthys stellatus*, cresthead flounder *Pleuronectes shrenki*) are also common at these depths, including mature specimens. Further information on some of the key commercial species is provided in the following subsections and additional information on commercial fisheries in Sakhalin is provided in Chapter 7 of the EIAA.

**Pink salmon (*Oncorhynchus gorbuscha*)**

Pink salmon is probably the main commercial species in Aniva Bay. Adults migrate into the Bay from offshore waters between June and September, with spawning occurring between August and October. Mass hatching takes place between January and April and migration of juveniles back to the open sea occurs between the end of April and June. The migration of chum salmon juveniles occurs within the same timescale as pink salmon.

**Japanese smelt *(Hypomesus japonicus)***

This species of *Hypomesus* is the main one found in Aniva Bay, where it is mainly concentrated in the coastal zone. It spawns in shallow water in sandy and sandy-pebbly areas during May-June, its main area of distribution being eastern and northern parts of the Bay in waters up to 10m in depth. In early autumn fish disperse and migrate to river mouths and lagoons in areas of lower salinity where they spend the winter months. Commercial fishing for this species occurs during spawning and autumn migrations and in winter from under ice in suitable areas.

**Saffron cod (*Eleginus gracilis*)**

In spring, saffron cod is observed in the northwestern part of the bay, limited by the isotherm 0°C at a depth of 50 m. In summer, as shallower waters warm up, saffron cod move to deeper and colder waters. During this period saffron cod become distributed throughout the whole of the bay, southwards to La Perouse Strait and the more open waters of the Sea of Okhotsk. The major concentrations of this species at this time are observed in the southwestern and eastern parts of the bay at the depth of 30-70 m with a near bottom temperature of 0.5-5.0°C. In autumn, young fish move further out into the open sea. Adults are distributed through almost the whole of the bay, but tend to concentrate in the northern part of the bay. By the end of December they move into their main spawning grounds along the Tonino-Anivskiy peninsula. Saffron cod also enter Busse lagoon and the mouths of the Lyutoga and the Taranay Rivers, where influenced by tidal currents. Small numbers of saffron cod are fished during the winter from the mouth of the Lyutoga River using fyke nets (SakhNIRO 2001). Spawning adults appear in the coastal zone in large numbers in the first part of January and stay here until the middle of March. The spawning period ends in the first half of February. In winter juveniles (1-2-years old) live separately from the adults and occur in the southern part of the Bay in the area where the warmer waters of the Tsushima Stream enter the Bay.

A fishery monitoring survey for coastal waters in the vicinity of the LNG plant (SakhNIRO 2004a) recorded small numbers (<20) of saffron cod from coastal waters, with smaller, immature individuals predominating in waters less than 5m depth. Figure 12.2a shows the distribution of this species in Aniva Bay on the basis of trawl sampling undertaken during October 1998.

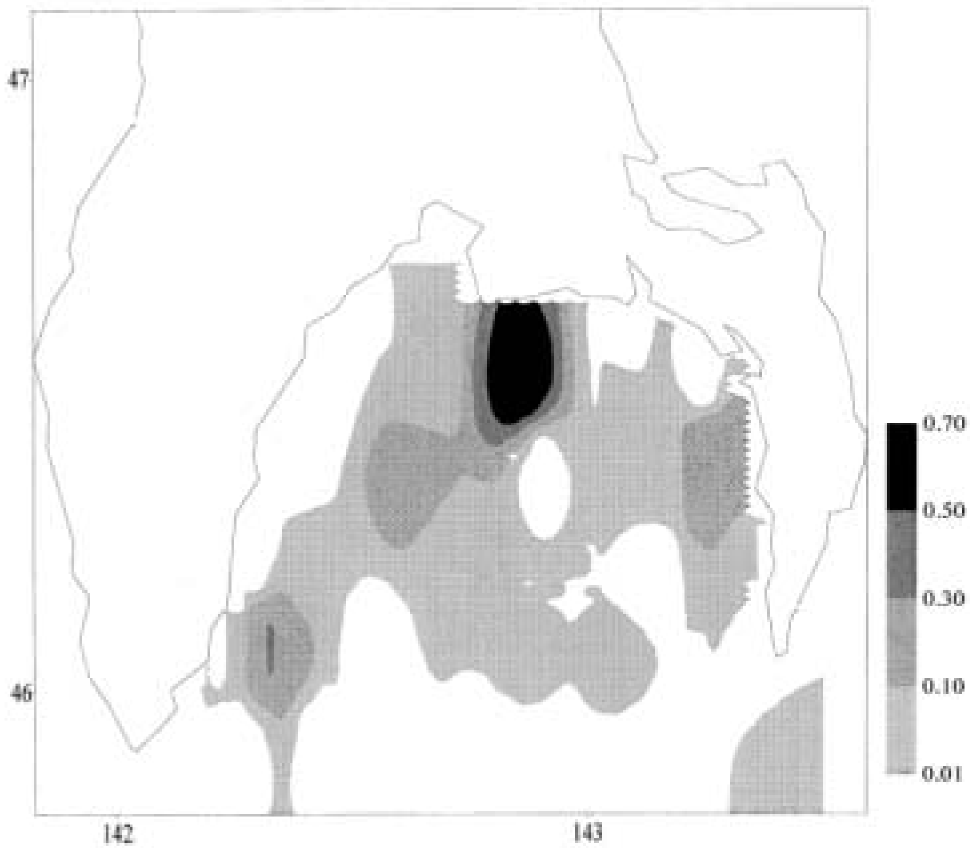



**Figure 12.2a Distribution of saffron cod in Aniva Bay from trawl surveys (October). SakhNIRO (1999)**

### Walleye pollack (*Theragra chalcogramma*)

Walleye pollack is the most abundant representative of the cod family in the northern part of the Pacific Ocean. It occurs in Aniva Bay without forming big aggregations, mainly in the southeast, south and western parts of the Bay during the spring. There are no extensive spawning areas for this species in Aniva Bay, the nearest being the western shores of Hokkaido and the southern Kuril Islands, although some spawning may take place to the south of Cape Aniva.  Juvenile fish tend to stay in the Bay. According to data from research surveys, walleye pollack is observed mainly at depths greater than 30m in the open part of the Bay, the population present in the Bay mainly comprising juveniles (SakhNIRO 2001a).

### Herring (*Clupeus pallasii*)

There are 2 groups of herring present within Aniva Bay, with differing rates of growth. One is a Sakhalin-Hokkaido group, with a high growth rate and a wide area of migration and the other is a local population group of lower growth rate and a limited area of migration. In the past, the spawning grounds of the abundant Sakhalin-Hokkaido herring group were located along the shores of Sakhalin and in the western part of the Aniva Bay (Atlasovo-Khomutovo settlements). Local herring used to spawn mainly in the central part of the bay

(The Salmon Bay – Prigorodnoye settlement-Ozyorsk settlement). Sakhalin-Hokkaido herring used to spawn earlier, usually in April, but herring of the "Aniva" population used to spawn later, in the first half of May. Spawning generally lasts 20 to 40 days. Active feeding by juvenile Sakhalin-Hokkaido herring and local herring has been observed in the coastal zone of Aniva Bay in the summertime. In August-October herring is usually observed in the northern and eastern parts of the bay at a depth not exceeding 50m where maximum catches have been recorded (see Figure 12.2b).

Herring abundance along the southern Sakhalin coast has been at a low level since 1980. Previously, spawning and abundant herring runs occurred in the Cape Yunona area. According to the research results no spawning grounds were observed in the period 1999-2000. Fisheries survey of the coastal area in the vicinity of the LNG site at Prigorodnoye did not record any herring eggs in suitable spawning habitat (SakhNIRO 2004a).

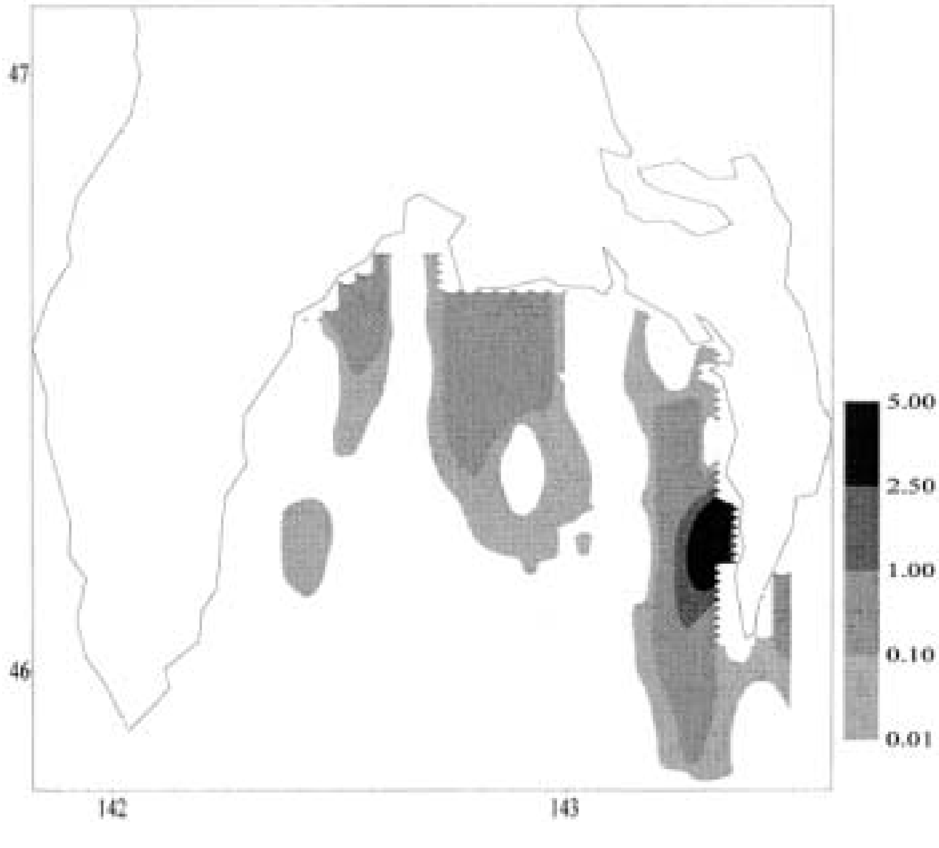



**Figure 12.2b Distribution of herring in Aniva Bay from trawl surveys (October). SakhNIRO (1999)**

### Capelin (*Mallotus villosus*)

Capelin spend winter months in deeper shelf waters and in the lower depths of the shelf– above a depth of 300-400m. In spring they move towards the shallower waters of the coastal zone where they concentrate above depths of 50-70 m. From here, the fish migrate to spawning grounds in May, beginning of July. In 2000, spawning in Aniva Bay was observed from the first half of

June to the beginning of July. Major aggregations were recorded in the western part of the bay, in the area from Kirillovo to Taranai and in the eastern section from Prigorodnoye to Novikovo. In autumn, the distribution of capelin is in the central part of the bay within areas of sandy-silty grounds at a depth of 34-108 m in bottom waters with a temperature of 0.1 to 6.9 C. During the main feeding period (spring-autumn) capelin usually migrate horizontally along the shore. After this period the fish return to their wintering grounds (see Figure 12.2c). Their main prey items are planktonic calanid and euphasid shrimps.

In June 2003 capelin eggs were recorded everywhere along the coastline within the vicinity of the LNG and MOF in the littoral zone and down to a water depth of 0.5m. The recorded spawning intensity (measured as egg density $m^2$) was not high with eggs being found over a zone up to 10m wide (SakhNIRO 2004a).

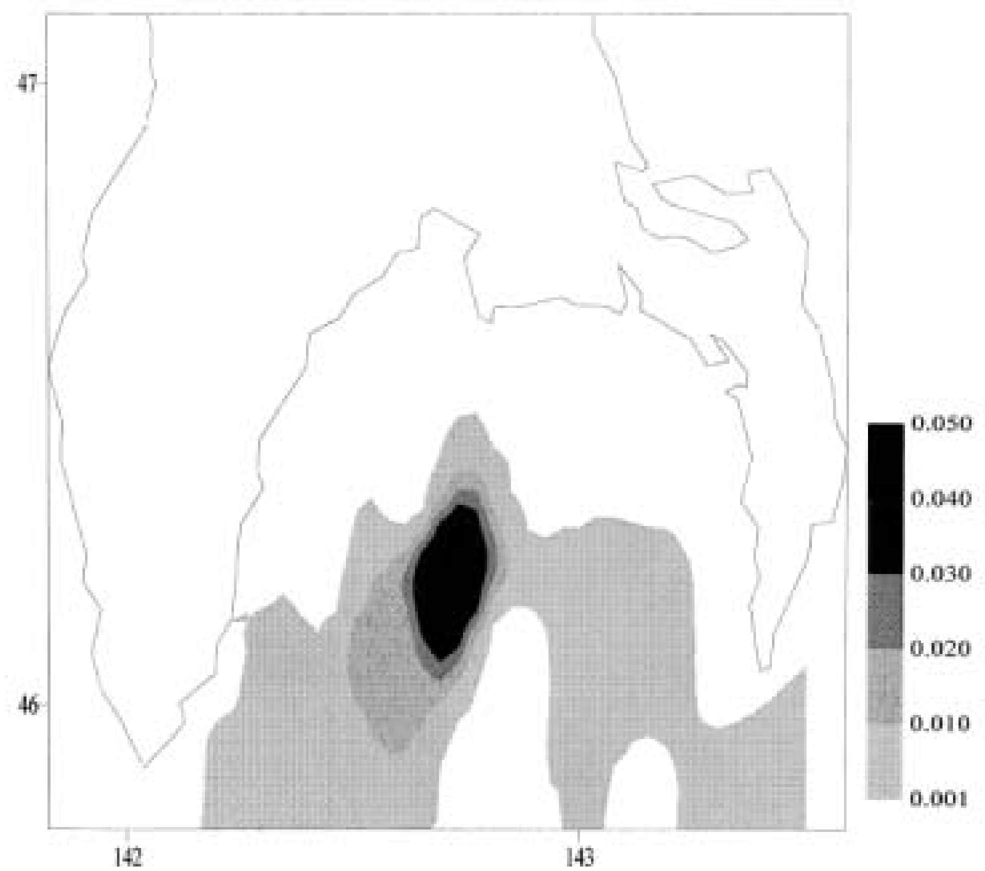



**Figure 12.2c Distribution of capelin in Aniva Bay from trawl surveys (October). SakhNIRO (1999)**

### Arabesque greenling (*Pleurogrammus azonus*)

This species is distributed throughout the southern Sea of Okhotsk, northern Japan Sea, and adjoining Pacific waters. It forms commercial aggregations near the southern Kuril Islands, in Primoriye, and along southwestern Sakhalin

(SakhNIRO 2004a). In 2003, this species was recorded from one trawl catch (from a total of 15) in Aniva Bay and is considered to be generally uncommon. Like many of the bottom-dwelling species (flatfish and sculpins) it makes seasonal migrations to deeper offshore waters during the late autumn-early spring, returning to shallower, coastal waters during the summer. Historically, there are no extensive spawning grounds for this species within Aniva Bay.

**Starry flounder (*Platichthys stellatus*)**

This euryhaline species is widely distributed in the Far East seas and adjoining Pacific waters. Its seasonal migrations, in contrast to other flatfish species, are expressed to a lesser extent, but during October 2000 (SakhNIRO 2001) it was found during survey work in deeper water in the eastern part of the Bay (see Figure 12.2d). It occurs throughout the year in brackish waters around Sakhalin. In Aniva Bay, this species was recorded in small numbers during survey work in the area of the LNG, but is known to be relatively common at water depths <5m (SakhNIRO 2004a).

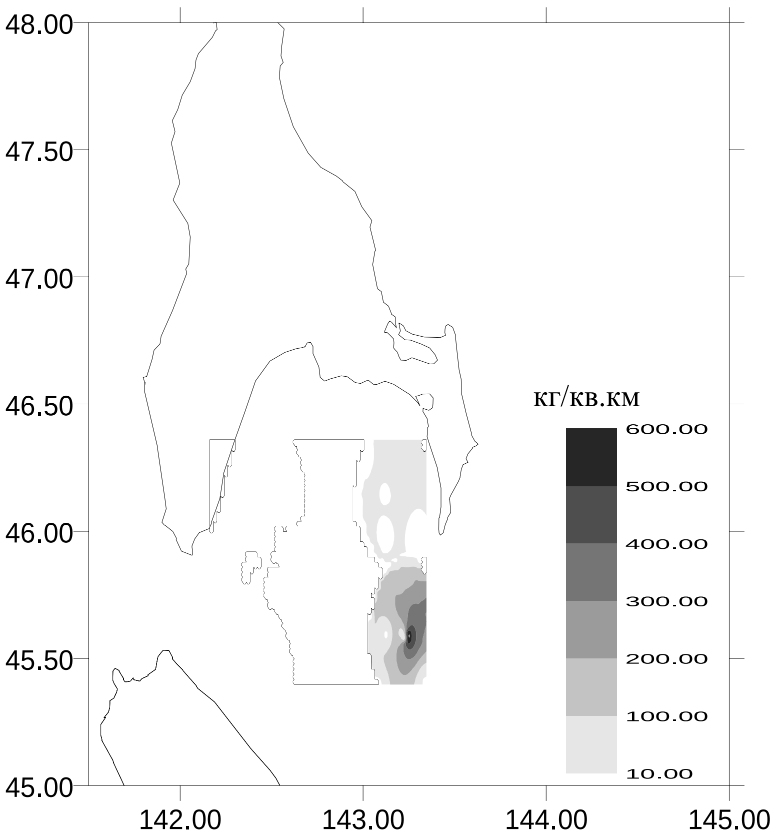



**Figure 12.2d Distribution of starry flounder in Aniva Bay from trawl surveys (October). SakhNIRO (2001)**

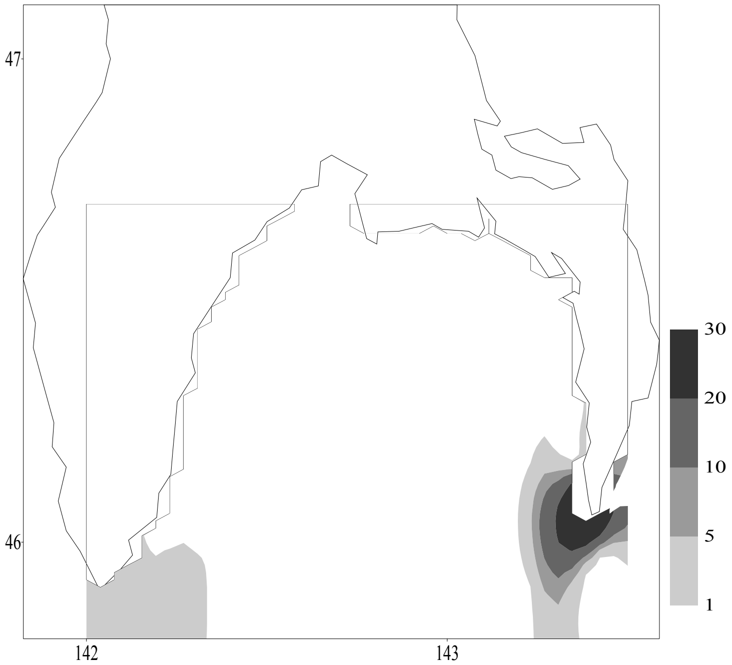



**Figure 12.2e Distribution of cresthead flounder in Aniva Bay from trawl surveys (October). SakhNIRO (2001)**

### Cresthead flounder (*Pleuronectes schrenki*)

This species occurs in the Sea of Japan, Yellow Sea and southern Sea of Okhotsk. During the summer this species migrates from deeper shelf waters into the bay, where it mainly feeds at water depths below 50m (SakhNIRO 2004a). It was one of the most commonly encountered species during trawl survey work in coastal waters of the bay (SakhNIRO 2004), occurring in catches between 5-15m. During survey work in October 1998 and 2000 (SakhNIRO 1999 and 2001) this species was mainly recorded from the eastern and western parts of the bay (see Figure 12.2e).

### Longsnout flounder (*Pleuronectes punctatissimus*)

This species is widely distributed in the northern part of the Japan Sea, the southern part of the Okhotsk Sea, and adjoining Pacific waters. As with other *Pleuronectes* species it undertakes seasonal migrations, feeding in the Bay during the summer-autumn at depths up to 50m. Survey work in the coastal zone of the LNG revealed the existence everywhere of juvenile fish in water depths from 1-2 to 15m. (SakhNIRO 2004a).

### Commercially important invertebrate species

Information on shellfish resources and stocks is available from a number of specific studies (e.g. SakhNIRO 1999, 2001a). The majority of this data concentrates on the bioresources of Aniva Bay rather than specifics of commercial activity.

Trawl surveys in the nearshore and offshore areas of Aniva Bay (*e.g.* SakhNIRO 2001 and 2004b) have provided information on the presence of commercial stocks of some shellfish species, notably crustaceans. The information indicates that there are stocks of snow crab (*Opilio*) and red king crab (*Paralithoides camtschatica*) present within the Bay although the level of exploitation of these resources is unknown. Snow crab appears to be widely distributed in Aniva Bay (see Figure 12.2g and h), while red king crabs were observed in trawl surveys around the Aniva Peninsula area and within the central part of the Bay, as shown in Figure 12.2f (SakhNIRO 2001). This species also occurs regularly and in commercial quantities in the nearshore coastal zone (SakhNIRO 2004b).

A number of commercially exploitable stocks of shrimp species, notably bear-cub shrimp, visored shrimp (*Argis lar lar*) and ridged crangon (*Crangon dalli*) also occur within the Bay (SakhNIRO 2001b).

In the coastal zone short spined sea urchins (*Strongylocentrotus intermedius*) can form aggregations of commercial importance in some areas, mainly where rocky substrates predominate. This species is not particularly common in the coastal area around the LNG/MOF site due to the predominance of softer seabed sediments. Sea cucumber (*Cucumaria japonica*) may be present in certain sections of the coastal zone of Aniva Bay in commercially viable numbers. It tends to have a patchy distribution, but is known to occur in the Prigorodnoye –Ozyorsk area at depths of 5-12m where it reaches a density of 0.15 ind/m2 (SakhNIRO 2001a).

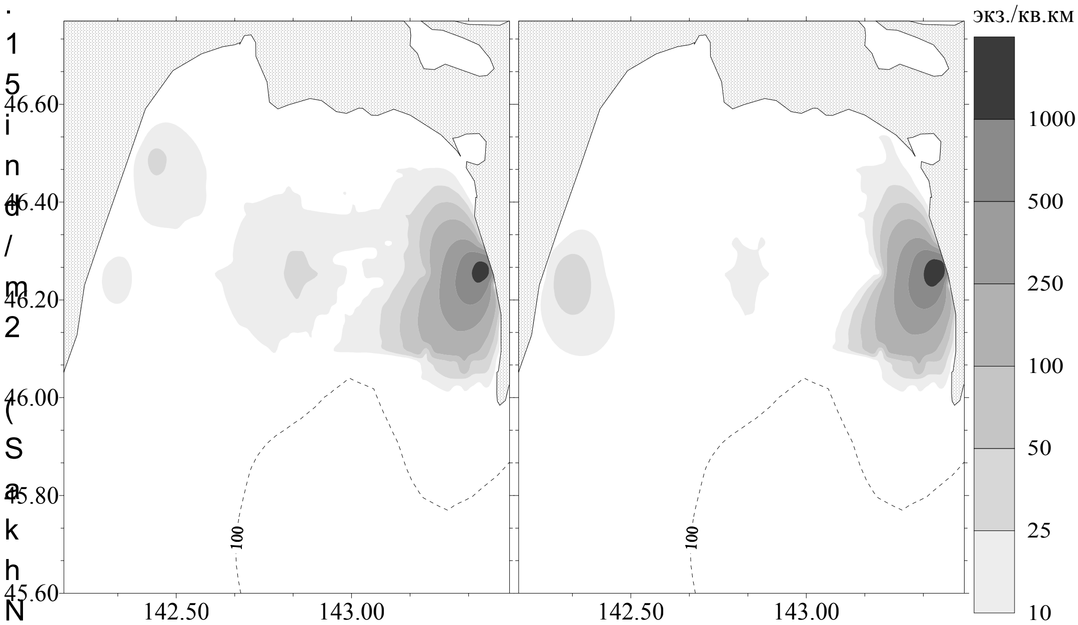



**Figure 12.2f Distribution of Male (A) and Female (B) Red King Crabs in Aniva Bay in 2000**

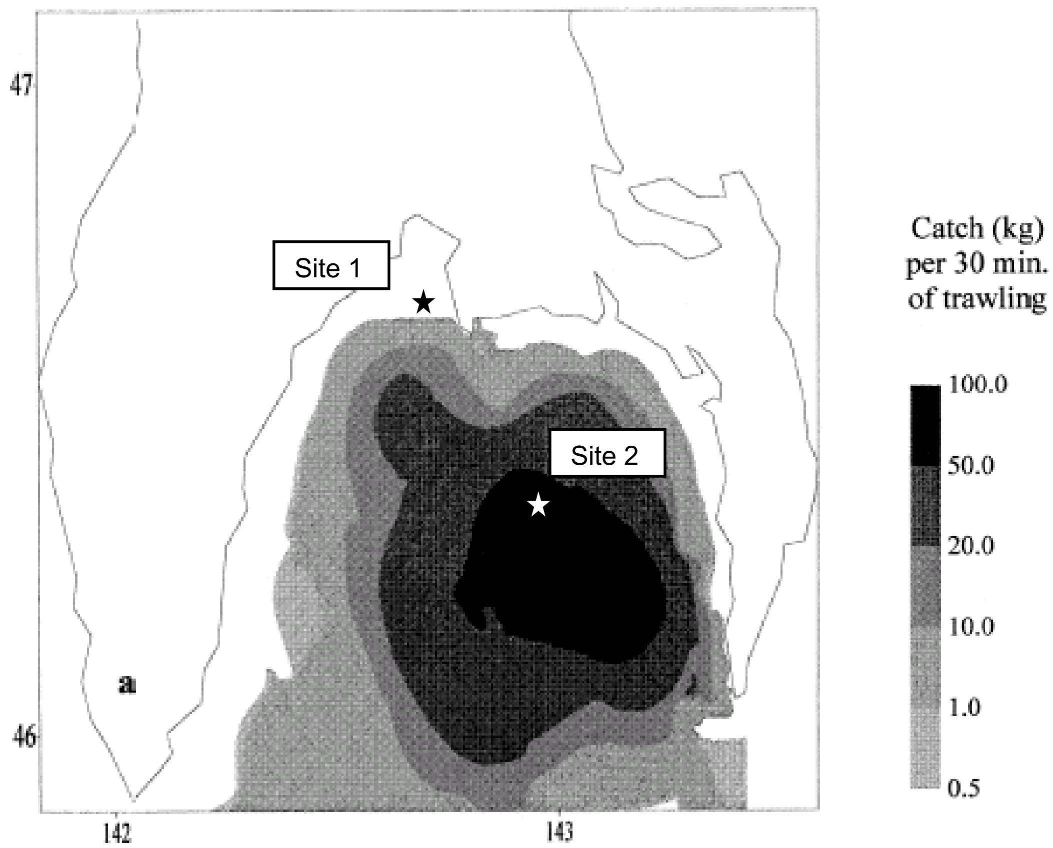
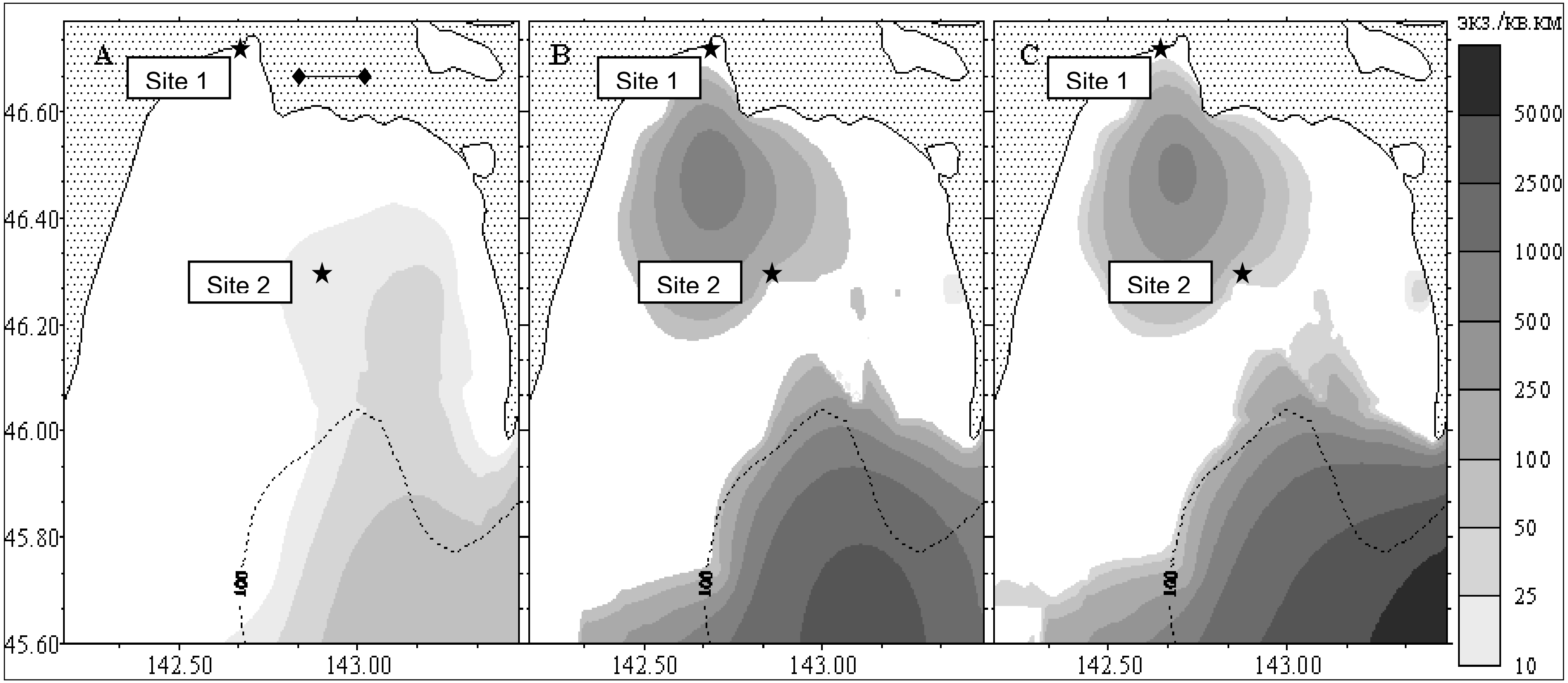



**Figure 12.2g Distribution of snow crab (Opilio) in Aniva Bay in October 1998 (catch kg/30 min of trawling, based on 32 trawls). From SakhNIRO (1999).**

**Figure 12.2h. Distribution of commercial adults (A); non-commercial juveniles (B); and juvenile males and females (C) of snow crab (Opilio) in Aniva Bay in 2000 (ind./km2). From SakhNIRO (2001b). Maps based on data collected from22 trawl samples taken during July-November 2000. Scale: approx 10km**



Trawl data (SakhNIRO 1999 and 2000) for Aniva Bay indicates that Japanese scallop (*Mizuhopecten yessoensis*) is present throughout the coastal zone of much of Aniva Bay. In 1998, this species was recorded from 6 trawls (out of 32) at water depths of 20-51m with the highest number being recorded from Cape Beliy Kamen on the south-eastern side of the bay (SakhNIRO 1999). Along the western side of the bay, catch never exceeded 2 individuals/trawl. In 1999, Japanese scallop was recorded from 2 trawl samples out of 22 conducted at depths of 20-21 and 22m in theTaranai area, south-west Aniva Bay (SakhNIRO 2000).

SakhNIRO (2001a) also carried out a characterisation survey of the status of commercial fish and shellfish distribution in Aniva Bay on the basis of the definition of a number of assemblages. According to this study, Japanese Scallop was present in 5 of 8 complexes defined for Aniva. Aggregations of this species were recorded in the coastal zone in the west, north and east of the bay. The largest aggregation was recorded in the west of the bay, specifically between the estuaries of rivers Kura and Taranai, and extended over an estimated area of 51 $km^2$. SakhNIRO (2001a) suggested that the area would be an important population centre for the whole of Aniva Bay, as a mix of ages and a predominance of juvenile specimens were recorded. SakhNIRO (2001a) also report that two aggregations of Japanese scallop occur on sandy and sandy-gravel substrates on either side of the Prigorodnoye area. One of them is located at a depth of 13-18m in the Nechaevka-Yunona Cape area, and is characterized by an average density of 0.32 ind./$m^2$ with an average biomass of 0.066 kg/$m^2$, covering an area of approximately 4.8 $km^2$. Adult specimens prevail in this aggregation and constitute 87.5% of the total population. The second aggregation is located in front of the Belokamennaya Rock at a depth of 13-17m, covering an area of 0.08 $km^2$. Juveniles are completely absent in this colony, which has a density of 0.2 ind./$m^2$ with a biomass of 0.1 kg/$m^2$. Neither of these populations is thought to be significant in terms of contributions to the scallop fishery. It should also be noted that surveys undertaken indicate that there are no Japanese scallop populations present at or in the immediate vicinity of the offshore disposal site.

Further detailed information is available on the distribution of commercial invertebrate species in the dredge and disposal areas from the dedicated monitoring work that has been undertaken to date (see Section 12.8 for information on the monitoring programme). Results from trawl and diving surveys at fixed stations within the LNG/MOF dredge area are provided in Table 12.2 and show comparison between 2003 and 2004 (dredging undertaken in October 2003 at the MOF). Five species of crustaceans were recorded in the area during the monitoring period 2003-2004. Red king crab was dominant in both years, but younger and smaller specimens were recorded in 2004. Biomass between the two surveys did not differ significantly, although one additional species (*Erimacrus isenbeckii*) was recorded in 2004. The data for the Japanese scallop indicates that overall biomass of this species in the coastal zone adjacent to the dredging area has remained the same (2003-2004). Monitoring work on this species and others is being continued as part of the overall monitoring programme for the dredging works (see Section 12.8).

In addition, four commercial species of molluscs and echinoderms were also registered in the dredging area and its vicinity as shown in Table 12.2. Trepang was not recorded during the 2004 survey, but this may just be a reflection of the low numbers of this species present in the area. For all other species, abundance and biomass remained approximately the same from 2003-2004.

**Table 12.2. Monitoring data for commercial invertebrate species recorded from the LNG/MOF monitoring stations 2003-2004.**

| **Invertebrate species** | **Average biomass per catch (KG)** | | | |
|---|---|---|---|---|
| | **2003** | | **2004** | |
| Red King Crab (*Paralithodes camtchatica*) | 0.360 | | 0.543 | |
| *Telmessus chieragonus* | 0.019 | | 0.143 | |
| *Sclerocrangon sp.* | 0.010 | | 0.018 | |
| *Erimacrus isenbeckii* | Not found | | 0.810 | |
| Shrimp (*Pandalus sp.*) | 0.010 | | 0.071 | |
| | **Abundance Ind/m2** | **Biomass g/m2** | **Abundance Ind/m2** | **Biomass g/m2** |
| Japanese scallop (*Mizuhopecten yessoensis*) | 0.5 | 141.4 | 0.5 | 146.9 |
| Sea Urchin (*Strongylocentrotus intermedius*) | 1.5 | 64.8 | 1.1 | 64.8 |
| Sea cucumber (*Cucumaria japonica)* | 0.9 | 57.0 | 0.3 | 54.3 |
| Trepang (*Stichopus japonicus)* | 0.2 | 41.6 | Not found | Not found |

## 12.4 OVERVIEW OF DREDGING AND DISPOSAL METHODS

Up until September 2005 approximately 280,000$m^3$ of material had been dredged from the MOF and LNG jetty areas, and was disposed of at the permitted disposal site (see Section 12.3). This did not include dredging from within the footprint of the turning circle. The dredging carried out to date was undertaken by a grab dredger, with a variable grab capacity of 20$m^3$ to 30$m^3$.

Dredged material has been loaded onto bottom dumping hopper barges (Slavyanskaya type) that have a hold capacity of 1600$m^3$, and then transported to the disposal site. Once at the disposal site, which is marked with an anchoredbuoy, the bottom gates of the hopper are opened and the dredged material released.

Grab dredgers have the ability to dredge material and place it in a hopper at near enough the *in situ* density, and relatively large cohesive lumps of material are released at the disposal site.

Originally, and as assessed in the TEOC and the international-style EIA (2003), dredging was to be undertaken using both a grab dredger and a cutter suction dredger, with a larger barge being used to transport material derived from the cutter suction dredger to the disposal site. The hydrodynamic modelling work presented in the TEOC and EIA for predicted extent and levels of suspended sediment concentration (SSC) resulting from the dredging and disposal process were based on these dredging/disposal methods. However, as mentioned above, to date all dredging has been undertaken solely using a grab dredger and hence individual disposal volumes from a barge have been smaller than those originally used in the predictive modelling work. The environmental consequences of this are further discussed in the monitoring section (see 12.8).

For the dredging work post September 2005, a grab dredger will continue to be used for all of the LNG jetty work (approximately 164,000m$^3$ remaining). For the dredging of the turning basin (approximately 1,000,000m$^3$ of material) a large cutter suction dredger and bottom dumping hopper barge (capacity of 25,000m$^3$) will be used. Using this approach, all of the remaining dredging work can be undertaken in one campaign in autumn-winter of 2005. Although the new approach does not vary in terms of technique, in comparison to the original method proposed (i.e. use of both grab and cutter suction), the rate of dredging and disposal will increase. This change has potential environmental consequences, particularly with respect to the volume of material disposed in one event (i.e. 25,000m$^3$ compared with approximately 2,200m$^3$) at the disposal site. As such, additional predictive modelling work of the fate of sediment at the disposal site has been undertaken. The results of this modelling work are presented in Section 12.5 and further consideration of environmental issues and impacts associated with the revised dredging approach is provided in subsequent sections.

The use of chutes deployed from the hopper barges was originally proposed as a technique to reduce fine sediment dispersal in the water column during disposal (International-style EIA, Vol 5, Ch 3, 2003). However, their use is no longer advocated as:

- To be effective, dredged sediment would have to be loaded into the chute from the hopper barge at the disposal site. This handling process would require a significant amount of time and would negate any net environmental benefit gained through shortening the overall dredging campaign that using the large hopper barge would provide;The material to be dredged is more consolidated than reported in the EIA and thus the total volume of fine sediment requiring disposal is less than originally envisaged.In areas where dredging has been undertaken to increase water depth, natural processes often lead to the deposition of sediment within the deepened area, resulting in a decrease in water depth over time.

Dredged areas may therefore require further maintenance dredging to remove sediment in order to provide continued safe navigation and berthing facilities.

The potential need for maintenance dredging during operation of the LNG jetty has been considered through analysis of sedimentary processes in the coastal zone and potential interaction of these processes with the dredged area, in particular the turning basin.

The main potential sources of sediment that could become deposited within the turning basin during operation are:

- Breaking waves;
- A combination of tidal current, large scale current circulations and orbital motion of non-breaking waves;
- Sediment transported into the area by the Mereya River.

In determining the potential effect of these aspects on sedimentation of the turning basin it is important to note that the design seabed level of the turning basin after completion of the dredging works will be -15.17m below sea level (BSL) and at its closest distance to the shore will be 600m. The level of the adjacent seabed is -11.0 m BSL with a dredged slope down to the base of the turning basin.

Breaking waves can cause disturbance of mobile sediment at the seabed due to the high associated energy. From an analysis of meteorological and hydrodynamic conditions it has been determined that breaking waves occur up to a depth of -7.97 m BSL. This water depth occurs at a distance of approximately 160m away from the turning basin and thus there is very limited potential for sediment mobilised by wave activity to be directly transported into the turning basin.

Current activity may also lead to mobile sediment entrainment at the seabed and the transport of sediment from areas of high current/wave activity (nearshore) to areas of lower current velocity and/or lower wave activity (for example the turning basin). The nearshore current runs parallel to the shoreline with a typical maximum velocity of 0.6m/s. Combining this data with a maximum significant wave height of 6.9m, it is predicted that the potential volume of sediment transport into the turning basin could lead to the deposition of a thickness of 0.01m/year of sediment under these conditions. The actual amount of sedimentation would be likely to be significantly lower, perhaps as much as 80% less, as the combination of maximum current velocity and maximum wave height may not be achieved every year.

As is typical for capital dredging operations, the design of the turning basin incorporates some over-dredging (in compliance with RF standards), in this case 0.3-0.5m depth. Assuming a predicted sedimentation rate of 0.01m/year occurs throughout the operation of the LNG Jetty, the total thickness of sediment that could accumulate in the turning basin would reach approximately 0.40m, which is within the designed over-dredging limits. For the reasoning presented above, this amount is likely to be an overestimate of the actual amount likely to be deposited in the turning basin.

Sediment input into the turning basin from the Mereya River is considered to be unlikely on the basis of the following two observations:

- The geotechnical profiles taken for the LNG Jetty and the turning basin show that there is a layer of 0.5-1.0m of more recent unconsolidated sediment overlying the solid weathered claystone bedrock. The thickness of this layer does not vary greatly in proximity to the mouth of the river, indicating that deposition of sediment load from the river is not locally significant;
- East of the LNG Jetty, possible rock outcrops are located on the seabed. This area has not undergone any apparent significant sedimentation over the past years, again suggesting that direct deposition of sediment from the Mereya River is not locally important.

On the basis of the above factors it is therefore considered unlikely that maintenance dredging of the LNG jetty turning basin will be required during the operational lifetime of the facility.

## 12.5 PREDICTIVE MODELLING RESULTS

### 12.5.1 Original dredging and disposal approach

For the original dredging and disposal process, as presented in the TEOC and the international EIA (2003), predictive modelling was undertaken to determine the extent of SSC levels and amount of sediment deposition in both the dredge and disposal areas.

As shown in figures 12.3a and 12.3b, for dredging work at the LNG turning area and for the MOF, the modelling work predicted that SSC in the water column would not exceed100 mg/l from the LNG dredge area by more than 310m, 50mg/l by 550m, 20mg/l by 830m and 5mg/l by 1090m. At the seabed it was calculated that SSC values of 20-100mg/l in the sediment plume would cover an area of 0.029km$^2$ around the LNG jetty. For the MOF, predicted SSC in the water column would not exceed100 mg/l from the LNG dredge area by more than 15m, 50mg/l by 25m, 20mg/l by 160m and 5mg/l by 420m. At the seabed it was calculated that SSC values of 20-100mg/l in the sediment plume would cover an area of 0.003km$^2$ around the MOF. These results are provided in Table 12.3.

Monitoring data for the actual dredging that has been undertaken (see Section 12.8) at the MOF/LNG demonstrates that SSC levels are lower than those predicted by the modelling exercise. This can be explained as a consequence of the fact that all of the dredging has been undertaken using a grab dredger rather than the combination of a cutter suction dredger and grab dredger that was originally modelled for the TEOC. Cutter suction dredgers tend to create a more sediment laden ‘slurry’ at the cutter head, leading to higher localised SSC levels, whereas grab dredgers tend to retain sediment in a more consolidated condition. However, an advantage of using a large bottom dumping trailing suction hopper dredger with a capacity of approximately 25,000m$^3$ is that the density of dumped material is so great that it acts as a consolidated “slug”, which means that aggregate and fines are entrained together and act as one mass, rather than as individual particles, and the result is a more limited dispersal of material and a greater accuracy of placement on the seabed. The modelling results shown below are therefore likely to be more conservative than the actual impact.

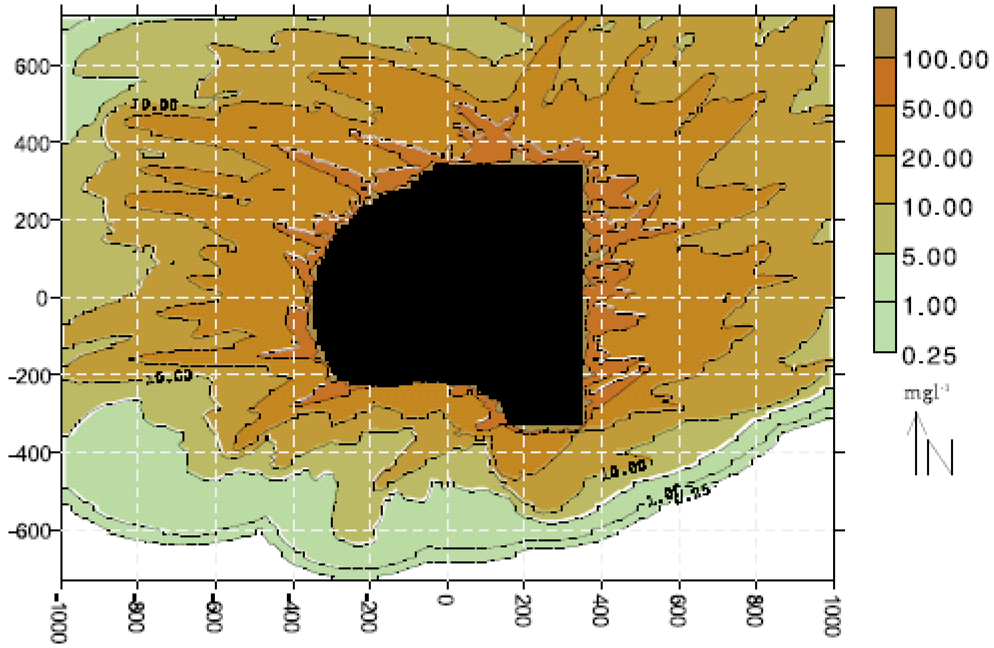



**Figure 12.3a. Distribution and concentration of suspended sediments associated with dredging of the LNG jetty and turning circle using a cutter suction dredger. Original model as presented in the TEOC and international-style EIA (2003).**

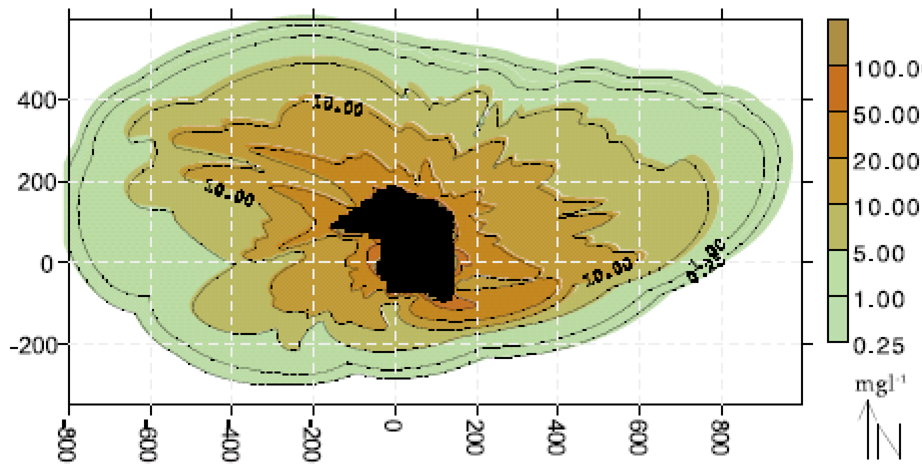


**Figure 12.3b. Distribution and concentration of suspended sediments associated with dredging of the MOF using a grab dredger. Original model as presented in the TEOC and international-style EIA (2003).**

Modelling of SSC and sediment deposition at the disposal site indicated that outside of the 200m x 200m disposal site, SSC in the water column up to 100mg/l would not extend beyond the boundary of the disposal site by more than 65m, 50mg/l by 329m, 20mg/l by 667m and 5mg/l by 1175m. At the seabed it was predicted that at its maximum extent the sediment plume (with SSC of 10-100mg/l) generated by the disposal of all of the material would affect an area of approximately 0.033km$^2$. Deposition of 10-100mm of fine sediment from the sediment plume (i.e. outside of the disposal site) would occur within an area of approximately 0.32km$^2$ (see Figures 12.4a and 12.4b). Relatively high SSC levels and thickness of deposited sediment would be confined to a narrow zone immediately around the disposal site (as shown in Figures 12.4a and b).

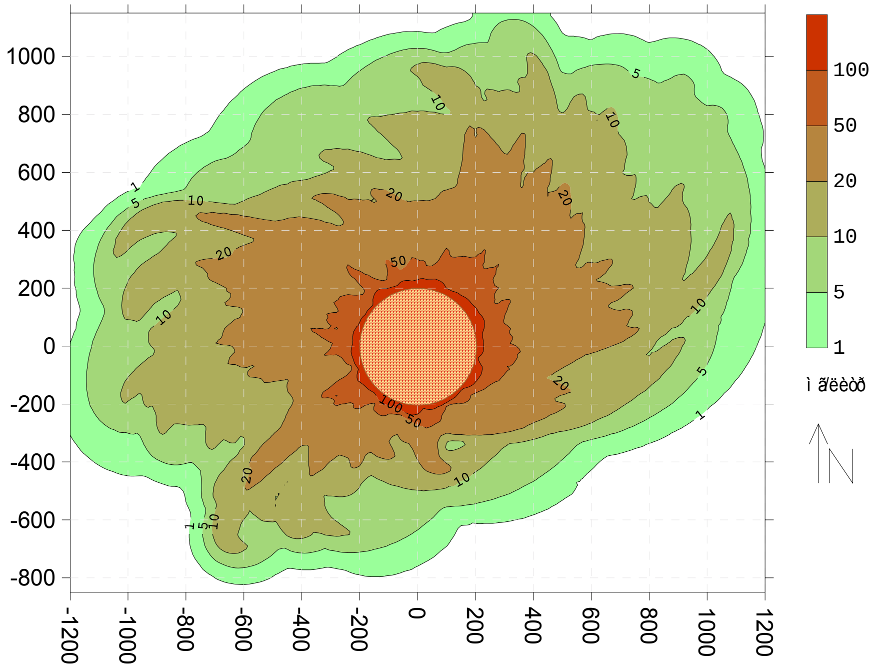



**Figure 12.4a. Distribution and concentration of suspended sediments associated with disposal of dredged material. Original model as presented in the TEOC and international-style EIA (2003).**

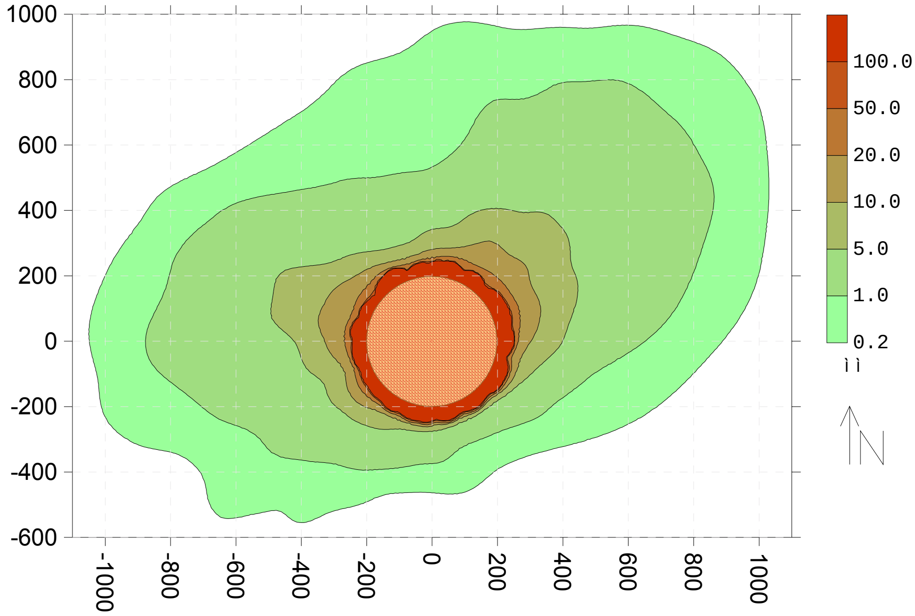



**Figure 12.4b.** **Distribution of fine sediment deposition associated with disposal of dredged material. Original model as presented in the TEOC and international-style EIA (2003).**

## 12.5.2 Revised dredging and disposal approach

The key difference between the original and revised dredging/disposal approach is the use of a large cutter suction dredger to dredge the turning area for the LNG jetty and the use of a larger hopper (approximate 10 fold increase from 2,200m$^3$ to 25,000m$^3$) to dispose of material. The actual dredging technique does not vary to that originally presented in the TEOC and International-style EIA (2003), however, the size of the cutter suction dredger does have some implications for the level of SSC created during the dredging process (see Figure 12.5).

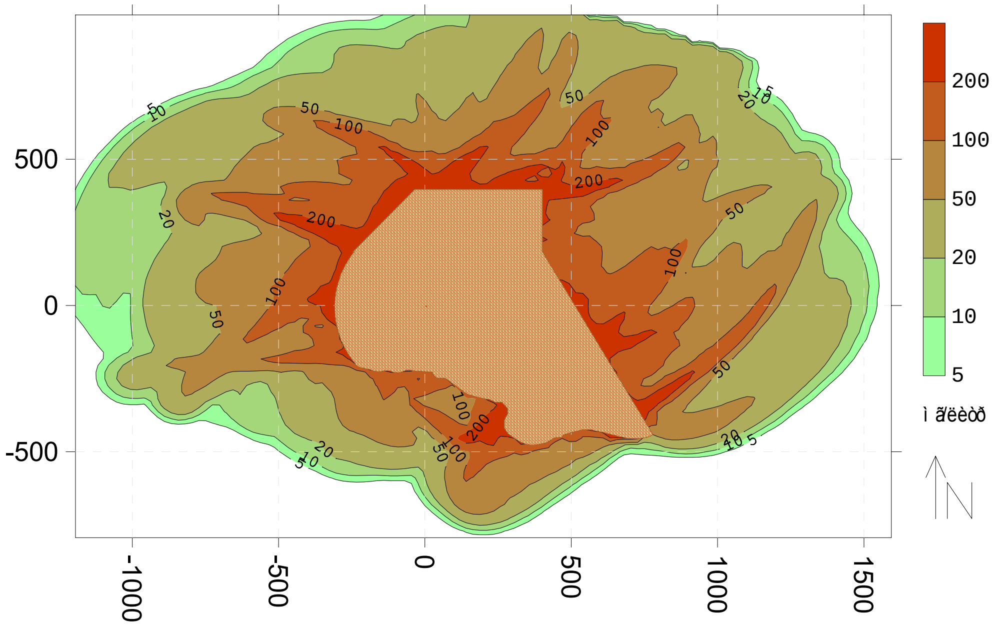



**Figure 12.5.** **Distribution and concentration of suspended sediments associated with dredging of the LNG jetty and turning circle using a large cutter suction dredger (revised proposal).**

Dredging for the MOF, which has been largely completed, will be finished using a grab dredger and hence there is no change to the previous approach.

**Table 12.3. Predicted extent of SSC in sediment plume from dredging activity at the LNG and MOF. Comparison of original dredging methodology against revised dredging approach.**

| **Dredging – SSC levels – maximum distance (metres) from dredge area** | **>5mg/l** | **>20mg/l** | **>50mg/l** | **>100mg/l** |
|---|---|---|---|---|
| MOF – original | 420 | 160 | 25 | 15 |
| MOF - revised | As original | As original | As original | As original |
| LNG – original | 1090 | 830 | 550 | 310 |
| LNG - revised | 1088 | 1029 | 772 | 530 |
| **Disposal - – SSC levels – maximum distance (metres) from disposal site. Figure in bracket is maximum area of plume in contact with the seabed – ($km^2$)** | **>5mg/l** | **>20mg/l** | **>50mg/l** | **>100mg/l** |
| Original | 1175 (0.056)* Figure given is for >10mg/l | 667 (0.029) | 329 (0.01) | 65 (0.004) |
| Revised | 1334 (0.11)* Figure given is for >10mg/l | 1302 (0.065) | 1240 (0.025) | 1021 (0.012) |

Comparison of the modelling results between the original and revised dredging approaches for the LNG turning area indicates the following:

- The area subject to raised SSC levels extends slightly further to the east;
- Predicted SSC levels >50mg/l could occur up to a distance of no more than 772 m around the perimeter of the turning circle area, in comparison with up to 550m for the original approach (see Table 12.3).

Additional modelling work has been undertaken for the disposal operation in order to determine potential differences in the behaviour of sediment deposited at the site when using a large hopper. The results of this modelling are shown in Figures in 12.6a and 12.6b.

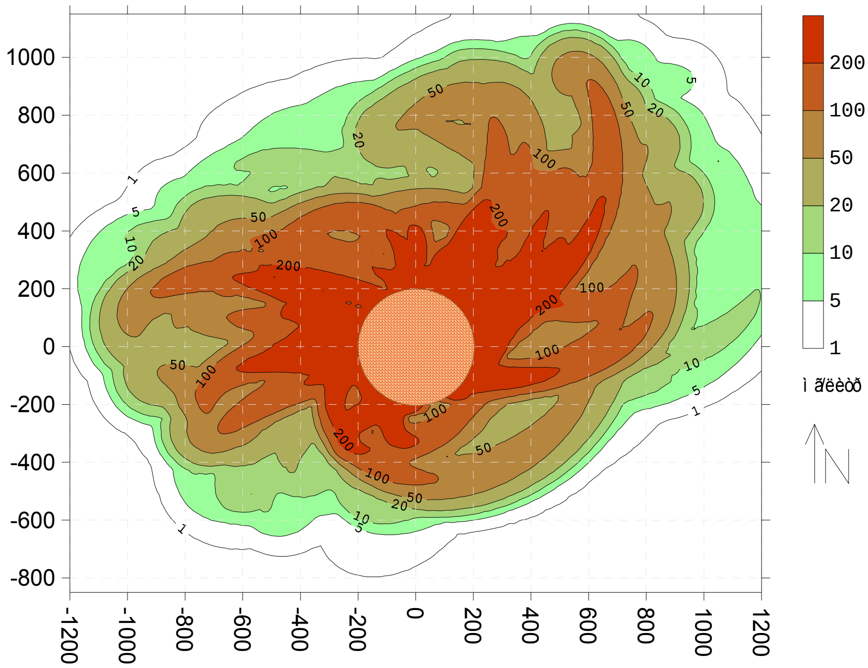



**Figure 12.6a. Distribution and concentration of suspended sediments associated with disposal of dredged material from a large hopper.**

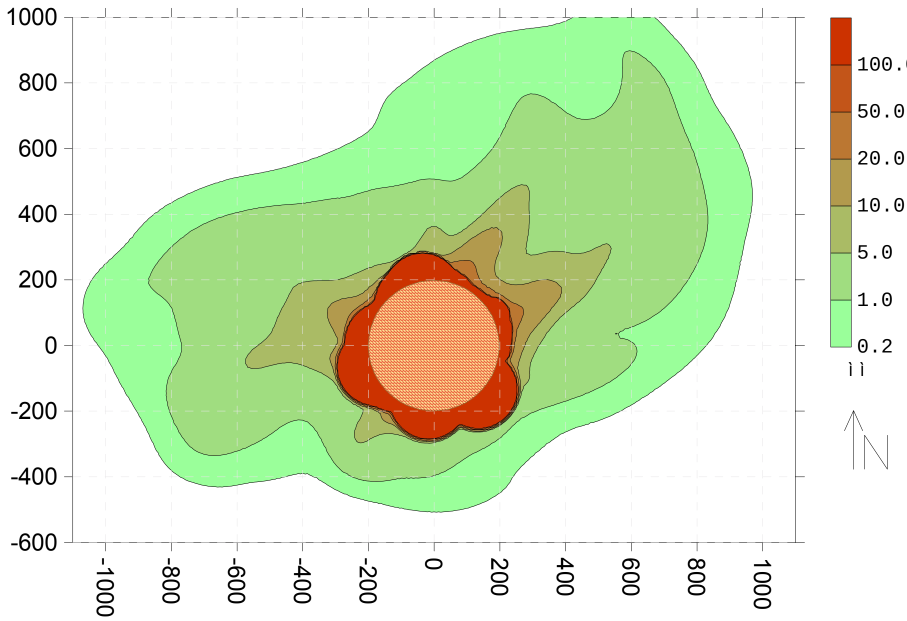



**Figure 12.6b. Distribution of fine sediment deposition associated with disposal of dredged material using a large hopper.**

Comparison of the modelling results between the original and revised disposal approaches indicates the following:

- The overall envelope for sediment deposition >5mm is reduced in size for the new approach (258,188m$^2$) in comparison with the original estimated (319,296m$^2$)(see Table 12.4). However, it is predicted that using a larger hopper for disposal would lead to a greater thickness of sediment accumulating closer to the disposal site than with a smaller hopper (see figures provided in Table 12.4);

- Using a large hopper for disposal significantly increases predicted SSC in the water column above levels using a smaller hopper (compare Figures 12.6a and 12.4a and data in Table 12.3). An area of approximately 0.025km$^2$ would be subject to predicted SSC levels at the seabed above 50mg/l compared with an area of 0.01km$^2$ for the original situation;
- With a large hopper an area of approximately 0.015km$^2$ outside of the disposal site would be subject to predicted SSC levels of >100mg/l at the seabed, an area approximately three times larger than for a small hopper, as originally modelled;
- The area outside of the disposal site in which predicted sediment deposition greater than 50mm could occur would approximately increase by 70% (compare Figures 12.4b and 12.6b).

This comparison is made in order to define the differences between the originally modelled and assessed situation and the revised disposal scenario, so that the environmental effects of the revised approach can be more readily appreciated with reference to the original disposal method. In the following sections the specific assessment of environmental impacts therefore relates to the revised large hopper disposal option. However, reporting of monitoring data available to date refers solely to the dredging and disposal work that has been undertaken using a grab dredger and small hopper barge for disposal

**Table 12.4. Comparison of predicted sediment deposition data for original and revised dredging and disposal approaches. Figures in brackets are the predicted maximum extent (metres) of sediment deposition of a given thickness from the perimeter of the dredge areas and disposal site**

| **Dredging - sedimentation thickness** | **>1mm** | **>5mm** | **>10mm** | **>50mm** | **>100mm** |
|---|---|---|---|---|---|
| MOF – original | 5.78 (69) | 2.17 (23) | 1.51 (21) | 0.25 (7) | |
| MOF – revised | 8.10 (69) | 2.82 (23) | 1.89 (21) | 0.31 (7) | 0.05 |
| LNG – original | 43.89 (276) | 6.64 (58) | 3.99 (40) | 1.19 (-) | 0.40 (12) |
| LNG – revised | 30.0 (265) | 4.59 (53) | 2.97 (35) | 0.87 (23) | 0.30 (12) |
| **Disposal - sedimentation thickness (10,000 m$^2$)** | **>1mm** | **>5mm** | **>10mm** | **>50mm** | **>100mm** |
| Original | 121.04 (811) | 31.93 (335) | 15.40 (172) | 6.58 (65) | 6.14 (59) |
| Revised | 106.11 (865) | 25.81 (375) | 14.34 (215) | 9.60 (120) | 9.23 (97) |

## 12.6 THE EFFECTS OF DREDGING AND DISPOSAL OF DREDGED MATERIAL

The dredging works and the disposal of the dredged material have the potential to affect a number of environmental parameters and concerns. These include:

- Loss of and change to benthic communities within the dredge area;
- Impact on benthic communities in the disposal area;
- Effects of increased suspended sediment concentrations on fish and commercial fisheries;
- Recovery of benthic communities following disposal of dredged material.

These effects are briefly discussed below, with particular emphasis on the potential effects of the disposal of dredged material.

### 12.6.1 Potential impacts of dredging on benthic communities

The most direct and obvious impact on benthic communities as a result of the proposed dredging works would be disturbance to the fauna/flora within the footprint of the dredge area and a change in the physical conditions of the affected area (water depth and potentially substrate type). These aspects are considered in more detail below.

Survey data indicates that two dominant benthic community types occur within the project area. In water depths of between 7-10m the assemblage is characterised by the bristleworm *Scoloplos armiger*; along with other polychaetes (24 species) such as *Aricia norvegica, Nephtys sp.* and *Glycinde armiger*. Amphipods (11 species), bivalves (5 species) and small gastropods (3 species) were also recorded (SakhNIRO 2004). With an increase in water depth to between 12-15m, this community is replaced by one in which the small gastropod *Cryptobranchia kuragiensis* becomes dominant. Within this community type polychaetes (19 species) and amphipods (9 species) were also common and between them contributed to 62% of the recorded biomass. The above communities are typical of mixed fine-coarse (fine sand-small gravel) substrates in shallow waters. Although not specifically recorded in the biomass calculations, it is apparent that macrophytes, notably the seagrass *Zostera marina*, may contribute significantly to overall biomass values, particularly in shallower waters (4-6m water depth), with a belt of macrophyte growth extending down to 10m water depth. The survey work undertaken (e.g. SakhNIRO 2004) does not indicate that *Zostera* occurs within the dredge area, probably because water clarity (as a function of water depth) is not sufficient to allow growth within this area.

The dredging process would lead to the removal of surface, mobile sediments and underlying rock, thus effectively eliminating existing benthic communities within the dredge area (approximately 60ha). Although it is apparent that these polychaete dominated communities are widely distributed in the shallower waters of Aniva Bay (SakhNIRO 1999) the dredging works would still represent a temporary and locally significant loss of these community types.

Apart from the loss of area due to the footprint of the LNG and MOF structures it would be expected that benthic communities would become re-established within the area of disturbed seabed. Recovery of the community types present within the area would be dependent on similar conditions being established following the cessation of dredging. However, the dredging process will lead to:

- A change in water depth within the dredged area (in the shallowest water, the depth increase may be as great as 5.8m, but on average it is estimated that the water depth change over the entire dredge area would be approximately 2m);
- The loss of surficial, mobile sediment overlying bedrock, which supports the existing benthic communities.

Of the above, the return of mobile sediment of sufficient thickness to support infaunal, burrowing organisms (e.g. polychaetes) is perhaps the most critical factor. Without this material being present the exposed substrate would favour colonisation and establishment of communities more typical of rocky substrates. This potential change would not constitute an absolute loss of benthic habitat, but the area within the bay occupied by soft sediment communities would reduce while conversely the area occupied by rocky substrate communities would increase. Both broad community types are widespread throughout the shallow subtidal area of Aniva Bay and the potential shift from one to the other would not be considered to represent a significant effect if it were to occur.

If finer sediment is transported into the dredged area, although it is difficult to define likely volume/thickness, then rapid recolonisation and establishment of new populations of characteristic infaunal and epifaunal species groups (e.g. polychaetes and amphipods) would be expected. Recolonisation rates reported in the literature (see Figure 12.7) suggest that a period of 2-4 years is a realistic estimate of the time required for recovery in gravels and sands (following the establishment of suitable substrate). Areas of undisturbed deposits adjacent to a dredged area may provide an important source of colonising species, which may promote faster recovery than might occur solely by larval settlement.

In sandy-pebbly deposits, periodic mortality of the longer-lived components may result in seasonal changes in community composition (van Moorsel 1994). Under these conditions, the community will be held in a transitional state by natural environmental disturbance, and is likely to recover within a period of 2-3 years after cessation of dredging. There is good evidence that disturbance of seabed deposits by man may result in a shift from an "Equilibrium Community" characteristic of undisturbed deposits towards a "Transitional Community" which characterises deposits in areas of natural environmental disturbance (MMS 1999).

The change in water depth due to dredging may result in a change in components of the soft sediment community structure. As reported above, baseline data shows that the dredge area for the LNG and MOF straddles two community types, with the polychaete *S. armiger* community prevailing in shallower water (7-10m) and the gastropod *C. kuragiensis* community in slightly deeper water (12-15m). Dredging may therefore produce conditions more suitable for colonisation and establishment of the *C. kuragiensis* community at the expense of the *S. armiger* community within the dredge area. In the context of the wider extent and distribution of shallow subtidal habitats present within Aniva Bay, this potential shift would be considered to be negligible.

On the basis of the physical conditions (e.g. current velocities, sediment transport) it is not considered likely that maintenance dredging would be required to maintain operational depth (see Section 12.4.1). As such, benthic communities that become established within the dredged area would be able to develop without significant and further disturbance from dredging activity.

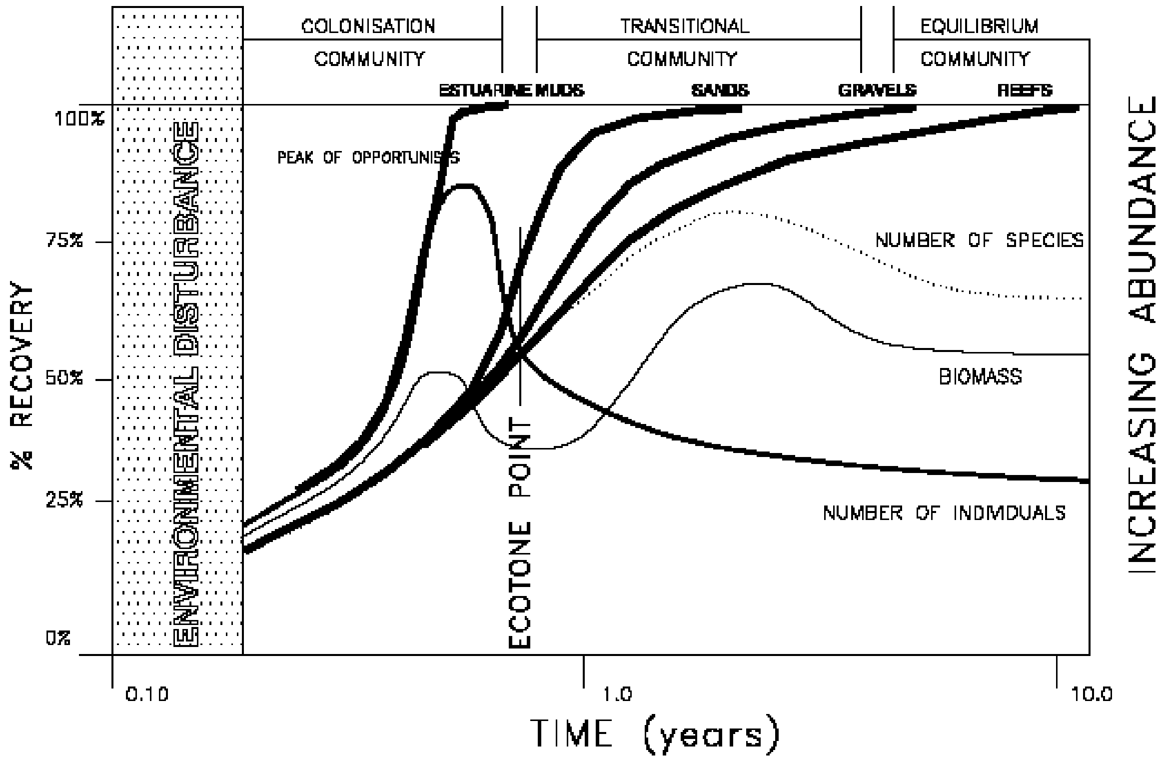



**Figure 12.7. Schematic diagram showing the likely recolonisation rates for the benthic community of estuarine muds, sands, and reef areas. The curves for recovery are superimposed onto a generalised colonisation succession and allow some predictions to be made on the rates of recovery of deposits following dredging.**

### 12.6.2 Potential impacts of dredging and disposal on fish

Dredging activity may impact upon existing fish resources and supporting environmental parameters within Aniva Bay through a number of routes, whichinclude the following:

- Increase in levels of suspended sediment (causing reduced visibility, physiological damage and mortality);
- Increase in background noise levels;
- Decrease in water quality;
- Direct entrainment of fish;
- Alteration and destruction of fish habitat.

The following text provides a brief overview of the types of effects that dredging may have on fish populations in coastal and estuarine waters. With respect to the proposed works in Aniva Bay, the remobilization of contaminated sediments during dredging is not considered to be an issue as investigations have shown that the marine sediments present in the area are uncontaminated. It should also be noted that the length and severity of the effects are directly related to the length of the dredging operation and the amount of material to be removed.

**Increase in suspended sediment concentration (SSC)**

It is generally accepted that the magnitude of the impact of suspended sediments on fish is a function of sediment concentration and the duration of exposure (Newcombe and MacDonald 1991; Newcombe and Jensen 1996; Wilber and Clarke 2001).

Typically, SSC at the seabed or in the water column are low in Aniva Bay (up to 7 mg/l; SakhNIRO (2001a)) although concentrations rise considerably closer to shore and at the mouths of estuaries (44.6-144 mg/l at the mouth of the Mereya River). The composition of the fish fauna found within the Bay reflects these background levels, with species distribution and abundance being partly controlled by marked variations in SSC (e.g. deeper, open water compared with nearshore, shallow estuarine waters). Therefore, potentially, the addition of even small amounts of fine sediment into relatively clear water ecosystems is likely to have more significant ecological consequences than increased fine sediment presence in more turbid systems.

Plumes of increased SSC form throughout dredging operations and disposal. When these activities cease the time taken for the sediment in the plume to settle is related to several factors. The most important is the size of the particles released. Small, light particles take much longer to settle than heavy ones. Latest modelling work undertaken for the dredging of the LNG jetty turning area predicts that SSC of more than 100 mg/l would occur up to approximately 500m from the dredge area and concentrations of more than 50 mg/l up to 772m from the boundary of the dredge area (see Figure 12.5 and Table 12.3). Similarly, concentrations of more than 100 mg/l were predicted up to 15m away and 50mg/l up to 25m from the edge of the dredge area for the MOF (Figure 12.3b), (TEOC, Appendix F2, Vol 5, Book 12, Part 2).

During dredging, fish may be exposed to the sediment plume if the operation starts in, or moves into, the area in which they live, or the fish move into the plume area. For adult and larger juvenile fish, exposure to high SSC is likely to be of short duration. Most adults are mobile enough to move out of an affected area if they find conditions hostile. Some benthic adults, most larvae and all eggs of fish have little or no ability to avoid a sediment plume and may be exposed to high SSC for the total duration of the plume in the water body or area of residence.

Increasing SSC will also reduce visibility in a water body. Since many open water fish are visual feeders a reduction in visibility could reduce their hunting success. For instance, in the silverside (*Atherina breviceps*) even quite small increases in turbidity (increased turbidity is often closely correlated with higher SSC) have been shown to reduce their ability to feed.

An increase in SSC can also cause respiratory problems in fish due to their gills becoming clogged by sediment particles. In extreme cases this can lead to suffocation. Raised levels of sediment in the water lead to higher mucus production in the gills and subsequently, increased gill clearing. Both of these have a metabolic cost associated with them and, if high SSC lasts long enough, may affect energy budgets. This factor is probably of more significance for those fish species that are not adapted to natural high SSC (e.g. open water, non-estuarine or nearshore species). It is interesting to note that Ritchie (1970) found no evidence of gill pathology in 11 species of estuarine fish exposed to conditions found in sediment plumes from dredging.

In Aniva Bay, it is considered highly unlikely that adult or juvenile fish would be adversely affected by the higher SSC generated during the dredging operation. Although the background SSC is relatively low, during storms and/or rough weather, disturbance of seabed sediments through wave activity will significantly increase SSC. The majority of fish species present in the nearshore are adapted to these variable conditions and can tolerate significant, short-term increases in SCC. Although dredging may generate higher SSC than typically found during storm conditions, this will be localised to the sediment plume. Apart from several species of flatfish the main commercial fish species are all pelagic feeders and it is considered highly likely that they would be able to avoid localised areas of higher SSC during dredging.

Specific concern relates to the potential impact of raised SSC on salmon and in particular salmon smoults leaving rivers and entering Aniva Bay. There has been significant study of the effects of turbidity and SSC on the physiology and behaviour of salmon. These studies generally indicate that salmon are well adapted to fluctuations in SSC and can tolerate short-term (a few days) pulses of high SSC without detrimental impact to either their health or migration. Such adaptation would be expected in species that inhabit watercourses subject to rapid changes in sediment loadings as a result of snowmelt or increased run-off. Studies in which salmon were exposed to longer term, high SSC show that detrimental physiological effects and mortality can occur (see Table 12.5). However, the levels of SSC used in these laboratory studies generally far exceed those to which fish would normally be subject, both in respect of duration and concentration (Newcombe and McDonald 1991).

As discussed above, modelling work indicates that SSC during dredging for the LNG jetty would be in the region of 50-200mg/l and extend up to 772m from the boundary of the LNG jetty area (see Table 12.3). In comparison with the SSC levelswhich salmon can tolerate, and that occur naturally (e.g. in stormy conditions), it is considered unlikely that raised SSC generated during dredging would pose any threat to the health of either adult salmon entering the nearby River Mereya and Goluboy Brook or young leaving the rivers. This is particularly so given the extensive area of the water mass at the mixing zone between the rivers and the open sea, thus ensuring unhindered ingress and egress for migratory movement, the intermittent nature of the dredging works and most importantly, the fact that the dredging works will be undertaken outside of the main period of migratory salmon movements (May-September). The above conclusions are also backed up by as yet unpublished monitoring data for pink salmon migration in the local rivers at the LNG site. Estimation of the number of fish migrating up the Mereya River indicates that numbers were twice as high in 2005 as during 2003 and for Goluboy Brook, six times as high.

**Table 12.5. Summary of suspended sediment effects on salmonids in the Yakima River Basin. From Newcombe and McDonald (1991)**

| Species | Concentration (mg/l) | Duration (hours) | Effect |
|---|---|---|---|
| Chinook Salmon | 1400 | 36 | 10% mortality of juveniles |
| | 488 | 96 | 50% mortality of smolts |
| | 82,000 | 6 | 60% mortality of juveniles |
| | 19,364 | 96 | 50% mortality of smolts |
| | 1,547 | 96 | Histological damage to gills |
| Rainbow trout | 90 | 456 | 5% mortality in sub-adults |
| | 19,364 | 96 | 50% mortality of smolts |
| | 100 | 1 | Avoidance response |

**Deposition of sediment from the sediment plume**

Some species of demersal spawning fish require particular sediment types to successfully bury or attach their eggs (e.g. herring (*Clupea harengus*)). Changes in the proportion of the different types of sediment found on the surface of the seabed due to dredging or sedimentation might make areas unsuitable for breeding or affect the suitability of an area as a nursery ground (e.g. for some species of flatfish).

Eggs and larvae of marine fish are sensitive to high SSC. In a review, Wilber and Clarke (2001) summarized the known data for several fish species. In the herring, a demersal spawning fish, egg development was not impaired by suspended-sediment dosages of 300 and 500 mg/l for 1 day. However, the burial of Atlantic herring eggs under even a thin veneer of sediment caused substantial mortality. However, it has also been demonstrated that exposure to suspended-sediment concentrations as high as 7,000 mg/l had no observable effect on hatching success.

Mortality occurred at relatively low suspended-sediment concentrations when sustained for several days for the larvae of some anadromous fish. Several species of fish (e.g. striped bass) showed increased mortality when exposed to suspended sediment doses of 500 mg/l for 4 days.

The settling of suspended solids can lead to smothering of benthic organisms and eggs. Species of fish with demersal eggs, such as herring, are particularly vulnerable to this impact. Even thin layers of sediment are shown to have an effect. In experiments, the smothering of white perch eggs to a depth of 0.45 mm had no effect. Once the depthincreased to between 0.5 to 1mm then 50% mortality was observed. Sediment layers of 2mm resulted in 100% death (Morgan et al. 1983). Adult and juvenile fish can generally avoid burial by moving, indeed they are often found returning very quickly afterdisturbance ceases. The greater loss for fish is probably damage to or lossof their food resource during dredging and disposal.

**Changes in water quality**

Fish try to avoid areas of low water quality, for example coho and sockeye salmon smolts will change depths to avoid low quality water (Newcombe and MacDonald 1991). If a large part of the cross-sectional area of a river or significant proportion of migration waters possesses low water quality then the migration of fish through an area may be reduced or constrained.

If the sediments to be dredged have a high biological or chemical oxygen demand, it is possible that the level of oxygen in the water near the dredging site will be depleted. Low oxygen has been linked to many sub-lethal effects in fish. Fish will not enter an area with very low oxygen levels and a large area of oxygen-depleted water may cause a temporary block to fish migration routes. In a well-mixed, turbulent water body the effect is likely to be short lived.

The sediments to be dredged for construction of the LNG and MOF jetties comprise sand, gravel and sandstone. Analysis of these sediments indicates that they do not contain high levels of organic material, nor are they anoxic and they would therefore not have a high biological or chemical oxygen demand when dredged. CSA (1999) report that total organic carbon (TOC) concentrations ranged from 0.16% to 0.72% in 37 samples collected from 31 sampling stations in the coastal zone in the Prigorodnoye area and from 0.14% to 2.28% in more offshore stations. These figures are lower than or similar to values obtained for non-polluted sediments of the Sea of Japan (Vostok Bay = 2.02 %). Changes in water quality resulting from dredging and sufficient enough to cause sub-lethal effects are therefore considered highly unlikely to occur.

**Effects of noise generated during dredging**

High levels of mortality have been found in fish exposed to 177 dB of sound and the threshold for internal injures to fish is around 160 dB. A recent major causeway project in California used 150 dB re 1 Pa (relative to 1 micro pascal) as a safe upper limit to avoid harm to fish. As these sound levels are far above what is likely to be generated by dredging, physical harm caused by excessively loud noise should not occur.

One of the most comprehensive studies of the underwater noise emissions from dredging was carried out by the United States Army Corps of Engineers in Cook Inlet, Alaska (Dickerson *et. al*. 2001). The research provides detailed records of the underwater noise generated by a bucket (grab) dredging operation. The dominant noise sources identified were:

- The bucket striking the channel bottom (particularly in cases where the bottom comprises of coarse gravel or rock);
- The winch motor that pulls the loaded bucket back to the surface;
- The bucket digging into and through sediment;
- The bucket closing.

Dredging of coarse sediment has been found to generate significantly higher noise levels then dredging in soft sediment. Measurements of the dredging in Cook Inlet showed that the bucket striking coarse gravels on the seabed generated the most noise with a recorded peak of 124 dB re 1 μPa-m at 150m from the dredge site which attenuated by 30 dB re 1 μPa-m over a distance of 5km. The digging operation was characterised by a grinding noise with a recorded peak of 113.2 dB re 1 μPa-m at 150m from the dredging site to 94.97 dB re 1 μPa-m, 5km away. These measurements were recorded for dredging of gravels and similar, or lower noise levels would be expected for dredging of similar sediments in Aniva Bay.

Recorded noise levels for large cutter suction dredgers are higher than those associated with grab dredgers. Broadband noise data for the large cutter suction dredger *JFJ de Nul* are given as 183 dB/1 Pa at 1m (Sakhalin Energy 2004). Measurements of two suction dredgers, the *Aquarius* and *Beaver Mackenzie*, are reported in Nedwell and Howell (2004). Their octave band spectra peak between 80 and 200 Hz, with the *Aquarius* having the higher of the two spectra peaking at approximately 177 dB re 1 mPa. In the 20-1000 Hz band, the *Beaver Mackenzie* and the *Aquarius* were measured to have a 133 dB re 1 mPa level at 0.19 km and a 140 dB re 1 mPa level at 0.2 km respectively.

As stated above, information from a number of studies indicates that acute damage to fish caused by sound does not occur below about 160 dB/1 Pa. During dredging activity this noise level is highly unlikely to be generated during grab dredging, even when dredging through partially consolidated rock. However, noise levels as high, or higher, than 160 dB/1 Pa could be generated in close proximity to the cutter suction dredger. Available data indicates that in shallow coastal waters, underwater noise transmission loss is typically of the spherical spreading type (Nedwell and Howell 2004). This means that for each tenfold increase in distance from the source the sound level will reduce by 20 dB. For the source measurements for the cutter suction dredgers provided above this means that a noise level of approximately 160 dB/1 Pa would occur at a distance of 10m from the cutter head and 140 dB/1 Pa at 100m. Henderson (2003), assuming spherical spreading of sound, calculated that the predicted sound level from a suction cutter dredger during dredging operations would be 100 dB/1 Pa at 1km. This calculation, although broad brush, demonstrates that potential acute damage to fish would only be likely to occur up to 100m of the cutter head and probably at a distance significantly less than this.

Thus at distances greater than this, acute damage such as internal injuries would not be expected to occur. As fish would avoid moving so close to a working dredger head, as the sound would cause an avoidance response, acute damage would only occur if fish were present in the vicinity when dredging operations started. This in itself would be highly unlikely given the physical disturbance that this activity would cause in the first place.

Experiments using a range of frequencies from 100 to 500Hz have demonstrated that sound levels need to be in the range 108-138 dB/1 Pa to produce an alarm or avoidance response in fish (including salmon). Some species such as flatfish are even less sensitive than salmon while others such as cod are more sensitive to low frequencies than salmon. For cod, the threshold for response at frequencies of 300 to 500Hz is around 100 to 120 dB/1 Pa.

On the basis of available evidence it is considered that the noise generated during dredging would not lead to fish mortality and at worse may cause temporary avoidance of nearshore waters immediately adjacent to the dredging activity. Dredging noise will vary through time and the activity will cease at regular intervals as the dredged material is taken away for disposal. This creates periods of calm and quiet during which fish can move through an area subject to periods of potential noise disturbance.

*Likely impact on fish species of commercial interest*

Taking into account available data on the sensitivity of fish species to dredging and disposal activities it is considered highly unlikely that the proposed activities in Aniva Bay (i.e. dredging for the LNG and MOF and the disposal of arisings) would have a significant impact on commercial fish resources. This conclusion is based on both the biology of the commercial species present in Aniva Bay and the timing and nature of the dredging and disposal process itself.

The remainder of the planned dredging and disposal will take place during the late autumn and winter (October-December). This timing has been programmed to avoid the key salmon migration periods when salmon (adults and juveniles) may be present in nearshore, coastal waters. Flatfish species such as flounder (*Pleuronectes* and *Platichyths* sp.) migrate to deeper waters during the winter, which means that they are effectively outside any zone of potential impact. Capelin, move out into deeper, more thermally stable offshore waters during the winter months, while saffron cod adults may be present in coastal waters at spawning grounds (mainly along the Tonino-Anivskiy peninsula). Herring, although relatively uncommon appear to be present mainly along the eastern coast (see Figure 12.3b) but may be found throughout the Bay in small numbers during late autumn. Dredging activity and disposal of arisings would therefore only have the potential to impact upon saffron cod, resident, non-migratory flatfish (e.g. starry flounder, flathead sole), herring and other minor commercial species such as sculpins.

As discussed above immature and adult fish are generally only adversely affected by dredging activity when sediment concentrations in the water column exceed 100mg/l (causing avoidance of the impacted area) and evidence suggests that levels have to be significantly greater to have lethal effects. The modelling work for both dredging activity at the LNG and the MOF indicates that SSC levels of >100mg/l would be registered only in the close proximity to the activities. Monitoring data for the MOF and foundations to the jetty using a grab dredger indicates that recorded levels are significantly lower than predicted (see Section 12.8). This data suggests that even for those adult and juvenile commercial species that may be present within the coastal area influenced by dredging, that the increase in SSC would be below levels that would lead to any physiological damage and therefore potential damage to stocks.

At the disposal site, SSC levels above 100mg/l are predicted to occur within an area of approximately 0.015km$^2$ immediately around the site. While such levels could have an effect on benthic and pelagic fish populations present in the area the likely reaction would be for fish to vacate the zone affected by high SSC levels (approximately >100mg/l). Fish would be likely to move in and out of this zone of higher SSC during the disposal process, depending on the level of SSC present in the area. Direct fish mortality cannot be ruled out as a result of the disposal process (e.g. direct smothering of some benthic species). However, it is considered unlikely that intermittent periods of increased SSC would be intense enough or of long enough duration to cause mortality of adult fish. The fry of some species, if present, could be susceptible within the immediate plume created during disposal (see Section 12.6.2), although within the context of the wider environment and likely population levels, any such mortality would be considered negligible.

The impact of the works on spawning grounds and spawning success for capelin would be negligible as the dredging works occur outside of the spawning period and SSC would be unlikely to have an adverse effect on the sedimentology and physical attributes of spawning grounds in the area. Herring spawning has not been recorded in Aniva Bay during the 1999-2000 monitoring season, nor in the LNG-MOF area during 2003 (SakhNIRO 2004). Disposal of dredged material would not affect spawning areas for these species, but could impact upon fish eggs of some flatfish and other species present in surface sediments at the disposal site, leading to potential mortality of eggs within the area influenced by deposited sediment.

Compensation for potential damage to commercial fish stocks (all species) as a result of dredging and disposal activity in Aniva Bay has been calculated (SakhNIRO 2001a). Calculated damage has been based on loss of food productivity (plankton and benthos) and fish eggs of commercial species present in surface sediments, as it is recognised that the works themselves would have a negligible impact on mobile adult and juvenile fish populations.

Fish damage calculations and compensation payments are reviewed and altered accordingly in line with any change to the dredging and disposal methodologies.

### 12.6.3 Disposal of dredged material and impact on benthic communities

**Baseline data**

Information on the benthic organisms present in the disposal area comes from several surveys undertaken for baseline characterisation or monitoring, but in particular DVNIGMI (2001) and SakhNIRO (2004). This survey data indicates that the community present in the area is dominated by burrowing polychaetes and bivalves, which are characteristic of the soft sediments (fine sand and silt) present at the site. Typical polychaete species included the detritivores *Praxillella praetermissa*, *Onuphis iridescens* and *Lumbrineris heteropoda.* The sipunculid worm (acorn worm) *Golfingia* sp. was prominent in the samples obtained as a result of its significant contribution to the overall biomass (45%). This genus of worms is characteristic of silty-fine sand, seabed substrates.

**Potential effects**

The disposal of the dredged material at the selected site is likely to have a number of impacts on the benthic communities (infauna and epifauna) present in the area:

- Burial of existing organisms within the direct footprint of the disposed material;
- Smothering of organisms through increased rates of sediment deposition;
- Increased SSC in the vicinity of the disposal site;
- Alteration of substrate conditions.

**Burial of existing benthos**

One of the main impacts associated with the disposal of dredged material at sea is smothering of the existing benthic infauna and mortality if individuals are unable to migrate through any deposited sediment and/or their feeding and respiration apparatus becomes clogged.

Several studies have examined the effects of the burial of invertebrates by sediment. Maurer *et al.* (1981a, 1981b) carried out experiments on the lethality of sediment overburden on selected macroinvertebrates. They concluded that many motile epibenthic and infaunal animals could withstand a light overburden of sediment (about 1 cm), especially when the overlying sediment was native to their habitat. Many of the macrofauna that live in areas of sediment disturbance are well adapted for burrowing back to the surface following burial. Studies by Maurer *et al* (1978) showed that some benthic animals could migrate vertically through more than 30cm of deposited sediment, and this ability may be widespread even in relatively deep waters.

Kukert and Smith (1992) showed, for example, that approximately 50% of the macrofauna on the sea floor of the Santa Catalina Basin were able to burrow back to the surface through 4-10 cm of rapidly deposited sediment.

Experimental work also indicates that the effective overburden stress, which incorporates both the bulk density of the sediment, as well as the depth of burial, is a better measure of the force exerted on organisms by sediment burial than depth of sediment alone. Potentially, even in areas where sediment thickness is reduced, the change in character of the sediment (from fine to more coarse) may make it either difficult or impossible for organisms adapted to fine sediments to burrow through to the surface.

Given the variable nature of the material being dredged at the LNG and MOF facilities, the overall volume and the fact that it differs significantly from the nature of the substrate at the disposal site, it is considered that disposal would result in the mass mortality of benthic organisms. This is largely a function of the significant increase in overburden stress that would arise at the site, even as a result of single depositional events (i.e. individual barge loads).

The extent of benthic mortality at the disposal site will depend on the thickness of the material deposited and the area over which it extends. This is difficult to estimate and will depend on both the exact area in which disposal from the dredging barges occurs and the behaviour of the dredged material as it falls through the water column. Clearly the coarser sediment will disperse over a relatively small area in comparison with the finer grained sediment (see Figure 12.8).

Calculations of the area over which sediment could accumulate at the disposal area were undertaken originally on the basis of the disposal of 1,640,500 $m^3$ of material (190,500$m^3$ more than estimated from recent data on the required dredge volume). The fractional composition of this material was given as 77.5% gravel/coarse sand (>1mm diameter), 8.8% sand (0.1-1.0mm diameter) and 13.7% sediment <0.1mm in diameter (Ecocenter 2001, as reported in Appendix F2 of TEOC Vol.5, Book 9, Part 2). The simulation considered the actual criteria for the disposal of material, which would be confined to a circular area with a radius of 200m (i.e. a total area of 125,000$m^2$, or 12.5ha) with material being dumped randomly within this area. The model assumed that 95% of the total amount of sediment would settle within the confines of the disposal area.

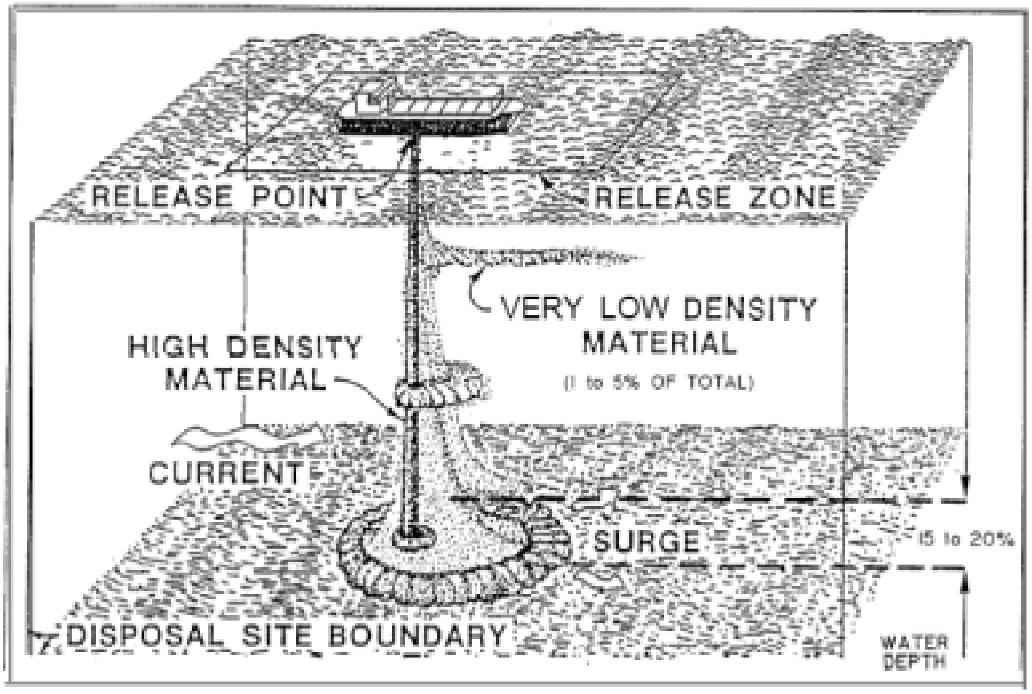



**Figure 12.8 Characteristic behaviour of sediment during open water disposal.**

On the basis of the above figures it was predicted that up to 100mm of fine sediment would accumulate at a distance of 59m away from the boundary of the disposal area; 50mm up to 65m, 10mm up to 172m and up to 5mm at a distance of 335m from the boundary. These figures equate to a total area of seabed of 9.23ha being covered by a sediment thickness greater than >100mm or 14.3ha by a sediment thickness >10mm (see Table 12.4). Since the work undertaken for the TEOC, further analysis of the type of material to be dredged has been undertaken and it is now apparent that a greater volume of rock will need to be removed (see Section 12.2). The total volume of finer sediment is estimated at 303,500m$^3$, or 21% of the volume to be dredged. However, this is similar to the volumes used in the original disposal simulation, assuming that this fine sediment is less than <1mm grain size, and therefore the simulation still represents a reasonable estimate of likely behaviour of material at the site.

As discussed previously in Section 12.4 approximately 280,000m$^3$ of sediment has been dredged and disposed of at the disposal site. Monitoring data for this disposal process and potential environmental effects is presented in Section 12.8. The original TEOC predictions as presented above related to a continuation of this process (i.e. the use of relatively small hopper barges for disposal). However, with a switch to the use of a larger hopper, the dynamics of the disposal process will alter, as presented in Section 12.5. Comparison of Figures 12.4b and 12.6b indicates that the distribution of sediment outside of the deposition site would change, with a greater thickness of sediment accumulating around the periphery of the disposal area. The additional modelling work suggests that sediment in excess of 100mm would cover an area of 9.23ha,outside of the disposal site, >10mm thick would cover an area of 14.3ha, giving a total area of 26.8ha (including the disposal site) in which sediment over 10mm would accumulate.

Despite intermittent disposal (i.e. sediment will be disposed at varying times during dredging periods) it is considered unlikely that infaunal organisms would be able to maintain their position over this time period within the sediment column (i.e. keep pace with the accumulation of sediment), resulting in mortality. The area in which mortality would occur would be the entire area of the disposal site (i.e. 12.5ha), where deposited sediment thickness could be in the region of 10m (assuming an even spread within the disposal site). Outside of the disposal site, and on the basis of ecological data (see previous section) it is considered that the accumulation of greater than 10mm of fine sediment could pose a threat to benthic fauna, particularly non-motile, sessile or slow-burrowing organisms. It is considered that over an area of approximately 26.8ha (including the designated disposal area) some benthic organisms would suffer mortality due to disposal of the dredged sediment. The level of mortality would vary within this area, with total loss of communities within the disposal site (12.5ha) and probably within the area affected by sediment accumulation up to 100mm (9.2ha), giving a total area of 21.7ha. However, beyond this area, the level of mortality is likely to decrease in line with a reduction in the thickness of accumulated sediment, depending on the physiological and physical tolerances of the organisms present.

**Effects of Increased Suspended Sediment Concentration outside of immediate disposal area**

During disposal an area of higher suspended sediment concentration will be created both within the water column and at the seabed (see Figure 12.9).

The potential consequences of increased SSC on mobile, nektonic organisms have been discussed in Section 12.6.1. Increased SSC can also affect organisms on the seabed, particularly filter feeders, which rely on extracting organic material from the water column for food. Blanketing or smothering of benthic animals by sediment settling out of suspension may cause stress, reduced rates of growth or reproduction and in the worse cases the effects may be fatal (Bray, Bates & Land 1997) if levels are maintained over relatively long periods. In general, however, studies of filter feeders which live in turbid coastal waters show that bivalves in particular are highly adaptable in their response to increased turbidity such as can be induced by periodic storms, dredging or spoil disposal and can maintain their feeding activity over inorganic particulate loads (Newell *et al* 1998). In deeper or naturally clear waters (>30m), fluctuation in SSC will be significantly lower than that occurring in shallow turbid waters and therefore potentially species characteristic of these areas are more likely to be sensitive to SSC increases.

Following disposal, suspended sediment will be transported away from the disposal site. The extent of dispersal will depend on a number of factors, but would be largely controlled by current strength and particle size. Modelling of dispersal during disposal was undertaken for the TEOC (Appendix F2, Volume 5, Book 12, Part 2) and was based on the disposal of approximately 1,640,000m$^3$ of sediment at the site using a relatively small hopper barge. This work predicted that suspended sediment concentrations in the water column of more than 100mg/l would occur within 65m of the disposal site falling to 50mg/l within 330m and 5mg/l by 1.1km. With the use of a much larger hopper, modelling shows that SSC levels in the water column would be significantly raised in the immediate vicinity of disposal point and extend further away from the immediate disposal site in comparison with the original approach (compare Figures 12.4a and 12.6a and data provided in Table 12.3). Using a large hopper it is calculated that the maximum area of a sediment plume in contact with the seabed outside of the disposal site with SSC >50mg/l would be approximately 2.5ha. This compares with an area of approximately 0.8ha for the original situation (small hopper).

With respect to the impact of the deposition of 1.2 million m$^3$ of sediment at the disposal site, the effect of increased SSC is insignificant, as benthos would suffer mortality due to smothering. However, away from the immediate disposal area, but within the zone of increased SSC, the effect may be more significant for some benthic species. Repeated pulses of higher SSC (i.e. significantly above typical background levels) could cause physiological harm to some benthic groups, notably attached epifauna and filter/suspension feeders, leading to mortality. Infaunal detritivores, such as the majority of polychaetes, would probably not be adversely affected. The potential short-term outcome of this effect could be a reduction in abundance in some species belonging to this trophic group and possibly the loss of some species from within the zone subject to highest SSC during disposal. On the basis of available sensitivity data (e.g. Marlin 2004) it is considered that benthic organisms within the area where prolonged exposure to SSC above 50mg/l would be most likely to suffer potential mortality. This would limit the seabed area likely to be affected to a relatively small area (i.e. 2.5ha) around the disposal site. Available baseline and monitoring data for the composition of the benthic fauna in the immediate vicinity of the disposal site shows that the diversity of filter/suspension feeders is relatively low (3-4 species) and overall biomass constitutes 1-2% of total biomass (data obtained from preliminary SakhNIRO monitoring data, 2005). It should also be noted that much of the area potentially affected by SSC at the seabed above 50mg/l could be contained within the potential area subject to >10mm of sediment deposition from the sediment plume. Thus, potentially, no additional organism mortality would be attributable to the effects of raised SSC over and above that caused by sediment deposition.

The longer-term consequences for the benthic community are difficult to predict with any certainty. However, basic ecological principles and evidence from monitoring studies of disposal sites (see below) indicate that recolonisation of vacant substrate space and re-establishment of former population levels can be relatively rapid. Potentially, initial recolonisation would comprise opportunistic species. However, as it is likely that the basic structure of the community would remain intact, this phase would be either relatively short-lived or limited in extent before re-establishment by those species affected. This can be viewed as a likely occurrence given the large area of similar habitat and community types that would remain outside of the disposal influenced area. Full recovery of the benthic community in the zone subject to increased SSC would therefore be expected.

**Alteration of substrate conditions**

Available survey data indicate that the sediments present within the area of disposal comprise sand, fine sand and silt. According to the latest calculations, the material to be disposed comprises 1,141,500$m^3$ rock (claystone) and 303,500$m^3$ soft sediment (sand-silt and some gravel). The deposition of over 1 million $m^3$ of rock, which differs significantly from the existing substrate conditions, will alter the physical substrate for recolonisation of the area by benthic organisms. Although it may be expected that some finer grained sediment would remain in the area of disposal, the majority of fine material is likely to either be transported some distance away from the main disposal area or fill interstices between coarser material at the disposal site.

The change from fine to coarse sediment will effectively alter substrate conditions to the extent that many of the existing species that constitute the assemblage would either be lost or their abundance would decrease. This particularly applies to species requiring soft sediment for burrowing.

The extent of this change in relation to the total area of seabed habitat within Aniva Bay is relatively small. It is estimated that there is an area of approximately 150$km^2$ with a water depth of between 50-100m in Aniva Bay. This is the water depth at which the communities typical of the disposal site are likely to occur throughout the rest of the Bay. If disposal is entirely confined to the designated area then the area occupied by introduced, rocky substrate would be 0.125$km^2$ (12.5ha) or approximately 0.08% of similar type seabed habitat within Aniva Bay. While this is rather a crude calculation it does suggest that the total area of change would be insignificant within the wider context of this habitat type.

**Recolonisation and recovery of benthic fauna in the disposal area**

As discussed in the previous sections, as a result of predicted change in the seabed substrate, it is considered highly unlikely that following the cessation of disposal that the benthic community would recover to its former state at the disposal site. This is not to say that there would not be benthic recovery, but that the recovered community would differ in species composition to that existing prior to disposal.

The colonisation of disturbed or new areas of exposed sediment following dredging has been relatively well documented. Available data indicate that recovery periods vary significantly from one substrate type to the next

(Nedwell & Elliot 1998; Newell *et. al*. 1998), but typically recovery following the process of colonisation-establishment takes place within 1-5 years in the majority of coastal environments. Studies of the colonisation of disposed sediment in offshore areas are relatively scarce in comparison, although the same basic ecological principles apply. Monitoring data from disposal grounds off the north-east coast of the USA (USACE 2003) show that the surface of dredged soft sediments disposed in 1998 had by 2001 been extensively recolonized by an advanced successional stage community consisting of both surface-dwelling and deeper-dwelling infauna (mainly polychaetes).

Biological monitoring undertaken following the disposal of dredged material at a site in the southern North Sea (United Kingdom) provides an indication of the likely time scale for, and nature of, recolonisation of stiff clay deposited subtidally. During disposal and in its immediate aftermath the benthic fauna was reduced at stations within and immediately adjacent to the disposal site. A survey in July 2001 recorded a marginal (non-significant) increase in numbers of taxa and a significant increase in densities at the disposal site. It was concluded that there was evidence of recolonisation some 14 months after the cessation of disposal but that diversity was reduced compared with similar sediments nearby (Murray *et al.* 2003).

There have been few studies where the colonisation of deposited rocks has been investigated. However, parallels can be drawn from studies of artificial reefs.

In the case of coarse material deposited onto finer sediments, the ecological effect is to diversify the available microhabitats. Through the diversification of the habitat, stable coarse material will therefore usually result in an increase in the total number of benthic species within a disposal ground. In this respect, there will be parallels with the way artificial reefs increase the diversity of species in an area. However, in most cases the coarse material will only be one component of a mixture of types of material (as in the case with disposal in Aniva Bay). In the immediate vicinity of disposal, the net effect in terms of diversity will be a balance between the depressing effects of blanketing and turbidity, and the enhanced habitat complexity of the coarse materials.

The coarse sediment arising from dredging for the LNG jetty and MOF constitutes a “once-off” capital project, and hence recolonisation, following disposal, would be envisaged to follow classical successional events analogous to those on rocky shores (Fig. 12.9). Such coarse material, if left relatively undisturbed, is also likely to be favoured by fish and shellfish, either as a source of food or as refuge, and adults of these groups may arrive very rapidly through inwards-migration after disposal. An analogy may therefore also be drawn between the disposal of coarse dredged material to a site characterised by the natural occurrence of finer sediments, and the construction of artificial reefs to enhance commercial fish or shellfish populations.

Studies of artificial reefs (e.g. Collins and Jensen 1997) and dredged sediment disposal sites indicate that colonisation of the deposited sediment would be likely to occur over a relatively short period (1-5 years). The characteristics of the community likely to develop are difficult to predict with any certainty. Colonisation by opportunistic species either present within the existing community (but, outside the footprint of the disposal area) or that occur within Aniva Bay and surrounding waters would be likely to occur relatively rapidly (within 1 year). The establishment of a complex and stable community would take longer and occur over an extended period. Given the presence of significant amounts of consolidated sediment, there is the possibility that attached and epifaunal species, which do not currently feature in the community, may eventually come to form a significant component of the fauna. Such species are likely to be present within Aniva Bay or the surrounding waters where suitable substrates at similar depths exist. The eventual benthic community may also be influenced by localised changes in depth and effects on hydrodynamics that this may have (e.g. increase in current velocities over and around the disposed material).

The overall effect would be to alter the substrate characteristics and associated benthic community within the disposal site (i.e. covering an estimated area of between 12.5-23ha). Within the context of the wider benthic environment of Aniva Bay this change is not considered to be detrimental and indeed it is possible that the change could lead to localised benthic diversity increase.

Monitoring data from artificial reef structures around the World clearly demonstrate their benefits with respect to enhancing fisheries interests and acting as habitat for crustaceans. Although disposal of the material in Aniva Bay would lead to change in substrate type the presence of the material may, once stabilised and colonised, provide additional and enhanced habitat for some commercial crustacean species.

Disposal of the material at the site would not lead to the loss of a particular faunal assemblage in the wider area.

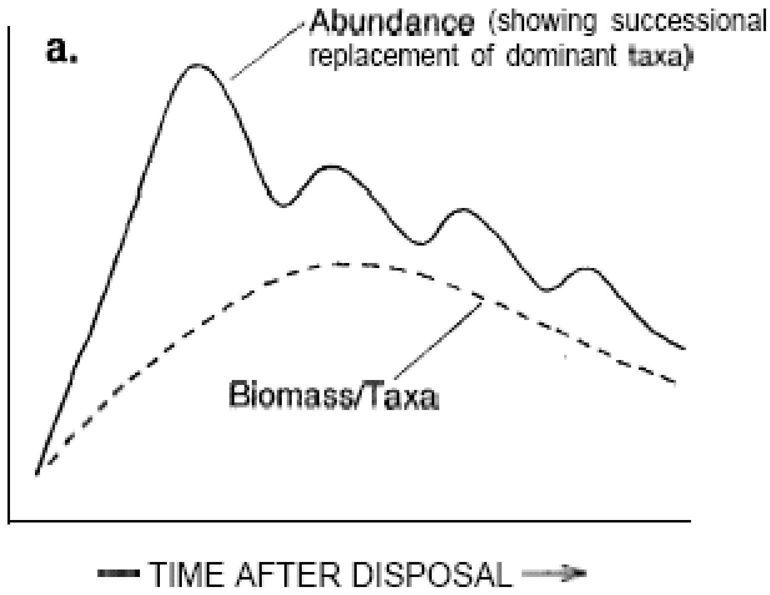



**Figure 12.9. Graph showing generalised recolonisation response over time to placement of coarse, stable sediment.**

### 12.6.4 Summary of potential impacts

The dredging and disposal operations in Aniva Bay associated with the construction of the LNG jetty and the MOF are likely to have a number of environmental impacts. These were originally assessed in the international-style EIA (2003), but following review of the EIA by stakeholders a number of additional aspects related to assessment of the works were highlighted. These factors have been discussed and more information and further assessment of likely environmental impact provided in the previous sections. In summary, the following effects and impacts have been identified and appropriate mitigation measures proposed (see Section 12.7):

- Exposure of fish populations to levels of SSC that could cause physiological harm. Available data indicates that the majority of coastal fish species are adapted to large natural changes in SSC. The estimated SSC for the dredging operations may rise above such levels but the affected area would be limited to the immediate dredging site. Potentially, fish which remain within the sediment plume for a prolonged period could suffer from physiological harm and/or mortality. However, it is considered that the vast majority of benthic fishes would move out of the area (temporary displacement) and return once dredging had ceased;
- Avoidance of the area of highest SSC generated during dredging and disposal by pelagic fish. This would be a temporary effect and given the large body of coastal and marine waters that would remain unaffected by raised SSC it is considered that there would be a negligible impact upon the ability of species to undertake migratory movements and/or continue effective feeding;

- Change to benthic communities within the sediment disposal site. The initial deposition of a large volume of sediment within the disposal area would be likely to result in the complete mortality of the existing communities. The change in sediment characteristics (from fine, soft sediment to more rocky, coarser grained material) in the disposal area would be likely to lead to the re-establishment of a different benthic community (over a period of 2-5 years). Potentially, given sediment characteristics, the disposal site could support a more diverse benthic assemblage than at present. The change in sediment type would constitute less than 0.1% of similar substrate conditions (within the 50-100m depth contours) within Aniva Bay and it is therefore concluded that disposal would have a negligible effect with respect to the benthic biodiversity of Aniva Bay;
- Smothering of benthic organisms by fine sediment outside of the main area of disposal. This is unlikely to have an adverse impact on those species of infauna, which can maintain their position in the sediment column (e.g. bivalves and free-burrowing worms). However, very localised mortality (outside of any area affected by sediment deposition > 10mm) of some filter-feeding infauna could occur. Recovery of the benthic assemblage in the affected area would be expected within a period of less than three years;
- Smothering of fish eggs by fine sediment during dredging and disposal. Within areas where >2-3mm of fine sediment would be likely to accumulate, the potential for complete mortality of the eggs of some fish species deposited on the sea floor exists. Any such mortality would be limited to an area less than 106ha around the disposal site (see data in Table 12.4, although predicted figure is for an area >1mm deposition and therefore the area likely to be affected would be less than this) and would be temporary (i.e. <2 years) and as a consequence is not considered to represent a significant impact with respect to the maintenance of fish populations within Aniva Bay. The dredging works would be unlikely to have an effect on species such as herring and capelin in the coastal zone as the works would be undertaken outside of the spawning season;
- The noise associated with the dredging operation may temporarily cause avoidance by fish of the water mass immediately in the vicinity of the dredging activity. Given the large area of open water in which noise levels would remain below thresholds at which harm could be caused to fish it is considered that this effect would not have a significant impact upon fish populations in the coastal zone.

## 12.7 MITIGATION

All of the proposed dredging works and the disposal of material will be undertaken in line with a Marine Operation Plan (MOP). The MOP is a detailed method statement for the proposed construction work and in the case of the works in Aniva Bay the MOP for the dredging works has to be approved by the harbour authorities in Korsakov Port. Separate MOPs are being produced for the construction of the LNG jetty, TLU and oil export pipeline.

The mitigation measures listed below have been employed throughout the dredging works undertaken so far and will continue to apply to the revised dredging approach. It is important to note that with the change from the relatively small-scale approach (i.e. use of grab dredger and small hopper) to the use of a large cutter suction dredger, the overall schedule of the dredging campaign has been significantly shortened in duration. With the use of cutter suction dredger and large hopper barge there is no requirement for dredging to be undertaken during 2006 (assuming that weather conditions permit uninterrupted dredging during October-December 2005). This reduction in the duration of the dredging campaign has several positive environmental consequences:

a) the potential for recovery of the benthic communities at the disposal site up to one year earlier in the project timeframe;

b) a reduction in the duration of higher suspended sediment concentrations at the dredge and disposal site, promoting an earlier repopulation by biota that inhabited or fed in the area prior to operations (e.g. zooplankton, crustaceans, ichthyofauna);

c) an overall reduction in the duration of potential impacts (e.g. noise levels, air emissions) associated with vessel activity at the dredging and disposal area;

d) furthermore, the use of a bottom dumping trailing suction hopper dredger with a large capacity of 25,000$m^3$ in conjunction with a cutter suction dredger is that the dumping of material will be less dispersive and more accurate given that the material will be denser and more entrained enroute to the seabed.

The following mitigation measures have either been employed or will be employed in association with the dredging and disposal operations in Aniva Bay. These measures will be included as commitments in the Health, Safety, Environment and Social Action Plan (HSESAP):

- Dredging and disposal operations will not be undertaken during the most sensitive period for salmon fisheries within Aniva Bay (May-August);
- Prohibition of any discharge of dredged material by barges outside the allocated disposal site. The disposal site (25km south of the dredge area) has a radius of 200m approximately at the water surface. A centre marker buoy identifies the exact location. Vessels will be provided with a GPS positioning system to ensure that accurate placement occurs;

- Daily control of the activity of disposal barges will be monitored through the use of records and inspections;
- All vessels will fully comply with MARPOL 73/78 Protocols. If no treatment facilities for bilge water and sewage are available onboard, wastes shall be collected and transported to land to an approved treatment facility;
- All garbage will be collected and sent to an approved waste management site.

## 12.8 MONITORING

A monitoring programme was developed prior to the Project activities starting in order to monitor the effects of the dredging and disposal operations in Aniva Bay and the success of the adopted environmental mitigation measures. The Program was reflected in SEIC Project document No. 7000-E-90-04-P-0010-01 Fishery Environmental Monitoring Methods (see summary of the programme in Appendix A).

A number of chemical and biological parameters in the water column and at the seabed were monitored prior to the commencement of activities in order to provide a baseline against which potential change could be measured. These parameters include: suspended sediment concentration; sediment composition and chemistry (including hydrocarbons); plankton; benthos; and fish fauna. It is a requirement (as set out in the Scope of Works) that any rare and protected marine benthic species (e.g. as contained in the Russian Red Data Book (RDB)) encountered during the survey/monitoring work are recorded. It should be noted that there are no marine benthos species listed in the Sakhalin RDB.

The first survey results from this monitoring have recently been reported (SakhNIRO 2004, 2005a and 2005b and see 12.8.1 below) and on the basis of the work undertaken in 2003, some changes to the programme were made (see addendum to the initial monitoring programme provided in Appendix B). This monitoring work provides data on the environmental effects associated with the disposal of sediment generated from the grab dredging work undertaken for the MOF. The results cannot therefore be applied to future disposal work that will be undertaken from a larger hopper. However, they do provide information on the general nature of the ecological and physical effects of the disposal process and can be used to verify the original predictive modelling work undertaken. This work will continue, as set out below, in order to monitor the effects of the change in the dredging and disposal approach.

The network of monitoring points embraces a wide area of Aniva Bay and incorporates the dredge area (i.e. the area around the LNG jetty and the MOF) and the disposal site. The disposal site will be monitored annually up to 2007 to determine benthic recolonisation and recovery.

At the end of the construction phase, the monitoring programme will be replaced by an operational monitoring programme, which will be maintained for the whole Project life cycle.

Where unforeseen adverse environmental impacts are identified through monitoring and these can be feasibly ameliorated then suitable additional mitigation measures will be implemented.

The information obtained from monitoring will be regularly issued to relevant authorities including the Sakhalin Committee of Natural resources.

### 12.8.1 Initial Dredging and Disposal Site Monitoring Results

Sampling was undertaken in August/October 2003 and December 2004 during dredging operations at the MOF and LNG in order to determine suspended sediment concentrations (SSC) and the concentration and total content of petroleum hydrocarbons (PHC) in the water column. These same parameters were also recorded at the disposal site in Aniva Bay, in addition to the composition and structure of the benthic community.

*Monitoring results for the dredge area (MOF and LNG jetty)*

Water quality in the dredge area (MOF terminal and LNG jetty) was determined from samples taken at predetermined sampling points in August/October 2003 and December 2004 (see Table 12.6). During dredging operations in 2004, temporary monitoring stations were used in the MOF area.

Recorded PHC during dredging were at the same level or slightly lower at both the MOF and the LNG than those in October 2003 (as reported in SakhNIRO 2004). As would be expected, during dredging, suspended sediment concentrations were higher than those recorded for the baseline situation. Recorded SSC in December 2004 varied between 13-23 mg/l in the MOF-LNG dredge area. This compares with a baseline SSC of 3-14mg/l for the area (SakhNIRO 2004). In the MOF area water samples were taken from near the barge/hydraulic dredge, 250m away and at the boundary of the dredging area. Values of SSC from this area varied between 20.7 and 23mg/l (SakhNIRO 2005a).

**Table 12.6 Recorded SSC levels and PHC from monitoring work at the LNG and MOF 2003-2004. Shaded columns represent measurements taken during dredging works. Non-shaded columns represent baseline conditions. (SSC = suspended sediment concs; PHC = petroleum hydrocarbons)**

| Location | Station | Depth (m) | Aug 2003 SSC mg/l | Oct 2003 SSC mg/l | Dec 2004 SSC mg/l | Aug 2003 PHC mg/l | Oct 2003 PHC mg/l | Dec 2004 PHC mg/l |
|---|---|---|---|---|---|---|---|---|
| LNG | 1 | 0 | 7.1 | | 20.3 | | 0.0253 | 0.007 |
| | 1 | 5 | 3.4 | | | | | |
| | 1 | 8 | | | 22.9 | | | 0.012 |
| | 1 | 12 | 4.5 | | | | 0.0559 | |
| | 2 | 4 | 4.7 | | 15.4 | | 0.0287 | 0.005 |
| | 3 | 0 | 8.6 | | 13.3 | | 0.0128 | <0.005 |
| | 3 | 5 | 5.0 | | | | | |
| | 3 | 8 | | | 19.6 | | | 0.007 |
| | 3 | 12 | 3.1 | | | | 0.0112 | |
| | 4 | 0 | 6.4 | | 20.6 | | 0.0231 | 0.020 |
| | 4 | 8 | | | 19.7 | | | <0.005 |
| | 4 | 12 | 6.2 | | | | 0.0653 | |
| | 5 | 0 | 7.3 | | | | 0.0199 | |
| | 5 | 5 | 4.0 | | | | | |
| | 5 | 12 | 6.7 | | | | 0.0180 | |
| MOF | 10 | 0 | 8.8 | | | | | |
| | 10 | 4 | 5.5 | 2.14 | | <0.005 | 0.0175 | |
| | 10 | 8 | 9.8 | | | | | |
| | 11 | 3 | 8.9 | 5.00 | | 0.028 | 0.0052 | |
| | 12 | 0 | 8.4 | | | | | |
| | 12 | 4 | 5.8 | 2.25 | | 0.0086 | 0.0042 | |
| | 12 | 8 | 4.9 | | | | | |
| | 13 | 5 | 5.1 | 2.68 | | 0.0077 | 0.0045 | |
| | 15 | 0 | 7.1 | | | | | |
| | 15 | 4 | 14.4 | | | 0.0132 | | |
| | 15 | 8 | 14.7 | | | | | |

### Monitoring results for the dredged material disposal area

*Suspended sediment concentrations and PHC*

As shown in Table 12.7, sampling during October 2004 revealed that SSC and PHC in the water column were similar to those previously recorded in 2003 (SakhNIRO 2005).

During disposal (samples taken in December 2004) PHC in the water column was raised slightly in comparison to the baseline but, apart from one sample, did not significantly vary from the baseline conditions. Overall the total PHC content at the disposal site, apart from the one sample (0.129 mg/l; 2.6 times the Total Allowable Concentration (TAC)) did not exceed the TAC value (SakhNIRO 2005).

SSC was significantly raised at the disposal site in comparison with recorded background levels (0.7-3.7mg/l, October 2004) in December 2004. Recorded SSC in and around a 300m radius of the disposal site varied from 12-35mg/l. The maximum concentration of suspended sediment was observed in near-bottom waters at all monitoring points:

- 300m to the east– 35.4 mg/l;
- In the centre of the disposal site – 33.9 mg/l;
- 300m to the west – 20.5 mg/l.

Recording of SSC is not instantaneous for all monitoring points during and following the disposal process due to the difficulties in sampling from a number of points during actual disposal.  But the data do show that SSC is raised, although not as high as predicted levels, during disposal in comparison with the baseline situation. On the basis of the monitoring data, there does not appear to be any correlation between SSC and distance from the point of disposal, as would be expected. This probably relates to a number of factors but may be due to the fact that the sediment plume created from an individual disposal event varies in extent and location depending on the hydrodynamic conditions. It should be noted that the monitoring programme has been altered for 2005 onwards to include additional monitoring points up to 2km away from the disposal site (see Appendix B).

**Table 12.7 Recorded SSC levels and PHC from monitoring work at the disposal site in Aniva Bay. Shaded columns represent measurements taken during disposal operations. Non-shaded columns represent baseline conditions.**

| Station | Depth (m) | Aug 2003 SSC mg/l | Oct 2003 SSC mg/l | Oct 2004 SSC mg/l | Dec 2004 SSC mg/l | Aug 2003 PHC mg/l | Oct 2003 PHC, mg/l | Oct 2004 PHC, mg/l | Dec 2004 PHC, mg/l |
|---|---|---|---|---|---|---|---|---|---|
| Centre of Disposal site | 0 | 5.9 | 2.96 | 2.1 | 11.9 | 0.006 | 0.082 | 0.017 | <0.005 |
| | 5 | 5.1 | | | | 0.017 | | | |
| | 10 | 2.1 | | | | 0.049 | | | |
| | 20 | <2.0 | 3.67 | 0.7 | 11.4 | 0.010 | <0.005 | 0.007 | 0.023 |
| | 50 | 3.2 | 5.96 | 3.7 | 33.9 | 0.025 | 0.007 | <0.005 | 0.020 |
| 300 m off the centre to the west | 0 | <2.0 | 6.96 | 1.4 | 15.4 | <0.005 | <0.005 | 0.008 | <0.005 |
| | 20 | 2.4 | 4.48 | 0.8 | 12.0 | 0.022 | <0.005 | <0.005 | 0.018 |
| | 50 | <2.0 | 7.04 | 3.0 | 35.4 | 0.020 | <0.005 | 0.008 | 0.129 |

| Station | Depth (m) | Aug 2003 SSC mg/l | Oct 2003 SSC mg/l | Oct 2004 SSC mg/l | Dec 2004 SSC mg/l | Aug 2003 PHC mg/l | Oct 2003 PHC, mg/l | Oct 2004 PHC, mg/l | Dec 2004 PHC, mg/l |
|---|---|---|---|---|---|---|---|---|---|
| 300 m off the centre to the east | 0 | 5.4 | 4.7 | 0.8 | 18.7 | 0.006 | 0.009 | <0.005 | 0.014 |
| | 20 | 3.13 | 4.93 | 1.1 | 15.6 | <0.005 | <0.005 | 0.010 | 0.006 |
| | 50 | <2.0 | 5.04 | 1.8 | 20.5 | 0.005 | 0.047 | <0.005 | <0.005 |

*Benthic communities*

The initial benthos monitoring program (as reported in SakhNIRO 2005a and 2005b) prior to disposal (baseline sampling in August 2003) involved data collection from three points located at the centre and at 300m, east and west of the disposal site. Monitoring continued in October 2003 (during disposal) at two locations (i.e. excluding central point in the disposal site), in October 2004 (before second dredging run) at 5 points and in December 2004 (during second dredging run), at 12 sampling points. The monitoring points have been increased during the disposal process in order to provide additional information on the impact of the operation and to compare the results with the EIA predictions.

In Appendix F1 of TEOC Vol.5, Book 9, Part 2 it was forecasted that a 100% death of the benthic community at the disposal site would occur in areas covered by >5mm of deposited sediment. This potential effect was predicted to occur in an area up to 335m from the disposal site. A preliminary interpretation of the results obtained so far suggest that the benthic community has been affected by the disposal operations, but the effect is, so far, lower than predicted.

Benthic samples collected in October 2004 at five points from the disposal area (centre, 300 m to the west and to the east, and 800 m to the west and to the east) revealed that the macrobenthos was represented by 7 species (see Table 12.8) from 4 taxonomic groups. Sipunculid worms of the genus *Golfingia* prevailed, constituting 95% of the total biomass. Two species of polychaetes contributed much (3.9%) of the remaining 5% of total biomass. The main points that can be made with respect to the monitoring findings for the sampling points at 300m from the disposal site are:

- A significant increase in the total benthic biomass in October 2004 (up to 25.96 g/m$^2$), compared to the analogous period of 2003 (8.47 g/m$^2$). This increase in biomass is attributable to an increase in the abundance of sipunculid worms as the biomass of all other groups decreased;
- A significant decrease in biodiversity for all benthic groups. In October 2004, no bivalve species were recorded although in October 2003 this group was represented by 3 species, with *Nuculana pernula pernula* being relatively common;

- Small benthic epifaunal/infaunal organisms (less than 5mm) and benthic filter feeders were found at the area adjoining the disposal site following disposal operations. For instance, the species *Eudorella emarginata, Harpiniopsis orientalis, Spionidae sp.* were still present at all locations 300m from the disposal site. This observation suggests that suspended sediment concentrations generated during disposal and associated sediment deposition have not been sufficient to cause 100% mortality of benthos within the 300m zone of the disposal site;
- Samples taken in December 2004 from four locations at 300m around the disposal site show a smaller number of species being present to the East and West of the disposal location, compared with the North and South. This is in line with the predicted dominant direction of sediment plume entrainment and deposition from the plume during the disposal process.

The difference in benthic community structure between 2003 and 2004 is somewhat difficult to explain as the samples taken in October 2003 were obtained during disposal, while the samples in October 2004 were obtained prior to the autumn-winter dredging campaign. Only two samples were taken in October 2003 and potentially the limited sampling may have misrepresented the actual relative importance of sipunculid worms in the benthic community. The results could also reflect the establishment of a sipunculid dominated, but otherwise impoverished fauna, in dredged material post October 2003, prior to any further disturbance by disposal activity.

**Table 12.8 Results of benthos monitoring from sampling points located 300m from the disposal site**

| | **Period of monitoring** | | | |
|---|---|---|---|---|
| | **Aug 2003 (baseline)** | **Oct 2003** | **Oct 2004** | **December 2004** |
| **Level of disposal activity** | **None. Baseline** | **Dredging since Sep'03** | **None.** | **Dredging since November** |
| **Number of benthonic species** | 36 | 24 | 7 | 17 |
| **Abundance (individuals/ $m^2$)** | 200 | 170 | 13 | 126.25 |
| **Biomass ($g/m^2$)** | 53,7 | 8,4 | 25,96 | 20.95 |

The results of the additional monitoring undertaken in December 2004 (see Appendix B) up to 2000m from the disposal site (i.e. outside of the zone of predicted effects) provide further information on the status of the benthic community around the disposal site. These results from the wider area show similar values to the baseline data obtained in August 2003, with 35 species recorded, an abundance of 205 individuals/$m^2$ and a biomass of 26.32 $g/m^2$. Further monitoring has been undertaken in Autumn 2005 and this data is currently being processed.

**Comparison of initial monitoring results with predicted impacts**

The data obtained through monitoring can be compared with the original modelling and predictive work undertaken as part of the environmental impact process (the input data for the modelling was based on use of a smaller cutter-suction dredger and hopper barge than now proposed) to gain both a better understanding of the level of impact and the nature of the predictions made.

For SSC during dredging for the LNG jetty, concentrations in the water of more than 100mg/l were predicted to occur up to 310m from the dredge area and concentrations of more than 50mg/l up to 550m from the site. Similarly, concentrations of more than 100mg/l were predicted up to 14m away and 50mg/l up to 37m from the dredge area for the MOF. The monitoring data obtained during the dredging operation for both the LNG jetty and the MOF indicates that SSC is significantly lower than predicted (see Table 12.3). Similarly for the disposal site, recorded SSC at the centre of the disposal area and in the surrounding area is lower (see Table 12.7) than the predicted 50-100mg/l (see Section 12.5.3).

The difference between predicted and actual SSC levels may be a function of the smaller amount (as a percentage of the total volume) of fine sediment being dredged and disposed of than originally estimated. The monitoring data therefore suggests that predicted impacts resulting from raised SSC levels at both the dredge site and the disposal area could be less than predicted. This is of particular relevance to potential impact with respect to sessile benthic fauna within the vicinity of the dredge site and benthic communities outside the immediate zone of direct disposal that could be influenced by sediment plumes arising during the disposal operation. The continued presence of small epifaunal species and filter feeders within 300m of the disposal site is probably an indication of the lower levels of SSC and possibly sediment deposition than originally predicted. The monitoring data also suggests that the levels of SSC in the water column are significantly below the levels that would cause physiological damage to pelagic or benthic fish species (see Section 12.5.2).

The generally very low PHC concentration recorded in the water column during dredging and disposal also backs up the prediction made that an adverse change in water quality resulting from dredging and sufficient enough to cause sub-lethal effects would be considered highly unlikely to occur.

*Monitoring of dredging activity*

Dredged material is transported by barge pulled by tugs to the disposal site in Aniva Bay. The Japanese tugs are equipped with GPS data loggers which record their movement through Aniva bay every minute. Each day all movements for all barges are plotted on a map (see example shown in Figure 12.10). In addition, the captain of each vessel maintains a log, which records number of trips and time of disposal. For the Russian tugs, which have now completed their work, the captain's log also records number of trips and time of disposal. All these data have been reported to SEIC.

**Figure 12.10 Map showing GPS plotted route for Japanese tug transporting barges to disposal site in Aniva Bay.**

Detailed bathymetric survey of the disposal site shows that material arising from the 2003-2005 dredging campaign was deposited within the confines of the designated disposal area. The disposal site (as of May 2005) now comprises an area of flat, sandy seabed with piles of rock and gravel up to 2.5m in height (Figure 12.11).

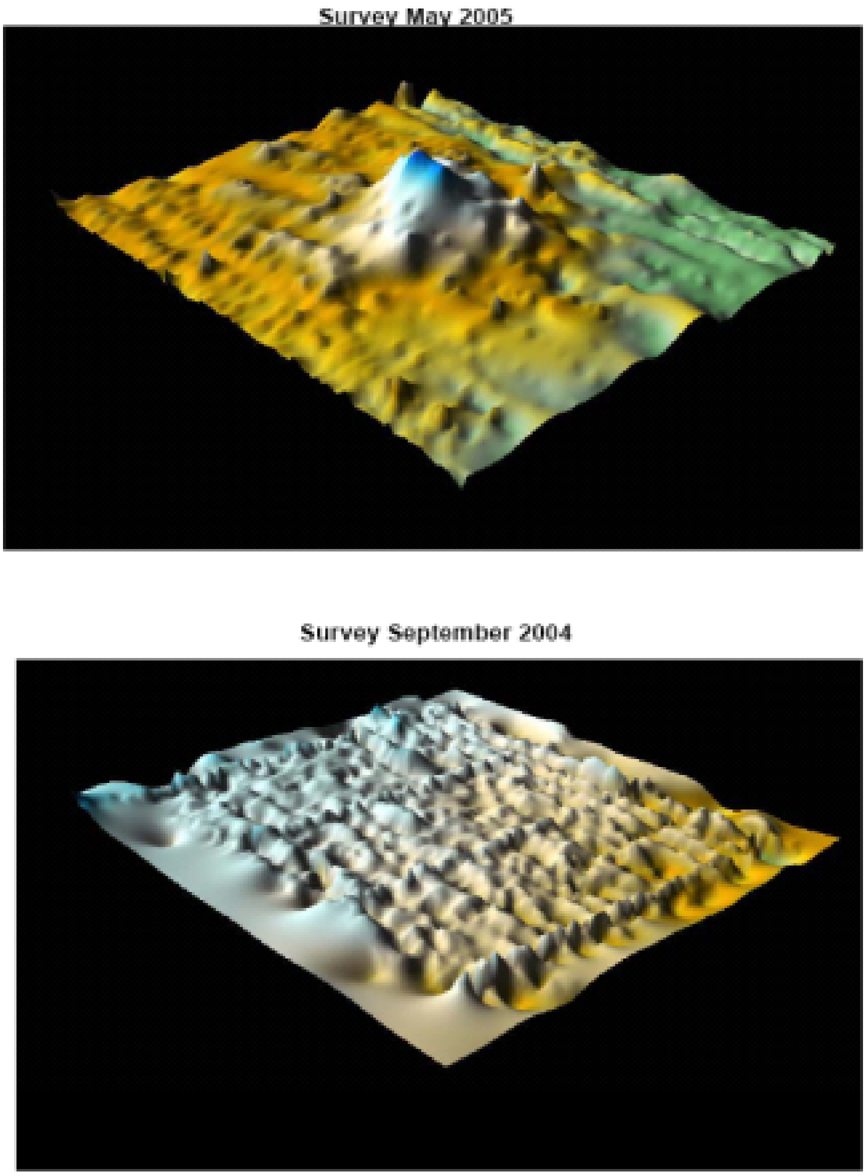



**Figure 12.11 3D representation of bathymetric data for disposal site showing accumulation of material at the site (comparison between September 2004 and May 2005).**

The first bathymetric survey of the disposal site during the disposal process was carried out in September 2004 (Pacific Engineering Co.). At this time, the study recorded only the dredged volume from the partial MOF dredging carried out in September 2003-April 2004. After completion of the MOF dredging, and during the first stage of LNG Jetty dredging (November 2004-April 2005) a further bathymetric survey was carried out (PECO, May 2005). The survey recorded approximately 220,000 $m^3$ of bulk volume disposed corresponding to 197,000 $m^3$ of gross dredged volume (bulk volume of dredged materials is always greater than gross dredged volume due to the interstitial water and air contained in the dredged material). The total partial bulk volumes found in both surveys (that excludes an approximately 10 % of dispersal fraction) were compared against the gross volumes dredged up to that moment. Results show that dredge materials were correctly disposed within the defined location as specified in the approved methodology.

## 12.8 REFERENCES

Bray, RN, AD Bates and JM Land (1997) Dredging. A Handbook for Engineers. Second Edition. *Arnold Publishing*. London, Sydney, Aukland.

Collins, K. & Jensen, A.C. (1997) Acceptable use of waste material. In European Artificial Reef Research. *Proceedings of the first EARRN conference*. March 1996, Ancona, Italy, ed. A.C. Jensen, pp. 123-140. Southampton Oceanography Centre, Southampton.

Continental Shelf Associates, Inc (1999) Environmental Report for the 1998 Characterization Survey for the Piltun-Astokhskoye Field and Two Proposed Pipelines Routes, the Lunskoye Field and One Proposed Pipeline Route, and Aniva Bay Offshore Sakhalin Island, Russia. Texas. USA.

Dickerson, C., Reine, K. J., and Clarke, D. G. (2001) Characterization of underwater sounds produced by bucket dredging operations. DOER *Technical Notes Collection* (ERDC TN-DOER-E14), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

DVNIGMI (2001) Integrated environmental observations on the continental shelf north-east, east, south and west of Sakhalin to determine background marine environment parameters at oil production platform and along offshore pipeline routes, and at other infrastructure facilities of Sakhalin II Project Phase 2. Report for SEIC.

Henderson P. (2003) In: Harbour Empowerment Order (HEO) for London Gateway. Environmental Impact Assessment. *Faber Maunsell et. al.* , for P&O Developments Ltd.

Hydrotex Company Ltd (2002) Engineering-Ecological Surveys in Korsakov Commercial Port. Volume 6. Book 4.

Kukert, H. and C.R. Smith (1992) Disturbance, colonization and succession in a deep-sea sediment community: artificial-mound experiments. *Deep-Sea Research* 39: 1349-1371.

Marlin (2004) Marine Life Information Network for Britain and Ireland. http://www.marlin.ac.uk/index.htm

Maurer, D. L., Keck, R. T., and Tinsman, J. C (1978) Vertical migration of benthos in simulated dredge material overburdens. VI. *Marine benthos*. WES-TR-D-78-35. Lewes College of Marine Studies, Delaware University.

Maurer, D., Keck, R.T., Tinsman, J.C. and Leatham, W.A (1981) Vertical migration and mortality of benthos in dredged material - Part I: Mollusca. *Mar. Env. Res*. 4: 299-319.

Maurer, D., Keck, R.T., Tinsman, J.C. and Leatham, W.A. (1981) Vertical migration and mortality of benthos in dredged material: Part II - Crustacea. *Mar. Env. Res*. 5: 301-317.

Minerals Management Service (United States) (1999) Marine aggregate mining. Benthic and surface plume study. *MMS OCS Study* 99-0029.

Morgan, R. P., V. J. Rasin and L. A. Noe (1983) Sediment Effects on Eggs and Larvae of Striped Bass and White Perch. *Transactions of the American Fisheries Society* 112: 220-224.

Murray L. *et. al*. (2003) Final report of the dredging and dredged material disposal monitoring task team. *Science Series, Aquatic Environment Monitoring Report*, CEFAS Lowestoft, 55: 53pp.

Nedwell, S. and Elliott, M. (1998) Intertidal mudflats and sandbanks and subtidal mobile sandbanks. *Institute of Estuarine and Coastal Studies*, University of Hull.

Newcombe, C.P., and Jensen, J.O.T. (1996) Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact. *North American Journal of Fisheries Management*, Vol. 16, pp. 693-727.

Newcombe C.P. and MacDonald D.D. (1991) Effects of suspended sediments on aquatic ecosystems. *North American Journal of Fisheries Management* 11, 72-82.

Newell, R.C., Seiderer, L.J. and Hitchcock, D.R. (1998) The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. *Oceanography and Marine Biology: an Annual Review* 1998, 36,127-178.

Ritchie, D. E. (1970) Fish, Chesapeake Bay Laboratory, Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. *Solomons, MD, National Resources Institute*, University of Maryland**:** 50-59.

SakhNIRO (2005a) LNG and OET facilities. Environment and hydrobiont communities monitoring for dredging (13.3). Book 1. Description of research results. Report for SEIC.

SakhNIRO (2005b) LNG and OET facilities. Supplementary Environment Monitoring for Dredging and Disposal on LNG and MOF Areas. Book 1. Description of research results. Report for SEIC.

SakhNIRO (2004b) LNG & OET facilities. Environmental Report. Environment monitoring for fisheries purposes (13.8). Book 1. Description of research results. Report for SEIC.

SakhNIRO (2004) LNG and OET facilities. Environment and hydrobiont communities monitoring for dredging, wastewater discharge and well water pipeline area. Report for SEIC.

SakhNIRO (2001a) Ecological and fisheries conditions of the Aniva Bay and preliminary calculation of possible damage to the marine biological resources from bottom dredging and excavated dumping works.

SakhNIRO (2001b) Assessment of state of fish stock of the sea waters adjoining the Eastern coast of Sakhalin (on a basis of the results of trawl–acoustic survey of 2000).

SakhNIRO (1999) Baseline Studies of the Piltun-Astokhskoye and Lunskoye Oil and Gas Fields, Subsea Pipeline Routes and Aniva Bay.

Typhoon (2002) Analysis of sea bottom soil and sediment samples. Report for SEIC, 139pp.

USACE (2003) Disposal Area Monitoring System (DAMOS) *Monitoring Survey at the Portland Disposal Site, August 2001*. Contribution 140.

Van Moorsel, G. W. N. M. (1994) The Klaverbank (North Sea), geomorphology, macrobenthic ecology and the effect of gravel extraction. *Report no. 94.24, pp.1-65. Culemborg*, The Netherlands, Bureau Waardenburg bv.

Wilber, D.H., and Clarke, D.G. (2001) Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. *North American Journal of Fisheries Management* 21(4): 855-875.

## Appendix A

### Original Environmental Monitoring Program Document No. 7000-E-90-04-P-0010-01 Fishery Environmental Monitoring Methods

The table below shows a summary of the original environmental monitoring programme for dredging and disposal based on TEOC Volume 5, Book 9, Part 1, section 13.3. It includes monitoring of physical-chemical and biological parameters, commercial species, and fish migration in local rivers.

| Impact type /controlled environment | Sites of measurement/observations | Controlled parameters/indices | Dates and periodicity of observations |
|---|---|---|---|
| **MONITORING OF DREDGING AND DISPOSAL ACTIVITIES** | | | |
| Aniva Bay – Dredging areas | In Aniva Bay, a total of sixteen monitoring stations are located in and adjacent to the dredging areas for the Material Off-loading Facility, LNG Jetty and turning area in the coastal region from 142° 53.2' E.L. to 142 56.7' E.L.<br>Six temporary stations also set up for dredging monitoring (one near the dredger, one at the boundary of the dredge area and one 250m away). | Water column (near bottom and near surface):<br>- pH<br>- Suspended sediment concentration<br>- Petroleum hydrocarbon content | Stations 1, 2, 3, 4, 10, 11, 12, 13 before, during and after dredging.<br>Stations 5 and 15, before and after dredging.<br>Six temporary stations monitored once during dredging activity. |
| | | Seabottom sediments :<br>- Particle size composition<br>- Heavy metal concentration (Cd, Cr, Cu, Fe, Pb, Mn, Zn)<br>- Oil hydrocarbons | Stations 1, 2, 3, 4, 10, 11, 12, 13, 15 -prior to dredging of surface sediments and after dredging. |
| Aniva Bay – Dredge disposal location | The dredge disposal area is defined by a circle with a radius of 200m with the centre coordinates 46°24.5.0' NL and 142°55.0' EL (approx 12 nautical miles from shore, opposite the LNG plant).<br>One sampling point set up at the site centre and two sampling points at 300 m at east and west of disposal site. | Water column (near bottom, midcolumn and near surface):<br>- pH<br>- Suspended sediment concentration<br>- Petroleum hydrocarbon content | Centre before and after disposal.<br>300 m at 1 point located downstream the current, and 1 point upstream the current, before, during and after. |
| | | Sea bottom sediments:<br>- Particle size<br>- Heavy metal concentration (Cd, Cr, Cu, Fe, Pb, Mn, Zn)<br>- Oil hydrocarbons | Centre before and after disposal.<br>300 m at east and west before, during and after. |

| Impact type /controlled environment | Sites of measurement/observations | Controlled parameters/indices | Dates and periodicity of observations |
|---|---|---|---|
| | | Benthos<br>- Species composition, biomass and abundance. | Centre before and after disposal.<br>300 m at east and west before, during and after. |
| **MONITORING OF IMPACT ON COMMERCIAL AND NON COMMERCIAL SPECIES IN ANIVA BAY** | | | |
| Aniva Bay –Commercial invertebrates | Aniva Bay, in the coastal region from 142° 53.2' E.L. to 142 56.7' E.L. at 10 selected zones adjacent to LNG Jetty and MOF. | Distribution of commercial invertebrates (crabs, shrimps, scallop, trepang, cucumaria, grey sea-urchin and others) using SCUBA and dredging techniques as appropriate. Sampling from Zone A or B, Zone C and Zone E, F or G at 5, 10, 15 and 20m depth. | Once a year during August 2003-2007. |
| | | Distribution of commercial invertebrates, Sampling from Zone H, I or J | Once, Aug 2003. |
| Aniva Bay – Benthos | As above. | Species composition, structure of benthic communities (fauna and flora) and their distribution<br>Sampling from Zone A or B, Zone C and Zone E, F or G at 5, 10, 15 and 20m depth | Once a year during August 2003-2007. |
| | | Species composition, structure of benthic communities (fauna and flora) and their distribution. Sampling from Zone H, I or J | Once, Aug 2003. |
| Aniva Bay –Commercial fish populations in coastal zone | As above. | Species composition and abundance of commercial fish species such as herring, capelin, anchovy and juvenile salmon.<br>Sampling from Zone A or B, Zone C and Zone E, F or G at 0-4m and 10-15m using seine net and small trawl. | Once in Aug 2003 and twice a year during May and Aug 2003-2007 |
| | | Species composition and abundance of commercial fish species such as herring, capelin, anchovy and juvenile salmon. Sampling from Zone H, I or J. | Once, Aug 2003. |
| Aniva Bay – Spawning grounds of commercial fish species | As above. | Examination of sediments in coastal zone to determine presence of capelin and capelin eggs. Sampling from Zones D, E, F, G, H and I. | Once every June 2003-2007 |
| | | Examination of suitable habitat in coastal zone to determine presence of herring and herring eggs. Sampling from Zone J. | *Once every June 2003-2007* |

| Impact type /controlled environment | Sites of measurement/observations | Controlled parameters/indices | Dates and periodicity of observations |
|---|---|---|---|
| Aniva Bay – Phytoplankton and zooplankton | As above. Also:<br>- effluent discharge point<br>- disposal site, defined by a circle with a radius of 200m with the centre coordinates 46°24.5.0' NL and 142°55.0' EL (approx 12 nautical miles from shore, opposite the LNG plan. | Plankton species and abundance in water column (near surface and bottom) in the LNG/MOF dredge area (stations 1, 3, 5, 10, 12 and 15) and at the disposal site (phytoplankton at water depths of 0, 5, 10, 20 and 50m; zooplankton at 0-10m and bottom 10m). | Twice – prior to and after dredging |
| Aniva Bay – Ichthyoplankton | As above | Fish species and abundance in water column in the LNG/MOF dredge area (stations 1, 3, 5, 10, 12 and 15) and at the disposal site. | Twice – prior to and after dredging |
| Aniva Bay – Bacterioplankton | As above | Presence and abundance in water column (near surface and bottom) in the LNG/MOF dredge area (stations 1, 3, 5, 10, 12 and 15) and at the disposal site at water depths of 0, 5, 10, 20 and 50m. | Twice – prior to and after dredging |
| Aniva Bay –Chlorophyll a estimate and primary production | As above | Measurements from water column (near surface and bottom) in the LNG/MOF dredge area (stations 1, 3, 5, 10, 12 and 15) and at the disposal site at water depths of 0, 5, 10, 20 and 50m. | Twice – prior to and after dredging |

| **Impact type /controlled environment** | **Sites of measurement/observations** | **Controlled parameters/indices** | **Dates and periodicity of observations** |
|---|---|---|---|
| Aniva Bay - Toxicological study of commercial invertebrates and commercial coastal fish species | As above | Tissue samples from muscle, gonads and other organs (e.g. liver) of sea-urchin, scallops and representative coastal fish species. Samples to be sourced from Zone C at depths of 2, 5, 10 and 20m.<br>**Parameters to be measured include oil hydrocarbons, chloro-organic compounds and heavy metals; Hg, Cr, Pb, Cd, Cu, Zn, Mn, As, Ba, Fe.** | Once every Aug 2003-2007. |
| | | As above – Sample selected from Zone C, D, E, F, G, H, I or J | Once in Aug 2003 |
| Aniva Bay – Fish migration and spawning (Mereya River) | Two permanent stations located at 500m and 3000m (spawning ground) upstream from river mouth. | Assessment of quantity of downstream migrant juvenile salmon (mainly Pink Salmon) and assessment of quantity of breeding salmon entering during spawning and degree of occupancy of spawning grounds. | Salmon migration – up to 17 times each year covering the period May-September (adult and juvenile migration). Spawning ground monitored up to October each year. |
| Aniva Bay – Fish migration and biota (Goluboy Brook) | Four permanent stations located at the following points:<br>• 500m upstream from river mouth,<br>• 1050m (30m downstream of the oil pipeline crossing) and<br>• 1850m (30m downstream the bridge crossing).<br>• 2000m upstream from the river mouth (upstream both the bridges) will be the check station.<br>Additional observation stations were established for the baseline monitoring located at 800m, 1000m and 1500m from the river mouth. | • Species composition, quantity and biomass of phytoplankton<br>• Composition and quantity of microheterotrophs<br>• Species composition, quantity and biomass of zooplankton and drift<br>• Species composition, structure of communities and distribution of benthos<br>• Species composition, quantity and distribution of ichthyofauna<br>• Assessment of quantity of downstream migrant juvenile salmon (mainly Pink Salmon) at station 500m from the mouth of the river<br>• Assessment of quantity of breeding salmon entering during spawning and degree of occupancy of spawning grounds | Once every August 2004-2007 for plankton and benthos.<br>Salmon migration – up to 17 times each year covering the period May-September (adult and juvenile migration). Spawning ground monitored up to October each year. |

| Impact type /controlled environment | Sites of measurement/observations | Controlled parameters/indices | Dates and periodicity of observations |
|---|---|---|---|
| MOF – Fish passes | Adjacent to fish tunnels located at the MOF jetty. | Usage of the fish tunnels by commercially valuable fish species, notably pink salmon, and other fish species in the MOF area.<br>Distribution and movement of other fish species at the MOF area. | 8 times during late July to mid-September.<br>Two observations during a 24hr period to cover day/night<br>Covering a 5-year period from July 2004.<br>The beginning of observations can vary due to a periodicity of a low and high tide current. |

## Appendix B

### Addendum of Monitoring Program for 7000-E-90-04-P-0010-01 Fishery Environmental Monitoring Methods

With regard to approval from MNR Federal Service for Environmental Supervise (Dated 8 October, 2004 / No. BB-03-47-534), the following additional environment monitoring shall be carried out, in addition to the initial monitoring program (see Annex A), to fulfil the requirement for dredging and dumping of sediment from the MOF and LNG Jetty.

| Requirement | Explanation | Location | Frequency | Parameter |
|---|---|---|---|---|
| To arrange carrying out of hydrobiological monitoring in the areas of dredging and soil dumping during execution of works and after their completion for the purpose of defining the accepted forecast assessments of damage from the level of affection of marine life in the water with diverse concentration of suspended particles, and about the process of recovery of the destroyed or formation of new biocenosis in the area of dredging and disposal. | Mobile hydrobionts are not suitable to monitor for Project influence. Therefore sessile benthos is selected as the direct receptor of the impact caused by sedimentation.<br>Other organisms are covered as part of the environmental monitoring in line with TEO-C Volume 5, Book 9, Part 1, Section 13.8. monitoring. To include effect of Current, Salinity change and Thermocline, four directions and three depths need to be considered. | 300, 800 & 2000m from centre of dumping area on:-<br>North<br>South<br>East<br>West<br>Total = 12 sampling point | Before=2003/08<br>During=2004/11<br>After= 2005/08<br>2006/08<br>2007/08<br>Total = 5 times | Benthos |
| | In case more than 50 mg/l of suspended solid exist Zooplankton will be affected. | 400 & 800m from centre of dumping area on:-<br>North<br>South<br>East<br>West<br>Total = 8 sampling point | Just before dumping<br>During dumping<br>Total = 2 times | Zooplankton |
| To carry out additional research of bathymetric distribution of and concentration of:-<br>Chlor-organic compounds<br>Oil hydrocarbons<br>Aromatic polycyclic hydrocarbons<br>In the soils designated for dredging. | Sea bottom consists of thin layer of loose soil and thick layer of Rock soil.<br>Dredging will carried out by a grab dredger and target depth will achieved by one grab. | MOF dredging area shall divided in three (3) zones.<br>Point-14<br>Point-16<br>West of Point-11<br>Total = 3 points | Before dredging (Surface Layer) 2004/10<br>During dumping (Rock layer) 2004/11<br>Total = 2 times | Chlor-organic compounds<br>Oil hydrocarbons<br>Aromatic polycyclic hydrocarbons |

| Requirement | Explanation | Location | Frequency | Parameter |
|---|---|---|---|---|
| | | LNG Jetty dredging area shall be divided into five (5) zones.<br>Point-5<br>Point-6<br>Point-7<br>Point-8<br>Point-9<br>Total = 5 points | Before (Surface) 2004/10<br>During 2005<br><br>Total = 2 times | |
| To define the actual location of boundaries for the zone of diffusion of suspended particles for verification of the forecasted data. | To include effect of Current, Salinity jump and Thermocline, four directions and three depths need to be considered. | 400, 800, 1200, 1600 & 2000m from centre of dumping area on:-<br><br>North<br>South<br>East<br>West<br>Near surface<br>Medium<br>Near bottom<br><br>Total = 20 sampling point | Just before dumping<br>During dumping<br>Total = 2 times | Suspended Particles |
| **Requirement** | **Explanation** | **Location** | **Frequency** | **Parameter** |

| **Requirement** | **Explanation** | **Location** | **Frequency** | **Parameter** |
|---|---|---|---|---|
| To determine the diffusion of actual concentration of<br>Oil hydrocarbons<br>Aromatic polycyclic hydrocarbon<br>Heavy metal (HG, Cd and Pb)<br><br>On the boundaries of soil dump by the depth, also near the boundary of water density jump. | To include effect of Current, Salinity jump and Thermocline, four directions and three depths need to be considered. | 400m from centre of dumping area on:-<br><br>North<br>South<br>East<br>West<br>Near surface<br>Medium<br>Near bottom<br><br>Total = 12 sampling point | Once a month during dumping.<br><br>2004/11<br>2004/12<br>2005 = 4 months<br><br>Total = 6 times | Oil hydrocarbons<br>Aromatic polycyclic hydrocarbon<br>Heavy metal (HG, Cd and Pb) |
| On the water area adjacent to the dumping area not to allow the violations of fishery regulations concerning the excess of concentrations of suspended particles and pollutants over the natural values. | | 1200m from centre of dumping area on:-<br>North<br>South<br>East<br>West<br>Near surface<br>Medium<br>Near bottom<br><br>Total = 12 sampling point | Once a month during dumping:<br><br>2004/11<br>2004/12<br>2005 = 4 months<br><br>Total = 6 times | Suspended Particles |