DREDGINGS DISPOSAL IN THE HAURAKI GULF

FINAL REPORT OF THE TECHNICAL REVIEW PANEL

Office of the
PARLIAMENTARY COMMISSIONER FOR THE ENVIRONMENT
Te Kaitiaki Taiao a Te Whare Pāremata

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Preface

Every port company is faced with the problem of where to dispose of spoil from maintenance dredging operations. Dredging is essential to maintain safe navigable depths for port operations but where dredged mud and sand is contaminated with urban pollutants their disposal can pose a threat to coastal ecosystems.

The proposal to dredge material from the Auckland port in 1992 caused concern partly because of the transfer of potentially contaminated sediment to a new disposal site in the Hauraki Gulf and partly because the initial application was for a combination of maintenance and a very large capital dredging programme. The effects on the Hauraki Gulf environment were expected to be detrimental.

Due to the concerns expressed by the public and iwi, consent was given for initial maintenance dredging to the Ports of Auckland Ltd with the condition that a rigorous monitoring programme to assess the effects of disposing of the spoil should be carried out. An independent review of the monitoring programme was suggested in order to allay public doubts as to whether the monitoring programme would be effective and impartial, given that the regulator, the Auckland Regional Council, is a shareholder in the Ports of Auckland Ltd.

Little is known about the seabed or the coastal ecosystem in some of our busiest harbour areas. The monitoring programme, as determined by the Planning Tribunal, has increased our knowledge of the Hauraki Gulf. However, not all of the monitoring programme was essential given the potential threats. Future monitoring programmes will benefit from the lessons learnt in the Hauraki Gulf study.

It is of some concern that recent advice from a Ports of Auckland Disposal Advisory Group has recommended dumping future dredge spoil in water of more than 100m depth. This will preclude any ability to monitor what happens to the spoil. Capital dredging of sand is not likely to be of concern but monitoring what happens to contaminated muds should always be a responsibility for port companies.

The establishment of the Technical Review Panel by my Office has not only assisted the Auckland Regional Council and the Ports of Auckland Ltd but the Panel has provided advice on dumping guidelines for New Zealand. Such guidelines would assist all port companies in New Zealand to establish with some degree of certainty the fate and possible effects of dumped spoil so that changes in our coastal environment can be managed to avoid degradation.

Helen R. Hughes

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Parliamentary Commissioner for the Environment

Contents

1. Introduction

1.1 Background

Ports of Auckland Ltd (POAL) applied to the Auckland Regional Water Board in 1990 for water rights to dredge the port and dispose of the spoil at a new disposal site in the Hauraki Gulf. Maintenance dredging of approximately 40,000 m^3 per annum is required by the Auckland port. Because the port had not been dredged for five - six years, a backlog of 270,000 m^3 of harbour sediment had accumulated.

The applications for water rights to dredge the port and to dispose of the dredged material were made under the Water and Soil Conservation Act 1967. The decision by the Auckland Regional Water Board to grant the water rights subject to conditions was appealed to the Planning Tribunal in 1991. The Planning Tribunal's decision,[1] in December 1991, upheld the water rights.

Special Conditions 11 and 12 of the water right established the monitoring programme for the disposal of dredged material. Condition 11 is:

That the Grantee shall carry out a monitoring programme as specified in Appendix C. The physical and biological monitoring shall be carried out monthly during disposal activities and 6 monthly for the balance of the water right, provided that bioaccumulation monitoring shall be carried out at the end of disposal activities and six monthly for the rest of the term of the right. Chemical monitoring shall be carried out every 12 months during the term of the water right. All results and interpretation except those which relate to the analysis of synthetic organic chemicals shall be forwarded to the Council within two months of completion of each monthly, 6-monthly or 12-monthly programme. Results and interpretation of the synthetic organics chemical analyses shall be forwarded to the Council within four months of completion of the 12-monthly programme.

Condition 12 is:

That prior to the commencement of discharge at the site, a baseline survey shall be carried out, at the standard, additional and bioaccumulation sites specified in Condition 11, which is sufficient to permit the detection of post-disposal change in physical, chemical and biological parameters at the respective statistical levels specified under Condition 11. Samples collected from additional sites may be archived for later analysis if post-disposal examination at these sites is triggered as described under Condition 11.

Condition 18 required the Grantee to undertake a water quality monitoring programme in respect of The Noises Islands as specified in appendix D of the water right.

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1 New Zealand Underwater Association Incorporated and Maruia Society Incorporated v The Auckland Regional Council and Ports of Auckland Ltd. Decision No a 131/91. Planning Tribunal.

The dredging operation commenced in August 1992 and was the focus of public concern and extensive media coverage.

1.2 Establishment of the Panel

The Parliamentary Commissioner for the Environment consulted with Ports of Auckland Ltd, the Auckland City Council and the Auckland Regional Council to seek a way to address some of the issues causing public concern. The Commissioner suggested to the public authorities that the establishment of an independent technical review panel could be a suitable mechanism to ensure that the public of Auckland had confidence in the monitoring programme and its ability to evaluate the environmental effects of the dredgings disposal.

Both the Ports of Auckland Ltd and the Auckland Regional Council supported the formation of a panel with Ports of Auckland Ltd making a substantial financial contribution. The Commissioner established the Panel under the Environment Act 1986 in February 1993.

The Commissioner consulted widely among the scientific community in New Zealand and Australia for people to participate in a panel. The disciplines required were: physics of the coastal marine environment including sediment transport processes, marine chemistry and marine biology. The people chosen were:

- Dr K. Black. Formerly Principal Research Scientist, Victorian Institute of Marine Sciences, Melbourne, Australia; presently NIWA Research Professor, Earth Sciences Department, University of Waikato, Hamilton;
- Dr K. Hunter. Professor of Chemistry, University of Otago, Dunedin;
- Dr K. Probert. Lecturer, Department of Marine Science, University of Otago, Dunedin.

1.3 Terms of reference

The terms of reference of the Technical Review Panel were to:

1. Review the results of the monitoring programme.
2. Note any appropriate modifications and additions that should be included in future monitoring programmes by identifying any missing objectives and reviewing the methodology of the existing monitoring programme.
3. Report findings to the Parliamentary Commissioner for the Environment, Ports of Auckland Ltd and the Auckland Regional Council.

The questions to be answered for the regulatory agency through these terms of reference were:

- Within the framework established by the existing discharge consent, what conclusions do the results of the monitoring programme allow about the environmental effects of the disposal operation in the Hauraki Gulf?
- Does the general scope of the existing monitoring programme adequately address the full range of environmental effects related to the disposal of dredged material at the Hauraki Gulf site?
- How much monitoring is actually needed to assess the environmental effects of dredgings disposal in the Hauraki Gulf?
- Is the detailed methodology of the monitoring programme (including such aspects as sampling strategy, selection of control sites, trigger levels, statistical analyses) robust enough to allow clear identification of these environmental effects?

The Panel met in Auckland on three occasions. After the meeting in February 1993 the first Panel report was published (Parliamentary Commissioner for the Environment, August 1993). The second meeting, in August 1993, one year through the two year monitoring programme, was reported in the second report (Parliamentary Commissioner for the Environment, February 1994). This final report evaluates the overall monitoring programme from August 1992 to August 1994. Copies of the first and second reports are included as appendices 1 and 2.

1.4 Design of the monitoring programme

The objective of the programme was to verify that no unacceptable environmental effects resulted from the disposal operation. In particular, the monitoring programme has tried to assess the nature of the effects on Hauraki Gulf biota, sediments and water quality as a result of the dredgings disposal.

The programme included both baseline assessments at a sensitive marine environment, The Noises Islands (3 km due south of the disposal site), and at a "control" site, Tiritiri Matangi Island (due west of the disposal site).

The statistical design of the monitoring programme at the disposal site provided for the establishment of standard sampling locations. It stipulates that where a statistically significant difference for any parameter is detected between pre- and post-disposal mean values at the standard sites, then sampling for that parameter is to be carried out at additional sites.

The initial design of the monitoring programme was based, in part, on the premise that the disposal site was a containment site. This issue had been extensively canvassed at the Planning Tribunal hearing. The Judge had concluded, on the basis of expert evidence presented to the Court, that measurable accumulations of sediment would not occur beyond the site. Most of the sediment was expected to be retained at the disposal site.

Thus the monitoring programme was established around the perimeter of the disposal site and tests which would identify the presence and impact of "bedload" drifts of sediment off the spoil ground into the surrounding seabed were put in place. The monitoring programme was not designed to track the movement of the fine components of the dredge spoil accurately.

Physical monitoring around the disposal site included:

- a bathymetric survey of the disposal site and surrounding seabed;
- an analysis of sediment samples for particle size and presence of man-made materials, eg pieces of plastic, paint fragments.

Biological monitoring around the disposal site included:

- analysis of samples of benthic biota for total abundance and biomass of all macrofauna;
- bioaccumulation testing of scallops for stated contaminants between the disposal site and The Noises Islands.

Chemical monitoring around the disposal site included:

- analysis of samples for stated metals and organic carbon content and comparison with pre-disposal samples.

Water quality monitoring was undertaken at sites close to The Noises Islands and Tiritiri Matangi Island.

The conditions of the water right are in appendix 3. The monitoring programme is also described in the publication *Immediate Maintenance Dredging 1992 Monitoring Programme.* (Prepared for Ports of Auckland Ltd by Beca Carter Hollings and Ferner, November 1992, along with time lines for the implementation.)

1.5 Additional studies

The POAL undertook additional monitoring programmes beyond those required by the water right. These have provided a much better understanding of the site and of the dispersal of the sediment plume during the disposal operation. In each case, the technology adopted has been recommended by dredge spoil specialists and the Panel is satisfied that the techniques were appropriate.

The Panel has regarded these extra studies as part of the monitoring programme for evaluation purposes. They included:

- use of the REMOTS® camera to undertake a detailed photographic inspection of the mound to assess recolonisation; and
- tracking of sediment plumes during disposal of the dredged material using acoustic (colour enhanced) depth sounders to depict the plume.

These studies have greatly assisted the Panel. Some changes to the programme have been made, as allowed for in the resource consent, including the adoption of Panel recommendations (refer appendix 3).

2. Results of the Monitoring Programme

At each meeting, the Panel appraised the results of the monitoring programme carried out to that time. The preliminary appraisal is contained in the Panel's first report (appendix 1). The appraisal of the first year's monitoring programme is contained in the Panel's second report (appendix 2).

At the Panel's final meeting in November 1994, conclusions on the ability of the two-year programme to assess the environmental effects of dredge spoil disposal were discussed. The Panel's view is that the monitoring programme has been undertaken to a thorough and high standard. The POAL has been assiduous in its facilitation and support of the programme.

2.1 Biological monitoring

Overall, the programme of biological monitoring has been well carried out. The consultants have been duly attentive to the requirements of the water right and have been careful to ensure that the monitoring has been undertaken rigorously.

Results of the monitoring programme indicate that the disposal operation has had no significantly deleterious effects on the sediment benthos adjacent to the disposal site and that the recorded differences in species richness and abundance can be attributed to natural variability. Furthermore, benthic sampling *within* the disposal site, whilst not required by the water right, has demonstrated that there has been rapid rehabilitation of the macrobenthos and that the seabed community at the disposal site now closely resembles that which occurred before.

Following a seabed disturbance, whether natural or man-made, there ensues a usually well-defined pattern of response, or successional sequence. The first macrobenthic species to recolonise are often small opportunistic polychaete worms living in the uppermost layers of sediment. In the absence of further disturbance, these early pioneer species are replaced and the community gradually attains a relatively more stable constitution characterised by larger, longer-lived species that burrow more deeply. In this part of the Hauraki Gulf the mature macrobenthic community of the fine sediments is one characterised by burrowing brittlestars and heart urchins. Results of sampling within the disposal site during the first post-disposal survey (April-May 1993) indicated that the species typical of this late stage of succession had already re-established.

Rapid benthic recovery was shown also by a survey of the disposal site completed in March 1993 using the REMOTS® sediment-profiling camera in which the species characteristic of the mature low-disturbance community were found at nearly all stations.

In the bioaccumulation monitoring, some significant differences in concentrations of trace elements and organic compounds were detected between sites and over time. However, there did not appear to be differences attributable to effects of disposal. Although there was evidence that concentrations vary widely, the baseline data provide no indication of the temporal magnitude of this variability.

2.2 Physical monitoring

The physical studies have been properly carried out by the consultants. Some questions, however, about the adequacy and the overall scope of the programme are raised later.

The physical monitoring undertaken was bathymetric surveys to determine the location and height of the disposal mound after disposal, grain size analyses and intermittent water sampling for turbidity at the control site and The Noises. Chemical techniques were used to trace the possible drift of sediment from the disposal site into the immediate surrounds. These techniques were:

- sampling at sites around the disposal mound for man-made objects;
- monitoring of sediments surrounding the disposal site for organic and inorganic chemicals; and
- monitoring of trace metal and organic compounds in shellfish samples around the disposal site, ie bioaccumulation monitoring.

The analysis of the man-made objects recovered from the sites experienced inherent difficulties in operator identification of micro-scale man-made objects. However, the other techniques yielded good information on the impacts of the disposal. Chemical monitoring is discussed in section 2.3 and bioaccumulation monitoring in section 2.1.

The last major survey (see table 1, pp 36-37, for surveys conducted) undertaken in May 1994 (Survey Four) included two bathymetric surveys of the disposal mound and the surrounding area. After consolidation and some losses of fine sediment from the region adjacent to the mound, the bathymetric surveys appear to indicate that the spoil ground may now have stabilised, suggesting that elevated turbidity on the site would be no longer occurring. Losses of sediment during disposal and the subsequent potential for loss during the consolidation phase would be expected but the large magnitude of the loss was not predicted by the consultants prior to the disposal operation.

The cause of the loss of sediment from the site has been attributed to a larger than expected water content in the dredge spoil, associated with the operation of the dredge[2]. Measurements after disposal showed that the fluidised sediment spread over a much wider region than expected. The evidence at the Planning Tribunal predicted that the spoil would form a mound some 9 m high. After horizontal spreading, the mound actually extended 0.9 m above the natural sea floor bottom. With a high fluid

[2] P. Kennedy. pers comm, 1994.

content, spoil is more easily lost during disposal and more easily re-entrained by storms during the compaction period.

The consultants for the POAL suggested to the Panel than an inability to more accurately determine the datum for the bathymetry surveys resulted in depth errors of order ± 0.3 m. Consequently, the value of the surveys was lessened and more care with the datum would improve future studies. Sediment concentrations were recorded intermittently at the control site and The Noises Islands. Large variations in turbidity, which were presumably mostly natural, were observed. It is necessary to interpret such measurements if they are to be of benefit to the monitoring programme; they otherwise have very little value.

2.3 Chemical monitoring

Overall, the quality of the chemical analysis carried out in this monitoring programme has been excellent. Both consulting laboratories used have good reputations for quality control and the Panel is satisfied with in-house procedures used for replication of analyses and control of sample identification. Sample collection, which was under the control of POAL's consultants, was also adequate to the task.

Chemical components that are enriched in the sediments dredged from the port relative to the original disposal site sediments were used as *tracers* for possible post-disposal movement of sediment off the site. Both trace metals and trace organic chemicals were used in this monitoring programme. The trace organics are the more sensitive chemicals to use.

The situation with respect to DDT, the most sensitive tracer, is equivocal at this point in time and more work is being undertaken by the POAL consultants as required by the water right. Very low concentrations of DDT were found at the test sites around the disposal zone prior to disposal (0.10 ± 0.06 ng/g, n = 9)[3].

The results of Survey Three (the first post-disposal measurements of sediment chemistry, undertaken in April-May 1993) showed DDT levels within the pre-disposal guideline at the sites south and west of the disposal zone, but slightly greater than the guideline at the northerly site. As a consequence, POAL's consultants suggested that the results for DDT be confirmed by further measurements during Survey Four.

The Survey Four (May 1994) results showed exceedence of the pre-disposal guideline (0.24 ng/g) at three sites south of the disposal zone and one control site to the west. The exceedence was caused, in each case, by an elevated concentration (typically 1-2 ng/g) in a single sample in each of the clusters. The isomer distribution for these anomalous samples showed a preponderance of the parent DDT isomer, rather than the more usual metabolic breakdown products found in the marine environment. Although the possibility of inadvertent sample contamination during collection, handling and analysis of the sediments cannot be ruled out,

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3 Ports of Auckland Ltd. Environmental Studies Report 13. Physical, chemical and biological characteristics of sediments from the Hauraki Gulf disposal site. Prepared by Kingett Mitchell & Associates Ltd.

the Panel believes the data are reliable. A hypothesis has been made that the preponderance of parent DDT isomer suggests the presence of pellicular forms of DDT that are resistant to microbial breakdown in these sediments.

During Survey Four, eight sediment samples were taken inside the disposal zone itself (in accordance with appendix C, 4ii of the water right). The DDT results for these samples show considerable variation from that expected from pre-disposal assessment of the port sediments: 68, 4.3, 3.2, 4.9, 360, 35, 106 and 15 ng/g for samples 4/93 through 4/100 respectively. These are to be compared with values 9.6 ± 1.1 ng/g (n = 13) for the dredged port sediments (see footnote 4). In this earlier study, only one sample of 13 had a total DDT concentration exceeding 15 ng/g, whereas only three of eight samples taken from the disposal zone are below this level. More importantly, half of the disposal zone samples have DDT concentrations that vastly exceed the pre-disposal mean of 9.6 ng/g for the dredged port sediments (viz 35, 68, 106 and 360 ng/g).

During Survey Three (April-May 1993), at which time the chemical composition of the disposal zone was first examined, similarly high total DDT concentrations were found in some samples within the disposal zone (39.8, 397 ng/g) and in some sites to the west of the disposal zone (30.6, 22.2, 36.0 ng/g). These differences are far too great to arise from normal statistical variations. In addition, most of the DDT in the aforementioned four samples is present as the parent isomer p,p DDT, as with the enhanced samples outside the disposal site.

It seems clear that the pre-disposal assessment of the port sediments was inadequate for DDT and that the true concentration of this component was, in reality, much higher. The arithmetic mean for the eight samples collected in the disposal zone is 75 ng/g, while a mean of 34 ng/g is obtained by combining these results with the 13 pre-disposal results. In either case, the concentrations well exceed the Puget Sound screening level (SL) of 6.9 ng/g, and may exceed the comparable maximum level (ML) of 69 ng/g, that were used as the benchmark for Level 1 assessment [4].

It is difficult to avoid the conclusion that the DDT data do provide evidence for some movement of spoil material outside the disposal zone. However, the extent of this movement cannot be great. Firstly, it is likely that pellicular forms of solid DDT (perhaps in its original physical form) may be transported more readily than heavier, mineral-containing sediments. Secondly, if the true mean level is more like 75 ng/g, then the adopted guideline would be exceeded in a 60 mm sediment core section if only 0.1 mm of the sediment depth arose from dispersed dredge spoil.

The Panel agrees that, although the DDT data have many unsatisfactory features, they still allow for the conclusion that the disposal mound has not substantially shifted into any of the adjacent test sites.

A more important question is whether the concentration levels of DDT revealed by Surveys Three and Four are, by themselves, of concern? In

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4 Ports of Auckland Ltd. Environmental Studies Report 12. Suitability of maintenance dredgings from the Port of Auckland for marine disposal. Prepared by Kingett Mitchell & Associates.

Report 12 (as cited on page 8), a maximum of 16.1 ng/g total DDT was reported for port sediments (Wynyard Wharf), which slightly exceeded the screening guideline of 6.9ng/g. On this basis, elutriate and biological testing was carried out (Levels 2 and 3). It was concluded from this work that the sediments posed no significant threat.

However, the latter assessment may have been deficient in two ways. As mentioned above, the wide variability in DDT concentrations found after disposal suggests that insufficient sample coverage was used in the preliminary assessment. Thus, those samples subjected to elutriate testing (Level 2) may not have been representative of the typical DDT levels. Secondly, the Puget Sound dredged materials assessment (PSDDA) guideline for bioaccumulation (Level 3) for DDT is 50ng/g. Since many of the samples taken in and around the disposal site have concentrations similar to, or greater than, this SL value it cannot be reliably concluded (as it was in Report 12) that bioaccumulation testing was not warranted.

Against this must be set the strong possibility that, since almost all of the DDT found in the high concentration samples comprises the parent isomer, the DDT must be present in a physical form that is resistant to biological degradation and uptake (as suggested in Report 24) [5].

2.4 Ecological monitoring at The Noises Islands

Three pre-disposal surveys to provide baseline data were carried out within the space of six-seven weeks in winter 1992, whereas the four subsequent surveys spanned a year. The data from the baseline surveys display some changes in species composition, although they probably represent only a limited range of the natural temporal variability that might be expected. Some large differences were evident over the span of the four subsequent surveys (eg in species diversity and abundance of fauna in seabed core samples between Surveys Six and Seven), but which may nevertheless be attributable to natural variation.

During much of 1992, as a result of an El Nino-Southern Oscillation event, coastal sea surface temperatures around New Zealand were unusually low relative to the long-term average due to upward vertical movement of nutrient-rich bottom waters. Such events have widespread ecological repercussions and appear to be associated with abnormal biological phenomena such as inducing algal blooms, possibly in part because cooler temperatures and weaker stratification facilitate vertical mixing of seawater. The report for Survey Seven[6] discusses the 1992-93 algal bloom off the north-east coast of New Zealand and its potential significance in affecting benthic communities.

Interpretation of these results is difficult, in view of the potential effects of natural large-scale oceanographic events on the biological communities.

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5 Ports of Auckland Ltd. Environmental Studies Report 24. Monitoring of the Hauraki Gulf Dredgings disposal site - Survey Three. Prepared by Kingett Mitchell & Associates, August 1993 (draft).

6 Ports of Auckland Ltd. Environmental Studies Report 27. Noises Ecological Monitoring - Survey Seven. Prepared by Kingett Mitchell & Associates, May 1993.

2.5 Information from revised Condition 11

The Panel suggested modifications to Condition 11 in their second report (refer appendix 2). The revised Condition 11, dated 11 April 1994, is given in appendix 3.

The review of Condition 11 not only deleted some monitoring requirements but also introduced supplementary monitoring to provide information about the nature of the mound, in particular the degree of fine sediment loss and the ability of fauna to survive the disposal operation and to burrow to the mound surface.

Erosion pins

In order to gain a better understanding of changes in the height of the disposal mound, the Panel suggested that a series of sediment accretion/erosion pins be installed into the mound. While recognising that the bulk of the mound erosion was likely to have occurred already during the consolidation phase, the pins offered a non-technical, inexpensive method to measure bottom level changes. These were added to the programme after POAL's consultants were unable to define the datum of the bathymetry surveys effectively. No other bed level monitoring had been included in the monitoring programme. Unfortunately, practical problems of locating the pins and unsuitable weather to take boats to the site from November 1994 to January 1995 hampered information collection.

Core sediment analysis

A series of cores was collected from the disposal site in November 1994. The sediment cores were analysed for both lead and zinc at different depth levels, including recently deposited natural sediment (0-1 cm), and depths above and below the seabed before disposal. The latter position was identified by x-ray examination of the core.

The results for Zn and Pb showed, as expected, elevated levels of both metals in the dredge spoil material above the original seabed. Results for Zn were quite variable, suggesting that the dredged sediments were not as uniform in Zn composition as implied by the pre-disposal studies. The same variability was not seen for lead. However, the lead data for the original seabed sediments below the dredge spoil are systematically different from those obtained during the pre-disposal assessment, almost certainly because of the analytical problems mentioned in section 4.1.

For both elements, the concentrations in the upper 0-1 cm layer are lower than those in the dredge spoil layer beneath. Since two years have elapsed since the disposal, this most likely reflects losses of fine sediment from the mound. The grain sizes in this layer were much coarser than in surrounding undisturbed regions, so the top layer could not be an accumulation of new sediment.

Another objective of coring was to provide information on the response of macrobenthos to the deposition of the dredged material, in particular if there was evidence of mass mortality at the interface between the original seabed and the dredged material. The interface was clearly distinguishable in five of the nine cores taken, but there was no evidence of stratum enriched in skeletal remains.

Because a small number of cores was obtained, their sampling area (0.008 m^2) and the mean number of *Amphiura* per sample determined for the disposal site (13 per 0.045 m^2 for the 1990 survey) meant one would expect to find the remains of only ~2 *Amphiura* per core in the vicinity of the interface if there had been a mass mortality. The cores indicated, however, that the dredged material had been deposited in thin layers, each about four mm thick, suggesting that instead of catastrophic burial the benthos had been subject only to minor depositional increments. Late successional-stage burrowing macrobenthic deposit-feeders occurring at the site can probably tolerate this level of sedimentation and maintain their preferred level in the sediment profile. The higher than expected water content of the dredged material, which resulted in a disposal mound of only minor relief, appears to have meant that the physical impact of disposal on the benthos at the site was highly dispersed and able to be accommodated by the type of community present.

2.6 NZUA monitoring at The Noises Islands

The New Zealand Underwater Association (NZUA) voiced concerns about the level of sediment evident at The Noises Islands soon after the disposal operation commenced. The NZUA had undertaken a voluntary photographic monitoring study of a rocky transect at The Noises Islands located in 18 to 22 m of water depth during the period of the monitoring programme. (This is in contrast to transects at the POAL's control site near Tiritiri Matangi Island located at 8 to 12 m of water depth.) The NZUA did not include a control site in their monitoring programme although other transects at the Aha Rocks were photographed on some occasions.

The NZUA's photographic record of their transect over time suggested that one or more major sedimentation events occurred at The Noises Islands soon after dumping commenced and that a gradual partial recovery had occurred by November 1994. The NZUA argued that the blanketing of the transect by sediment was not a natural event but was associated with the dredging.

The POAL had undertaken additional studies to track the plume of sediment at the time of disposal which suggested that no significant input could have occurred ("significant" being an input which was measurably higher than natural regional turbidity). Subsequent tests of the sediment deposits at The Noises Islands showed no elevated chemical loads, suggesting that the material was not derived from the disposal site. However, the sediment was collected several months after the NZUA first noted the deposits and the results may not be conclusive.

Only the bioaccumulation tests provided integrated measures of contaminated sediment inputs to The Noises Islands. No current meters were placed on site and no continuous turbidity measurements were taken. The biological surveys are "downstream" indicators and some of the results were compounded by natural effects (algal blooms, depth dependence of sediment transport and the suitability of the monitoring/control site).

Thus, in the absence of direct (dump-by-dump) information about plume excursions and concentrations during the critical disposal and consolidation periods, the monitoring programme remains unable to confidently assign cause and effect unambiguously to the changes to the benthos observed at The Noises Islands by the NZUA.

3. Evaluation of Biological Monitoring

Biological monitoring was expected to assess whether changes in benthic structure due to dredge spoil disposal had occurred and whether any sediment affected communities at The Noises Islands and the control site.

3.1 Monitoring design

The benthic sampling strategy was based on a BACI (Before-After-Control-Impact) design with nests of stations north and south that are in the upcurrent and downcurrent boundary zone and a control nest to the west, although it should be noted that currents to the west do occur.

The benthic monitoring programme included only one pre-disposal survey (the April 1990 sampling was for a different suite of stations). Arguably, however, a BACI design should incorporate sampling at two or more control sites on two or more occasions before and after impact (eg Stewart-Oaten *et al*, 1986; Osenberg *et al*, 1992). In contrast to the monitoring of the sediment benthos, the programme of ecological assessment at The Noises stipulated that three surveys be undertaken before the commencement of disposal to provide an assessment of natural variability.

The water right stipulated a within-site sampling precision for *Amphiura* of 30%, though the derivation of this value and what change in density might be considered ecologically meaningful is not discussed. The baseline survey demonstrated a considerable natural spatial variability of *Amphiura* abundance and the need for an alternative approach to overcome practical constraints on sampling to achieve statistical criteria.

There was a lack of information on the likely degree of seasonal variability of benthic populations. Inshore soft sediment communities commonly exhibit considerable natural temporal variability at seasonal and longer-term scales. The single pre-disposal survey was carried out in summer, the two during-disposal surveys in spring, and the two post-disposal surveys in winter. Significantly fewer individuals were recorded in the pre-disposal survey in February 1991, mainly it appears because juveniles had become less abundant by late summer. It would have facilitated comparison if pre- and post-disposal surveys had been carried out at the same time of year.

It may be very relevant that the monitoring programme followed the 1991-92 El Nino, which turned out to be a major oceanographic anomaly for the region. The unusual lowering of sea surface temperature would be expected to influence significantly the reproductive success of different species.

A baseline for bioaccumulation monitoring needs to include information on the temporal variability of trace metal and organic compound concentrations. Results of the bioaccumulation monitoring indicate that there may be wide background variability in this regard. For instance, the concentrations of most of the organic compounds were lower in the second post-disposal survey than in the baseline survey. In the case of organic compounds, an important factor is likely to be seasonal changes in lipid concentrations associated with life-cycle stages.

3.2 Improvements to the programme

There is no standard approach in the use of benthos for monitoring the impact of dredge spoil disposal, although there are a number of appropriate techniques (eg Warwick, 1993). For monitoring of the sediment benthos, conditions of the water right specify the use of certain univariate measures, notably measures of numerical abundance and biomass. More comprehensive use could appropriately be made of the large amount of information generated without greatly increasing the time and cost of analysis, such as the application of multivariate techniques.

Some researchers (eg Warwick & Clarke, 1991) strongly advocate the use of multivariate measures, claiming that they are generally more sensitive than univariate methods. Reservations about multivariate measures have focused on possible statistical limitations, that it is difficult to test for causal links. However, newer multivariate programs can now be used to compare faunal and environmental datasets to optimise the matching (eg Clarke & Ainsworth, 1993). The relative simplicity of approach of multivariate methods and resulting graphical presentation are aspects which the public can appreciate.

Species diversity index

The monitoring programme adopted the number of species (species richness) as a measure of species diversity, rather than a species diversity index *per se*, on the basis that species richness determinations together with species composition are more important to site characterisation. It would, however, be helpful also to include the use of a species diversity index *per se* (such as the commonly used Shannon-Wiener index), given the changes in the distribution of individuals by species that are typically observed in successional patterns. Provided there is good biological and ecological information on the fauna, species richness together with species composition may be adequate, but for the New Zealand benthos there is commonly insufficient knowledge about individual species to aid interpretation.

Identification to species level may be unnecessary for detecting impacts in marine environments. Identification to this level can be extremely labour intensive and does not necessarily improve the identification of impacts. Identification to family level has been found to be sufficient in a number of studies undertaken overseas. This can significantly lower the cost of monitoring (and permits sample size and/or replication to be increased if this allows for an increase in statistical power). Looking at the polychaetes (the most species-rich group) in the present study, most of the families are represented by only one species.

Choice of sieve mesh size

In surveys of sediment benthos, the choice of sieve mesh size is an important consideration as it can significantly affect the time and cost budgeted for sample processing. The coarsest mesh size that will yield sufficient information to answer the question should be used. For surveys of coastal benthos, the usual choice is between mesh sizes of 0.5 or 1.0 mm. The use of a 0.5 mm mesh may not be justified by the disproportionately greater amount of time involved in sample processing, and certainly for many monitoring programmes the use of a 1.0 mm mesh has been advocated (eg Hartley, 1982). Macrofaunal samples from disturbed areas characteristically contain a greater abundance of smaller species and a potential disadvantage of using a 1.0 mm mesh is that these may then be somewhat undersampled. A major difference between shallow-water benthic samples screened on a 0.5 and a 1.0 mm mesh is often the number of juveniles present. (The significantly higher species abundance in the first during-disposal survey may be accounted for by an abundance of juveniles.) These, however, are likely to be ephemeral peaks that are not necessarily good indicators of environmental conditions; more significant is the survival of recruits and their establishment as integral members of the community. The presence of large numbers of juveniles in benthic samples can confound univariate measures such as species diversity indices. For these reasons the use of 1.0 mm mesh is likely to be adequate.

It is essential that preliminary biological sampling provides an adequate basis to establish the spatial pattern of faunal and environmental patterns. The detection of temporal trends depends on the ratio of spatial to temporal variability (eg Thrush *et al*, 1994). It is common for populations to exhibit spatial variation that is equal to or greater than temporal fluctuations in mean density. Large-scale changes in abundance due to ephemeral settlement of larvae may be an important feature of samples, particularly if a smaller mesh size is chosen. It may not be realistic to stipulate what change in mean density is ecologically meaningful.

Biomass can be a useful community parameter to obtain in benthic impact studies, particularly if it can be used in conjunction with data on numerical abundance of species. Analysis of the distribution of biomass by taxa (the Abundance Biomass Comparison method) can provide a graphical method of indicating a community dominated by early successional and mature phases of community development. It is, however, very labour intensive to determine the biomass for each species in each sample.

Sampling at the disposal site

Benthic (box-core and REMOTS®) sampling was undertaken within the disposal site during post-disposal surveys and provided valuable information on the (rapid) rate of recolonisation. This sampling at the disposal site was not required by the water right and was undertaken voluntarily by the POAL to provide supplementary information. It would have been of even greater value if the REMOTS® and biological sampling could have directly complemented each other to provide a better understanding of the process of recolonisation. The REMOTS® technique has been used mainly in the USA and at locations where the pattern of benthic succession is far better documented than for New Zealand.

Baseline and subsequent benthic monitoring at the disposal site itself was not specified as necessary in the Hauraki Gulf monitoring programme. Nevertheless monitoring of the disposal site can serve useful purposes.

1. Benthos at the disposal site, being the most severely affected by

physical disturbance, would be expected to exhibit the largest fluctuations of community and population structure. A knowledge of the magnitude of these changes could be instructive in providing an indication of the relative sensitivity or resilience of the benthos to such disturbance, and by way of comparison with the level of change observed in the boundary zone and at control sites.

2. Information obtained could be relevant to future applications.

3. A rapid re-establishment of the benthic community is likely to be seen by the general public as a particularly reassuring sign. Opinions had been aired at the Planning Tribunal hearing and in the media on the likely course and duration of the benthic recovery (or expected lack of it).

With any biological monitoring programme there will always be components that are site specific. An important consideration is likely to be whether there are communities in the proximity to the site that might be regarded as being particularly vulnerable to dredge spoil disposal, notably those adapted to live in areas of low natural turbidity and sedimentation. For instance, many animals of rocky subtidal communities are filter feeders that are relatively intolerant of smothering and protracted periods of high suspended sediment, conditions that would lead to the clogging of feeding mechanisms.

The susceptibility of sediment benthos to the physical effects of dredge spoil disposal is also largely a function of animal-sediment relationships that would naturally prevail. The macrobenthos of muddy sediments is typically dominated by deposit-feeding species adapted to depositional environments. But as the silt-clay content decreases, and sediments become more sandy and/or gravelly, an increasing proportion of the benthic species will be filter feeders. An important component of the bottom fauna of gravelly sediments will be sessile species (eg sponges, hydroids, bryozoans, ascidians) that can exist only where there is a firm substratum for attachment.

3.3 Summary

In this particular disposal situation, with a relatively short period over which disposal occurred in relation to the likely response of the community, benthic sampling during disposal may be of limited use provided there is good monitoring of physical and chemical parameters to indicate whether or not the disposed sediment is behaving as forecast.

The sediment macrobenthos in the vicinity of the disposal site would not be expected to be dramatically impacted given the similarity in physio-chemical properties between the dredged sediment and the native sediment at the disposal site, and the nature of this community naturally dominated by burrowing deposit feeders tolerant of high turbidity and an often ill-defined sediment-water interface.

It would, however, be advantageous to obtain more pre-disposal information to aid interpretation of the data, especially for establishing the natural variability of ecological systems. Samples should be taken at the same seasonal times in order to facilitate comparisons of communities.

4. Evaluation of Chemical Monitoring

Chemical monitoring was expected to show any toxicity in the disposal site from the disposal of dredgings and whether spoil had moved off-site.

4.1 Tracers to detect sediment movement

The principle of using an enriched component of the spoil as a movement tracer is simple. If the concentration of the component in the spoil is larger than that at the disposal site, then a statistically-based test can be developed to determine, at a given level of confidence, when spoil material may have arrived at a site outside the disposal zone. In the present case, the criterion used was to set a pre-disposal guideline, this being the concentration level for the component above the mean pre-disposal level of three times the standard deviation of the pre-disposal concentrations. This means that the probability of the target value being exceeded through natural variation is only 1%.

The sensitivity of a given tracer used in this way depends on a number of factors. It is enhanced as the concentration ratio for spoil to pre-disposal sediments increases; this clearly depends on the nature of the spoil and the sources of contaminant components. Many, such as lead (derived from leaded gasoline use) and zinc (galvanised materials, rubber tyre wear), are widely distributed in urban communities and can be expected in all maintenance dredgings. Others, such as DDT and PCBs, will be related to historical use and sporadic "accidental" spillages within the catchment.

The successful use of a tracer also demands that prior measurements of the component be made in statistically meaningful sample sets of both the spoil to be dredged and the sediments from the chosen test sites in the region adjacent to the disposal zone. The pre-disposal assessment of the nature of the dredged material[7] was carried out in a detailed manner following the best available protocols used overseas.

Data on the concentrations of contaminants used as tracers in different size fractions would assist in interpreting possible changes in composition of the spoil during dumping and/or winnowing (loss of fines through suspension). An alternative approach is to use normalisation techniques based on the major element composition of the sediment, as recommended by the Oslo Commission[8]. Neither approach was used in the present investigations.

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7 Ports of Auckland Ltd. Environmental Studies Reports 8, 9 & 10. Prepared by Kingett Mitchell & Associates.

8 Oslo Commission. *Guidelines for the Management of Dredged Material.* London Dumping Convention LC/SG 17/2/7, International Maritime Organisation, 1993.

Two types of tracers were used in the current monitoring programme:

- the trace metals Cu, Pb, Zn and Hg that are all moderately enriched in the port sediments and relatively cheap to analyze; and
- several trace organics which are, by and large, more sensitive tracers.

Polynuclear aromatic hydrocarbons (PAH) are enriched in the port sediments by a factor of about 13 relative to the disposal site (pre-disposal), while the factors for PCB and DDT are 32 and 100 respectively. The results of Survey Three (April-May 1993) at the disposal site show that PAH and PCB concentrations at the site are within the range expected from the pre-disposal studies of the port sediments.

Some problems of interpretation of trace metal data arose because of the nature of the extraction methods used for chemical analysis. Metals were extracted from the sediments using a mild acid treatment that does not remove metals tightly bound by mineral phases in the sediment. The basic justification for using acid-extraction techniques of this type was sound: the methods used are simple, rapid and give a measure of some kind of "biologically available" fraction of trace metals in the sediment. More importantly, the enriched anthropogenic component of these trace metals frequently occurs mostly in the fine-particle, readily-extracted fraction of the sediment.

However, it is also clear that these so-called selective extraction methods can give rise to variable results depending on exactly how the samples are processed for analysis. These variations arise because trace metals are present in the samples in a whole range of different chemical forms that respond differently to particular conditions of extraction. Moreover, subtle variations in the conditions of extraction can give rise to quite variable results.

This is a difficult problem to overcome. Total digestion of the sediment sample will remove the ambiguity associated with subtle changes in the extraction conditions from batch to batch, but will diminish the sensitivity of the tracing ability, perhaps to the point where the technique will no longer be useful.

The Panel's view is that it is more reliable to use some form of total element analysis that removes these possible ambiguities. In this approach, the sample is either entirely digested or is analysed by a non-destructive instrumental technique such as x-ray fluorescence. While total analysis may render a contaminant less sensitive as a tracer, it is off-set by the greater inherent reliability of the analytical results.

The analytical variation between surveys for lead was so great that it became useless as a tracer. Thus, after the third survey, the POAL consultant recommended that this metal be removed from the list of tracers for subsequent surveys. The Panel agreed with this conclusion. The results for copper also show some inter-survey variation (likely caused by the same problems), reducing its value as a tracer in this case.

The results for the use of DDT as a tracer are discussed in section 2.3. The organics, particularly DDT and PCB, have proved to be useful indicators that sediment has not moved much from the disposal area.

The nature of urban maintenance dredgings means that heavy metals like Zn and Pb, and several trace organics, will almost always be present at elevated concentrations in the dredge spoil. However, they are similarly likely to be widely dispersed in disposal zones that have been used in the past, particularly if the disposal operation has been carried out without tight controls on the geographical location of the dredging vessel during actual disposal. Thus the chemical tracer technique is unlikely to be useful for future assessments in marine systems that have already been subjected to less well-controlled disposal.

4.2 Summary

The above discussion makes it clear that the choice of tracers for sediment movement depends very much on the nature of the sediment being dredged. Most maintenance dredgings will contain enriched quantities of contaminants that are widely dispersed in stormwater eg Pb, Zn, PAH. PCB and DDT should become less common in the future as historical deposits are removed by dredging and better disposal controls are introduced (eg the Hazardous Substances and New Organisms Bill presently before Parliament). Many sediments removed for capital dredging will consist of uncontaminated marine sands and will contain no suitable chemical tracers.

5. Evaluation of Physical Monitoring

Physical monitoring is concerned with measurement of sediment movement during and after dumping, both at the bed and in suspension. The ultimate fate of eroded sediment and the magnitude and duration of erosion events resulting in concentrations exceeding natural levels should be discerned. The following evaluation uses these criteria to measure the success of the monitoring.

A limited number of physical measurements were required within the monitoring programme (bathymetric surveys, off-site grain sizes and intermittent measurements of turbidity at two sites located several kilometres from the spoil ground). The POAL's consultants additionally recorded plume sediment concentrations during disposal and the Panel recommended coring and erosion pins to measure bed levels on the disposal site.

Notably, because of the limited toxicity of the port sediments, chemical monitoring, counting of man-made objects and percentage mud measurements acted primarily as tracing techniques to determine whether sediment from the disposal site had settled in the immediate surroundings. Bioaccumulation methods were used to identify the integrated far-afield effects.

5.1 Bathymetric surveys

Bathymetric surveys can be a very effective method of determining the shape and total volume of the mound and any net losses from the site. In open waters, however, bathymetric surveying is prone to datum errors which introduce an offset in the absolute depths between surveys. The datum error most commonly occurs when sea levels are not measured on site, or when variations in the speed of sound through water are not accounted for. As such, depth errors of around ± 0.3 m between each of the surveys were reported by the consultants.

There are several ways to reduce this error; the most simple one is to place a good reflector, such as a metal plate on a supporting frame, at a small (order 2 m) known distance above the bed before any surveys are undertaken. For each survey, the datum can then be taken as the fixed level of the plate. It is necessary to embed the supporting frame properly to eliminate subsidence.

A second simple method in a stable region is to ensure that the bed off the spoil ground is always included in the survey so that the undisturbed contours can be matched. A bottom-mounted tide gauge placed at the site can also be used to reduce the datum error.

Additionally, the potential for consolidation of the underlying natural bed should be considered prior to recommending the use of bathymetric surveys. If consolidation due to the added weight of the spoil lowers the natural bed level, the soundings indicate an erroneous loss of sediment.

While the bathymetry surveys suggested sediment had been lost from the mound, the Panel was disappointed that, in the consultants' opinion, errors in the surveys made these estimates unreliable, particularly as bathymetric surveys were the only physical measurements on the mound. To clarify the calculations of the disposal mound volume, the Panel recommended placement of erosion pins. Sediment cores were also taken through the spoil and into the original bed. The interface at the bottom of the spoil, which allows the volume calculations to be refined, was identified.

In view of the difficulties encountered during the bathymetric surveys, better control of the datum is needed. Electronic bed level sensing devices or erosion pins placed throughout the disposal site prior to disposal may need to be considered. The pins would be graduated rods projecting up from a horizontal frame placed on the seabed prior to disposal. This technique has been employed successfully to monitor offshore oil and gas drill cutting mounds in Bass Strait using an ROV (video camera) to observe the pins in deep water. Divers can be used in shallower depths. In addition, the survey datum should be properly linked to the natural contours of the spoil ground. As such, the surveys should include a larger region than the disposal site.

5.2 Characterisation of sediment

Percentages of sand/silt/clay were determined using the pipette technique for the initial study of the disposal site. Percentage mud/sand was subsequently used during the monitoring programme. Port sediments were characterised by the percentage mud, although the percentage silt and clay was determined at some sites within the port. The pipette technique used by the consultants is one of the appropriate fall velocity methodologies. Care needs to be taken to ensure that the sediment flocs are minimally damaged and that the samples remain wet and are analysed in salt water.

Selective winnowing of fine sediments from the disposal site demonstrated the importance of knowing the full distribution of fall velocities and grain sizes and so a more complete analysis (at least on a subset of the samples) would have been useful to identify the particular fractions being lost from the site. The distribution of sediments would be more appropriately broken up into 0.25 - 0.5 phi divisions.

5.3 Settling of sediment plumes

In situ sediment concentrations in the plume immediately after disposal were recorded on behalf of the port by SAI-BECA and Science Applications International Corporation (1992) using colour enhanced acoustic techniques. The consultants describe three main stages of the plume:

1. Convective descent.
   The spoil falls rapidly (30-45 s) after discharge from the vessel as a dense sediment plume.

2. Dynamic plume collapse.
   A residual plume remains in the bottom 10 m of the water column and collapses over the next 5-10 minutes.

3. Settlement of surface material.
   Fine-grained suspended material from the surface and just above the bottom settles up to 60 minutes after disposal.

These measurements at the site showed water column turbidities, which were greater than 400 mg/l after disposal, returning to levels below 10 mg/l within 68 minutes. The consultants concluded that all detectable plumes stayed well within the confines of the disposal site's boundaries and that there is no evidence to suggest that suspended sediments from the disposal plume would reach The Noises Islands or any other nearby land mass.

The port sediments are typically 80-90% mud (combined silt and clay fraction as defined in table 2 a). The sand component is fine (< 180 micron) and the muds consisted of almost equal proportions of silt and clay. Table 2 shows the standard settling times used to define the sediment fractions when analysed by the pipette technique [9].

Using the data from table 2, the following simple calculations illustrate the rate at which sediment settles through the water column.

At the mud/sand (63 micron) boundary:
The sediment falls 20 cm in 1 minute. In still water, the sediment would take 150 minutes (2.5 hours) to fall through 30 m (the site depth).

At the silt/clay (2 micron) boundary:
The sediment falls 10 cm in 8 hours and 10 minutes. In still water, the sediment would take 2450 hours (102 days) to fall through 30 m.

The finer sediments within the clay fraction (about 40% of the port sediments):
In still water, the sediment would take longer than 102 days to fall through 30 m.

The apparent discrepancy may be resolved if the sediment flocs were large or the muds were clumped during disposal.

With the pipette technique used for grain size analysis of port and Gulf sediments, the sediment/water mixture is initially briskly stirred and this often breaks the sediment flocs and clumps. Consequently, settling tube techniques (where undisturbed sediment is released at the surface and the mass accumulation rate at the base of the water column is recorded using a balance) is considered to be a more appropriate technique for predictions of plume settlement as it more closely simulates the field conditions. Laboratory experiments with muddy sediments (by one of the Panel members at the Victorian Institute of Marine Sciences) have shown that the fall velocities measured in a settling tube vary with the

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[9] Tucker, M. Techniques in sedimentology, *Blackwell Scientific Publications. 394*, 1989.

initial concentration of the sediment. Thus, to predict plume behaviour properly, a range of initial concentrations, including the concentrations expected at disposal, will generally need to be tested in the laboratory or in a trial disposal of a small quantity of the sediments at the disposal site. The method of dredging and subsequent handling of sediment on the vessel are also important factors to consider.

It should be noted that dewatering of port sediments in the dredge prior to disposal at the site was rejected after inspection by the consultants revealed that the fines did not settle quickly enough.

Thus, in view of the very slow measured fall velocities of the sediments, some uncertainty about the time evolution of plume concentrations and the plume excursions remains. The above calculations, which are based on the consultant's laboratory measurements of sediment fall velocity, indicate that plumes may remain in suspension for long times and travel large distances in the Gulf. Even the sands at the mud boundary, which are not strongly affected by flocculation of grains, take 2.5 hours to fall through 30 m.

The potential excurions of these plumes can be estimated using current measurements made near the bed during a variety of conditions prior to disposal[10]. The net (residual) water movement was to the south and net excursions of up to approximately six - seven km per day were calculated. This distance is further than the distance to The Noises (3.5 km) and so a sediment plume had the potential to reach The Noises.

5.4 Improvements to the programme

One of the weaknesses of the monitoring programme was the lack of information provided about the concentrations during transport and the ultimate fate of dredge spoil.

In addition, the disposal site had been described as a containment site, ie one where very little sediment (if any) is re-entrained after disposal, but the subsequent monitoring suggested that up to 25% of the sediment was lost from the site. Expert opinion only, rather than adequate measurement of sediment transport and the physical conditions, was available prior to disposal. Given that the Gulf "turns brown" during storms and the spoil grain sizes were matched with natural sediment sizes, total containment was always unlikely.

Where containment of dredge spoil is required, long-term monitoring of waves, currents and turbidity on the site prior to disposal are essential to define the actual movement of natural sediments and to infer the probability of containment of the spoil. Concentration and fate measurements after disposal, when compared to natural turbidity levels, provide a numerical measure of potential impact on surrounding muddy or hard substrates, which can be specified as an exceedance level above the measured baseline natural levels for a storm of defined intensity (eg 1:1 - 1:10 year storm).

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10 Ports of Auckland Ltd. Environmental Studies Report 9. Environmental assessment of the disposal of dredged material at the Hauraki Gulf disposal site. Prepared by Kingett Mitchell & Associates, September 1990.

While site characteristics and the nature of the sediments will vary at other sites, the Panel recommends the following minimum improvements to the physical monitoring for the Hauraki Gulf disposal site. Measurements need to be made over a period from several months before to several months after dredging:

1. current and near-bed wave orbital motion measurements near the disposal site;

2. turbidity and light measurements on and adjacent to the spoil ground near the seabed;

3. well-controlled bathymetric surveys and placement of erosion pins (particularly in muddy sediments) prior to disposal for datum control and visual observation, if necessary;

4. sediment characterisation including size analyses at 0.25 - 0.50 phi intervals, rheology and tests of cohesiveness;

5. benthic survey of the physical character of the bed (size of bedforms and other physical features) using, for example, divers, video or side scan sonar;

6. sediment traps around the disposal site and at all key sites of public value;

7. an adequate sediment tracing technique (natural, chemical or artificial tracers), particularly during the disposal and consolidation phases;

8. full interpretation of the measurements prior to disposal, including a numerical simulation of plume settlement if inputs of sediment to key sites of public value are shown by the current measurements to be possible.

The Panel recommends the above physical measurements as a minimum requirement for future disposal proposals in the Gulf. However, the number of instruments used and the length of the measurement period may vary with the scale of the dredging operation and nature of the environment at other sites.

Historical measurements in the Gulf show that the water column can be thermally stratified. Such stratification is common in similar water bodies, particularly during the warming period in autumn. In these cases, currents need to be measured at multiple depths using either multiple current meters on a mooring or with a bottom-mounted Acoustic Doppler Current Profiler, which simultaneously records currents throughout the water column. Near-bed wave orbital currents can be recorded with readily available bottom-mounted current meters.

As tides are repetitive, 30 days of measurements are usually sufficient to define the tidal flows. Wave motion and wind-driven currents, however, are weather dependent and so the sampling duration needs to be related to the number of storms sampled, rather than a fixed time interval. To minimise the cost of such a programme, the measurements can normally be extended by relating the measured data to historical weather records once several storms have been sampled.

The local waves generated within the Gulf are fetch limited and the orbital currents would not be strongly felt at the sea bed in depths exceeding 30 m. Thus, it is necessary to sample for longer period swell which may reach the site from the north and north-east. It would be necessary normally to record prior to disposal until several storms have been sampled. Wave refraction numerical models can be used to determine the relevant (if any) ocean wave directions.

Direct turbidity monitoring on and off the disposal site would identify any exceptional sediment loads relative to the surrounding natural bed. During the monitoring programme, water samples were taken prior to and during disposal at The Noises Islands and Tiritiri Matangi Island (control site). The Panel believes that instantaneous water sampling (particularly several kilometres from the disposal site) has very little practical value, relative to continuous or integrated monitoring techniques, because of the chance that a plume will be missed and because of the variability in the natural environment.

Integrating techniques, such as bioaccumulation, are more appropriate. Simple alternatives/additions include the placement of sediment traps at key sites (for subsequent analysis of the sediments) in conjunction with continuous-recording turbidity or light sensors. Sediment traps or continuous sensors at The Noises Islands and Tiritiri Matangi Island would have been cheaper to maintain than the more expensive biological surveys, which are an indirect measure of sediment inputs. Indeed, the NZUA monitoring remained ambiguous in part because extra measurements were needed to attempt to identify the source of the sediment deposits noted in their photographs. If adopted, monitoring devices should be placed on site for several months before, during and after dumping.

The Panel also noted the value of sediment tracers that are mixed with the spoil prior to dumping. These may be fluorescent or other tagged particles that can be detected subsequently in sediment samples taken from the monitoring sites. Artificial tracers are most useful when chemical concentrations in the dredge spoil are near the detection limits.

5.5 Summary

For the Hauraki Gulf, the consultants included several of the recognised techniques (grain size, tidal currents, bathymetry) to define the volume of the mound and to assess the likelihood of sediment moving off-site. However, measurements of wave orbital currents, natural turbidity and water column density structure were not considered necessary. The use of additional techniques would have defined the concentration during transport and the fate of the spoil.

6. Principles of a Future Monitoring Programme

6.1 Conceptual Design

The conceptual design of a scheme for the safe disposal of dredge spoil in the marine environment, and associated monitoring to ensure the safety of the disposal and the environmental integrity of the disposal site, should conform in essence to that laid out by the Oslo Commission Guidelines for the Management of Dredged Material. These Guidelines form part of the London Dumping Convention, to which New Zealand is a signatory. The Guidelines comprise Part A: Assessment and Management of Dredged Material and Part B: Monitoring of Dredged Material Disposal Operations, together with Technical Annexes.

The monitoring programme specified for this disposal operation has, by and large, followed the Oslo Commission Guidelines and in some respects has been more comprehensive than the requirements of the Commission Guidelines.

In future monitoring programmes, it would be useful to adopt the Oslo Commission Guidelines as the framework for the assessment and monitoring of dredgings disposal. However, the Guidelines are general and would need to be made more specific to the environmental effects that might be expected in New Zealand coastal waters.

In particular, the Guidelines developed are primarily concerned with toxicity due to industrial and urban impregnation of sediments in the high population European cities. In New Zealand, as in the Auckland case, toxicity of sediments may be low. Indeed, in capital dredging operations, the sediments may be very old and have very little toxicity.

In the New Zealand estuaries and tidal inlets, which have relatively clear waters, extra turbidity from the disposal site may be the main concern. For example, increases in turbidity have been blamed for large scale losses of seagrass beds in southern Australian bays, and the seagrass provided important juvenile fish nursery sites. Thus, while an assessment of the suitability of the dredge spoil for disposal in the marine environment under the Oslo Commission Guidelines would normally focus on toxicity, the grain size of the spoil (with respect to the likelihood of re-entrainment of spoil) should be an added criterion for the suitability assessment in low turbidity New Zealand estuaries and bays.

The task to give guidance to regulatory agencies on how to use the Oslo Commission Guidelines could be done at a national level.

Each monitoring programme has to be tailored to the specific environment and locations where dredgings disposal is required. There are some matters that must be addressed before a site-specific monitoring programme is designed. These include the choice of a disposal site and the choice of indices to measure change within the monitoring programme.

Choice of indices

The choice of variables for monitoring an impact is a critical issue, but often there is little or no discussion in the rationale for monitoring surveys why a particular variable should be used. What evidence is there for a linkage between the type of measure and the impact in question? It is commonly assumed that a decline in an indice being measured is deleterious. If there is likely to be some link, the relationship between the variable being measured and the impact may not be straightforward. For instance, species diversity indices are not unambiguous indicators of stress or impact. An intermediate level of disturbance may, in fact, increase diversity because it provides for a mix of successional species, so the relationship between disturbance and diversity is unlikely to be linear.

Choice of disposal site

The ability to predict which site constitutes an impacted site and which a control site is crucial to the design of a monitoring programme. There has been continued discussion on whether the Hauraki Gulf disposal site is a containment site. If "impact" and "control" areas are to be compared, proof of a lack of disturbance in the control is needed.

Current measurements could be used to define control and impact sites, although, for the case under consideration, the impact site was selected for its proximity to the disposal site and its high public amenity value.

The depth of impact sites needs to be carefully chosen and should be related to the depth of control sites.

A judgement about the geometry of expected impacts was made in the water right. It may be safer not to make such suppositions. In the approach that is very commonly used for monitoring benthic impacts around oil platforms, a single transect of stations is aligned along the line of the residual current, with a second transect at right angles. Stations are sited at increasing distance from the source of impact so that stations at the periphery can be expected to be beyond the influence of the disposal and act as reference stations [11].

A similar approach could be used for monitoring the disposal of dredge spoil, with samples taken along radii: within the disposal site, within the bedload boundary zone, and beyond the likely impact. The radially symmetric design does not depend upon a simple assumption of exactly which direction is upstream or downstream relative to the potential source of impact; and it seems to allow a large area to be covered with relatively little sampling effort. Nevertheless, the design assumes a continuity of response which may not be the case for an impact in a patchy environment[12].

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11 Hartley, J.P. Methods for monitoring offshore macrobenthos. *Marine Pollution Bulletin 13*: 150-4.

12 Carney, R.S. A review of study designs for the detection of long-term environmental effects of offshore petroleum activities. In *Long-Term Environmental Effects of Offshore Oil and Gas Development*, ed. D.F. Boesch and N.N. Rabalais, pp.651-96.

6.2 Stages in a monitoring programme

The Panel suggests that there are five stages in the monitoring programme which arise from the physical dynamics of the sediments and the natural biological time scales. These are:

- Stage One — Prior to disposal
- Stage Two — During spoil disposal
- Stage Three — Consolidation (0-6 months after completion of disposal)
- Stage Four — Longer-term monitoring
- Stage Five — Closure.

The rationale for this approach is that there are differences in the nature and extent of monitoring at each of these stages to assess the environmental impacts.

A number of essential baseline physical, chemical and biological studies are needed in Stage One and would normally be undertaken as part of a feasibility assessment. The studies should include: characterisation of the dredge spoil, assessment of the disposal site suitability, and should provide essential input (flow excursions and streamlines) into the selection of control/impact monitoring sites. The studies should also provide sufficient information to estimate the sediment losses from the site during and after disposal. Baseline biological studies undertaken in Stage One should take account of spatial and temporal variability of benthic populations.

Stages Two and Three are based on the physical behaviour of the dredge spoil and reflect the short-term behaviour during the disposal and consolidation phases when sediments, particularly the fines, are most easily lost. Sediment is mostly carried by currents in suspension during these phases. Because of the variability in the natural environment, integrating measurement techniques are most appropriate for tracking the suspended sediment plume during disposal (Stage Two) and up to six months following (Stage Three). Measurements could include bioaccumulation, sediment traps and continuous-recording current meters.

The longer-term drift as bedload off the site (Stages Three and Four) may be treated by monitoring around the disposal site (eg chemical analyses of sediments around the perimeter). Stage Four is a reflection of the transition in physical behaviour from losses in suspension being dominant to the slower moving bedload processes when the sediment may drift off the disposal site while remaining in contact with the bed.

The nature of the monitoring undertaken in each stage is also a reflection of the rate of change which may occur in biological communities, particularly the recovery phase which may be very long. The biological monitoring addresses biological change, particularly during Stage Three, while also acting as a trigger to determine the status of the dredge spoil recolonisation (Stage Four) and to formulate a rationale to "close" the site (Stage Five). In terms of potential biological impact, an important factor is therefore the particle size of the dredged material in relation to the sediment type and depositional environment at the proposed disposal site.

6.2.1 Prior to disposal

Assessment of the suitability of dredge spoil for disposal in the marine environment must be carried out before disposal. With the addition of turbidity criteria, the procedures adopted for the Ports of Auckland exercise as described in Ports of Auckland Ltd Reports[13] are considered suitable for most situations in New Zealand. This process comprises several stages:

1. Assessment of the important critical contaminants in the dredge spoil. This process will include not only representative sampling from the areas to be dredged and chemical analysis, but also assembling historical information relating to known sources of contaminants and, if applicable, results of monitoring previous disposal mounds.

   The choice of critical contaminants should be made taking into account historical information on known contaminants and public perceptions. The list should include all primary group determinants in Annex I of the Oslo Commission Guidelines (Cd, Cu, Hg, Zn, Cr, Pb, Ni and the PCB congeners IUPAC 28, 52, 101, 118, 138 and 180). Based upon local information on sources of contaminants (point sources or diffuse inputs) or historical inputs, other determinants from the secondary group may be applicable. These include As, further PCB congeners, PAH, oil, DDT and organo-tin compounds.

2. Comparison of the results with concentration thresholds set for management purposes at which disposal may take place without further assessment (Level 1). Thresholds used for this assessment would normally be based on approaches such as those used in Puget Sound, Port of Melbourne or the Port of Auckland.

3. Where contaminant concentrations exceed these action levels, additional testing would be carried out using methods such as chemical elutriate tests or direct biological toxicity testing. Higher action levels would normally be set above which no disposal would be permitted.

4. Full grain size analyses of the port sediments and those of the off-shore disposal site should be undertaken. It should be acknowledged that matching of sediments is normally done to ensure minimum biological disturbance. For a sediment containment site, it would be more appropriate to select a site where the grain size was significantly finer than the material to be dumped. However, re-colonisation is likely to be less successful, or at least much slower, in mismatched sediment.

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13 Ports of Auckland Ltd. Environmental Studies Reports 8, 9, 10. Prepared by Kingett Mitchell & Associates Ltd.

5. If the grain sizes indicate that the sediment may be re-entrained after disposal, then an assessment of the likelihood of increased turbidity over sensitive habitats (eg hard substrates and near to marine species of plants that are turbidity-sensitive) would need to be considered before the sediment was deemed suitable for disposal. An influx of sandy sediment onto such plants may also lead to bed degradation. Thus, the suitability assessment would expect to use the results of the baseline biological survey.

This toxicity component of the scheme leads to a classification of the spoil based on its suitability for marine disposal that is controlled largely by its most toxic components, and thus can be flexibly applied to different sources and types of dredge spoil. Where the spoil fails to meet the accepted guidelines, alternative methods of disposal must be sought.

6.2.2 During disposal

Monitoring in Stage Two should depict plume movement during disposal and in the early phase when sediment is consolidating. The list of minimum requirements for physical monitoring (section 5.4) is relevant in Stages Two and Three. It is important to realise that the intensity of the physical monitoring should be at its maximum during these two stages. The physical monitoring becomes much less important in later stages.

It may be appropriate to undertake an analysis of man-made artifacts in order to help characterise the sediment to be disposed of, but it appears to be of somewhat limited value in the subsequent monitoring. It is labour-intensive, susceptible to contamination and operator bias, and the results can often be tentative. It would be useful to put aside such samples in case there is a subsequent need for analysis.

Disposal during favourable conditions may reduce sediment losses from the site. These include:

1. periods during the year when wave heights are smallest;
2. neap tides;
3. disposal during either the ebb or flow current phase. The tidal currents may be used to carry plumes away from important sites;
4. the least stormy/windy period during the year.

This kind of data should be obtained for all sites prior to disposal.

6.2.3 Consolidation

The duration of the consolidation period depends on sediment type (grain size, pore space, cohesiveness) and moisture content in the dredge spoil. Time scales may be of order 3-6 months for fine, greatly disturbed sediments, depending on the frequency of storm. Sediment is mostly carried by currents in suspension during this phase.

As consolidation is a temporary (short-lived) phase, the intensity of monitoring should be maximised in this period and the previous stage. Thus, regular surveys within a six-month timeframe are appropriate and needed to consider properly the physical changes occurring on the site. Once again, the list of minimum requirements for physical monitoring (section 5.4) is relevant.

6.2.4 Longer-term monitoring

Stage Four is a reflection of the transition in physical behaviour from losses in suspension being dominant to the slower-moving bedload period when sediment may drift off the disposal site while essentially remaining in contact with the bed. The nature of the monitoring undertaken in this stage is also a reflection of the rate of change which may occur in biological communities, particularly the recovery phase which may be very long.

The techniques adopted in the Hauraki Gulf monitoring programme (inspection of sediments and benthos around the perimeter of the disposal site) were satisfactory.

In the Hauraki Gulf monitoring programme, assessment of any bedload movement of the spoil mound into adjacent seabed areas was made possible by the use of chemical tracers, ie chemical substances present in the spoil at much higher concentrations than in those of the disposal zone. Some of the difficulties arising from this approach are discussed in section 4.1, but in general this is a useful technique where it is possible. Because of ambiguities that may arise, it is sensible to have several different tracers, as used in the Hauraki Gulf assessment.

Where chemical tracers are found appropriate, a thorough investigation of the reliability of the analytical methods used must be carried out. For some trace metals, inter-survey variations in results can easily arise through subtle, uncontrolled changes in the sample pre-treatment, extraction and analysis. Strict controls must therefore be placed on how the samples are handled. These must include consideration of aeration and oxidation of the sediment minerals, time of extraction, nature of extracting agent and ratios of sediment to extractant used; all of these affect the efficiency of extraction. Where sufficient tracer sensitivity can be achieved using total extraction methods, these are preferred.

In assessing the rehabilitation of the disposal site, periodic benthic surveying can be used but is expensive. An alternative technique is to determine the re-establishment of normal benthic activity in dredged sediments using the natural radionuclide Be-7.

6.2.5 Closure

The biological monitoring on the disposal site addresses biological change while also acting as a trigger to determine the status of the dredge spoil recolonisation and to formulate a rationale to "close" the site.

A closure plan should address longer-term issues that become important after it has been demonstrated that the disposal site has consolidated and is not contributing significant quantities of contaminated sediment to adjacent areas. In many cases, actual closure of a disposal site may only occur after its potential for disposing spoil has been exhausted. However, closure may be brought about by changes in management procedures, ie the adoption of alternative methods or sites for disposal.

The primary environmental concern about a closed disposal site would be the possibility that as time passes and the area remediates, it becomes (perhaps again) a seafood resource that may contain contaminated organisms. This concern can be addressed by periodic studies of the composition and nature of indigenous organisms. It may be necessary to introduce restrictions on the gathering of affected organisms, or to consider capping the sediment with clean material.

7. Conclusions and Recommendations

Much of the public concern about the dredge spoil disposal has been related to the toxicity of the port sediments. The Panel confirms the consultants' findings that the sediments in the port are mostly of low toxicity (according to international guidelines). The benthic surveys provided a valuable confirmation of the low toxicity of the spoil.

The pre-disposal assessment of the nature of the dredged material was carried out in a detailed manner following the best available protocols used overseas. The spoil was found to be well within the requirements for unconfined marine disposal according to these criteria. However, the pre-disposal assessment was later found to be inadequate for DDT.

The dredging operation can be seen as the transfer of mildly toxic, fine sediments from one part of the Gulf to another, with no obvious medium-term change in the overall chemical and biological quality of the whole system.

Marine organisms have successfully colonised within the port and, after an unexpectedly short time, the spoil ground has been colonised successfully by organisms from the Gulf. The numbers and types of marine animals in the dredge spoil are very similar to those in surrounding sediments (after about two years). Thus, the assumption that the spoil ground should be treated as sacrificial has not been confirmed.

The Panel commented that the monitoring programme for the disposal of dredge spoil from the port of Auckland to the Hauraki Gulf has been one of the most complex and expensive programmes yet undertaken in New Zealand to assess the impacts of a dredged spoil disposal operation and was carried out to a thorough and high standard.

However, the overall scope (and cost) of the monitoring programme is very large compared to the Panel's perception of the technical environmental issues at stake.

The Panel's findings at the conclusion of the monitoring programme can be summarised as:

- up to 25% of the disposed sediment has dispersed from the site;
- the disposal operation has not caused any significant impairment of ecological systems in the Hauraki Gulf;
- the disposal site has recovered from the dumping of spoil;
- the benthic communities surrounding the disposal site do not appear to have been adversely affected and recolonisation of the mound has occurred;

- the mound has now stabilised;
- the mound is lower than predicted due to the high fluid content of the spoil;
- chemical monitoring indicates that the mound has not substantially shifted into any adjacent test sites;
- ecological data gathered at The Noises Islands was difficult to interpret due to large natural variability and confounding effects such as the extended El Nino during 1992;
- the chemical quality of the sediments in the disposal region has been shown to be sufficiently good that there should be no concerns about longer-term effects;
- the concentrations of DDT found in the disposal region do not pose a significant threat and are in a form resistant to biological degradation and uptake.

The Panel concluded that the results of the monitoring programme, including the reviewed conditions, addressed a range of environmental effects related to the disposal of dredged material. The major exception was the ability to track sediment movement, particularly through the consolidation phase. This aspect was not included in the monitoring programme as the Planning Tribunal Judge accepted expert evidence that measurable accumulations of sediment would not occur beyond the site. There still remains some doubt about the transport and deposition of sediment in relation to vulnerable benthic communities dominated by filter feeders.

Aspects of the monitoring programme that were not particularly relevant included:

- tracing movement of man-made objects because of the difficulty in determining whether objects were man-made;
- chemical monitoring of Pb and Cu because of large variation between surveys in the analytical results;
- water quality monitoring several km from the disposal site.

There were also inadequacies in that:

- pre- and post-disposal biological surveys were not carried out at the same time of the year;
- insufficient pre-disposal baseline data meant spatial and temporal biological trends and chemical tracer movement could not be determined with confidence;
- pre-disposal assessment of DDT concentrations in the port sediments involved too few samples to reveal "hot spots" that became obvious after disposal;

- insufficient or inadequate selection of control sites meant some sampling data could not be effectively interpreted;

- no long-term measurements of waves, currents and turbidity were available to quantify natural and dumped sediment movement;

- remediation of the disposal site itself was not considered important to study.

Future programmes

The Panel is of the opinion that the conceptual design of a programme for safe disposal of dredge spoil in the marine environment should conform to the Oslo Commission Guidelines for the Management of Dredged Material, with additional consideration of turbidity for New Zealand waters.

It is important to recognise that monitoring programmes for maintenance and capital works dredging will differ because of the different nature of dredged spoil and the different potential environmental effects.

Maintenance dredging monitoring programmes for mud and sand spoil should be designed to meet the requirements of the specific environment. Programmes for capital works dredging of sand that is not contaminated by toxic materials may not need to be so comprehensive.

The Panel suggested monitoring programmes for disposal of dredged spoil should recognise five stages which arise from the physical dynamics of the sediments and the natural biological time-scales. The stages include: prior to disposal, during disposal, consolidation; longer-term and closure. Each stage should have its own programme.

Recommendations

To the Auckland Regional Council

In designing any future monitoring programme for the disposal of maintenance dredging spoil within the Hauraki Gulf:

- It is desirable that the programme conforms to the Oslo Commission Guidelines for the Management of Dredged Material while ensuring the programme is more specific to environmental effects that might be expected in New Zealand coastal waters.

- Recognise that different monitoring will be required for each of the five stages of dredgings disposal.

- Ensure sampling and control sites are adequate.

- Ensure pre-disposal and baseline data are adequate.

- Ensure biological monitoring is effective by initiating it prior to and during consolidation and the longer-term stages.

- Consider using multivariate analyses at coarser taxonomic resolution.

- Ensure the volume of dumped spoil and any sediment movement can be effectively measured.

- Consider long-term monitoring at a disposal site so that information on the occurrence and magnitude of natural sedimentation effects could be collected.

- Consider incorporating some deeper sites to assess any effects on rocky subtidal communities if such communities are likely to be affected by sediment movement off the disposal site.

- Consider bioaccumulation studies in the disposal zone accompanied by remediation studies.

To the Ports of Auckland Ltd

As a result of the Hauraki Gulf monitoring programme, there would be few locations in New Zealand where the sediment benthos has been surveyed in such detail. It would be beneficial if principal findings were published in an appropriate scientific journal.

To the Minister of Conservation

There is an urgent need to develop guidelines on what constitutes an appropriate level and scope of environmental monitoring for New Zealand port companies and regional authorities concerned with dredge spoil disposal. Such guidelines should follow the Oslo Commission Guidelines.

The appropriateness and feasibility of developing sediment quality screening guidelines that employ New Zealand species should be assessed. The possibility of identifying suitable New Zealand-wide species, given the wide geographical span in biota and environmental conditions, should be considered. The importance for fish nurseries, marine habitats, etc of increases in turbidity due to dredge spoil disposal in New Zealand bays and estuaries should be addressed.

Table 1: MONITORING REPORTS FOR EACH SURVEY

THE NOISES : ECOLOGICAL MONITORING

SURVEY	DATE	REPORT
1	May-July 1992 (Baseline)	POAL. Environmental Studies Report 15. *Noises ecological monitoring - Survey One.* Prepared by Kingett Mitchell & Associates Ltd, September 1992.
2	1 August 1992 (Baseline)	POAL. Environmental Studies Report 16. *Noises ecological monitoring - Survey Two.* Prepared by Kingett Mitchell & Associates Ltd, November 1992.
3	8 August 1992 (Baseline)	POAL. Environmental Studies Report 17. *Noises ecological monitoring - Survey Three.* Prepared by Kingett Mitchell & Associates Ltd, November 1992.
4	October 1992 (During Disposal)	POAL. Environmental Studies Report 19. *Noises ecological monitoring - Survey Four.* Prepared by Kingett Mitchell & Associates Ltd, December 1992.
5	Jan- Feb 1993	POAL. Environmental Studies Report 23. *Noises ecological monitoring - Survey Five.* Prepared by Kingett Mitchell & Associates Ltd, April 1993.
6	May 1993	POAL. Environmental Studies Report 25. *Noises ecological monitoring - Survey Six.* Prepared by Kingett Mitchell & Associates Ltd, October 1993.
7	November 1993	POAL. Environmental Studies Report 27. *Noises ecological monitoring - Survey Seven.* Prepared by Kingett Mitchell & Associates Ltd, May 1993.

WATER QUALITY MONITORING

SURVEY	DATE	REPORT
Baseline Survey	August 1992	POAL. Environmental Studies Report 14. *Hauraki Gulf Water Quality Monitoring Programme - Baseline Assessment.* Prepared by Kingett Mitchell & Associates Ltd, August 1992.
Disposal Monitoring Survey		POAL. Environmental Studies Report 22. *Hauraki Gulf Water Quality Monitoring Programme - Disposal Monitoring Assessment.* Prepared by Kingett Mitchell & Associates Ltd, March 1993.

Table 1, continued

PHYSICAL AND BIOLOGICAL MONITORING

SURVEY	DATE	REPORT
1	Sept. 1992	POAL. Environmental Studies Report 18. *Physical and biological monitoring of the Hauraki Gulf disposal site - Survey One.* Prepared by Kingett Mitchell & Associates Ltd, November 1992.
2	Oct. 1992	POAL. Environmental Studies Report 20. *Physical and biological monitoring of the Hauraki Gulf disposal site - Survey Two.* Prepared by Kingett Mitchell & Associates Ltd, July 1993.
3	April - May 1993	POAL. Environmental Studies Report 24. *Monitoring of the Hauraki Gulf dredgings disposal site - Survey Three.* Prepared by Kingett Mitchell & Associates Ltd, August 1993 (draft).
4	May 1994	POAL. Environmental Studies Report 31. *Physical and biological monitoring of the Hauraki Gulf disposal site - Survey Four.* Prepared by Kingett Mitchell & Associates Ltd, October 1994.
Sediment Characteristics Survey		POAL. Environmental Studies Report 13. *Physical, chemical and biological characteristics of sediments from the Hauraki Gulf disposal site.* Prepared by Kingett Mitchell & Associates Ltd, August 1992.

BIOACCUMULATION MONITORING

SURVEY	DATE	REPORT
Baseline	June 1992	POAL. Environmental Studies Report 21. *Bioaccumulation monitoring - Baseline Survey.* Prepared by Kingett Mitchell & Associates Ltd, March 1993.
1st Post-Disposal	Oct.- Dec. 1992	POAL. Environmental Studies Report 26. *Bioaccumulation monitoring - Survey One.* Prepared by Kingett Mitchell & Associates Ltd, March 1994.
2nd Post-Disposal		POAL. Environmental Studies Report 29. *Bioaccumulation monitoring - Survey Two.* Prepared by Kingett Mitchell & Associates Ltd, October 1994.

Table 2 : SEDIMENT SETTLING TIMES FOR A RANGE OF GRAIN SIZES

Phi	mm	cm	Depth (cm)	h	min	s
4.0	0.063	63	20			58
4.5	-	-	20		1	56
5.0	0.0312	31.2	10		1	56
5.5	-	-	10		3	52
6.0	0.0156	15.6 silt	10		7	42
6.5	-	-	10		15	
7.0	0.0078	7.8	10		31	
7.5	-	-	10	1	1	
8.0	0.0039	3.9	10	2	3	
8.5	-	-	10	4	5	
9.0	0.00195	1.95	10	8	10	
9.5	-	- clay	10	16	21	
10.0	0.00098	0.98	10	32	42	
10.5	-	-	5	32	42	
11.0	0.00049	0.49	5	65	25	

Table 2a : PHI GRAIN SIZE SCALES

Udden & Wentworth (1922)		phi	mm	Friedman & Saunders (1978)	
				V. large	Boulder
		-11	2048		
				Large	
		-10	1024		
				Medium	
		-9	512		
Cobbles				Small	
		-8	256		
				Large	Cobbles
		-7	128		
				Small	
		-6	64		
				V. coarse	Pebbles
		-5	32		
Pebbles				Coarse	
		-4	16		
				Medium	
		-3	8		
				Fine	
		-2	4		
Granules				V. fine	
		-1	2		
V. coarse				V. coarse	Sand
		0	1		
Coarse	Sand		microns	Coarse	
		1	500		
Medium				Medium	
		2	250		
Fine				Fine	
		3	125		
V. fine				V. fine	
		4	62		
				V. coarse	Silt
		5	31		
				Coarse	
		6	16		
				Medium	
		7	8		
				Fine	
		8	4		
Clay				V. fine	
		9	2		
				Clay	

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Appendix 1:

DREDGINGS DISPOSAL IN THE HAURAKI GULF

FIRST REPORT OF THE TECHNICAL REVIEW PANEL

AUGUST 1993

Office of the
PARLIAMENTARY COMMISSIONER FOR THE ENVIRONMENT
Te Kaitiaki Taiao a Te Whare Pāremata

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background to the Dredgings Disposal

Ports of Auckland Ltd (POAL) applied to the Auckland Regional Water Board in 1990 for water rights to dredge the port and dispose of the spoil in the Hauraki Gulf at a site 34 km from the wharfs. Dredging of the port is required to ensure that the wharfs are usable by all vessels. In the case of the Auckland port, dredging of approximately 40,000 m^3 per annum is required. Because the port had not been dredged for 5-6 years, a backlog of 270,000 m^3 of dredgings was needed.

The application was heard by the Auckland Regional Water Board and its decision was appealed to the Planning Tribunal in 1991. The Planning Tribunal's decision,[1] in December 1991, upheld the water right granted by the Regional Water Board although some conditions were added to the monitoring programme as a result of negotiations between the Maruia Society and the POAL.

The dredging operation commenced in August 1992 and was the focus of public concern and extensive media coverage.

1.2 Establishment of the Panel

The Parliamentary Commissioner for the Environment consulted with Ports of Auckland Ltd, the Auckland City Council and the Auckland Regional Council to seek a way to address some of the issues causing the public concern. The Commissioner suggested to the public authorities that the establishment of an independent technical review panel could be a suitable mechanism to ensure that the public of Auckland had confidence in the monitoring programme and its ability to evaluate the environmental effects of the dredgings disposal.

Both the Ports of Auckland Ltd and the Auckland Regional Council supported the formation of a panel with Ports of Auckland Ltd making a financial contribution. The Commissioner established the Panel under the Environment Act 1986 and chairs the Panel.

The Commissioner consulted widely among the scientific community in New Zealand and Australia for people to participate in a panel. The people chosen were:

- Dr K. Black. Principal Research Scientist, Victorian Institute of Marine Sciences, Melbourne, Australia

- Dr K. Hunter. Associate Professor of Chemistry, University of Otago, Dunedin

- Dr K. Probert. Manager Portobello Marine Laboratory, University of Otago, Dunedin.

1.3 Function of the Panel

The terms of reference of the Technical Review Panel are:

1. To review the results of the monitoring programme.

2. Note any appropriate modifications and additions that should be included in future monitoring programmes by identifying any missing objectives and reviewing the methodology of the existing monitoring programme.

3. Report findings to the Parliamentary Commissioner for the Environment, Ports of Auckland Ltd and the Auckland Regional Council.

The Panel will meet from time to time to assess the progress of the monitoring programme. The Panel is not part of the statutory process of consent granting and cannot alter or amend the operation of the monitoring programme which is the responsibility of the Port Company or the evaluation of the data which is the function of the Regional Council. There is, however, scope for the Regional Council to review some of the special conditions at the end of the first year of monitoring in August 1993.

The Panel met in Auckland in February 1993 for the first meeting and was briefed by the Regional Council, the Port Company and its consultants and representatives of the New Zealand Underwater Association. The briefing included background to the application to dispose of the spoil and details of the monitoring programme as defined by the conditions of the water right.

This report is the Panel's initial evaluation of the monitoring programme.

1.4 Summary of the Monitoring Programme

The Panel is assessing the monitoring programme at and near the disposal site and has not assessed the monitoring of the dredging operation which took place over a three month period.

The monitoring programme provides for the establishment of standard sampling locations. It stipulates that where a statistically significant difference for any parameter is detected between pre- and post-disposal mean values at the standard sites, then sampling for that parameter is to be carried out at additional sites. The programme also requires establishment of bioaccumulation sampling locations between the disposal site and the Noises Islands, north of the disposal site, and two control sites in areas comparable to the vicinity of the disposal site.

Separate programmes are provided for physical, biological and chemical monitoring. Physical monitoring involves a bathymetric survey of the disposal site and surrounding seabed; and analysis of sediment samples for particle size and presence of anthropogenic materials. Biological monitoring includes analysis of samples of benthic biota for total abundance and biomass of all macrofauna; and bioaccumulation testing of scallops for stated contaminants. Chemical monitoring involves analysis of samples collected from the standard sites for stated metals and organic carbon content; and comparison with pre-disposal samples.

A detailed description of the monitoring programme is contained in the publication *Immediate Maintenance Dredging 1992 Monitoring Programme. Prepared for Ports of Auckland Ltd by Beca Carter Hollings and Ferner. November 1992.*

1.5 Operation of the Monitoring Programme

The Panel is satisfied that sample collection and sample analysis is being carried out to high technical standards. The way in which monitoring requirements are addressed and become incorporated into a programme depends, to some extent, on the expertise of individuals involved in the process. The quality and thoroughness of the consultants' work is impressive. The laboratories being used for the analytical work have suitable procedures for replication of analyses and control of sample identification.

2.0 INITIAL EVALUATION OF THE MONITORING PROGRAMME

2.1 Sediment Chemistry Monitoring

The first of the two sets of sediment chemistry measurements was due to be made in April 1993 so comment on the meaning and interpretation of the results was not possible when the Panel met in February 1993. This aspect of the programme involves study of sediments from both the disposal site itself and from locations surrounding the disposal site. The purpose of studying sediments from the disposal site is to determine that the material actually deposited at the disposal site has a chemical composition similar to the average composition of the dredged material as determined in the assessments prior to the water right application.

Provision is made in the water right for further toxicity testing of the sediment if its composition proves to be outside statistical limits. The whole protocol procedure will be run through again if the sediment concentrations fall more than three standard deviations above the pre-dredging mean values.

This seems a reasonably well designed component of the programme. Its stated purpose is clear and straightforward and the measurements should answer the questions posed.

The purpose of repeating the tests one year later is unclear. The same results as the first set of measurements should be evident in the second series of tests unless:

- there has been a massive shift in the deposited dredge spoil, or

- the variation in chemical composition of the spoil is very large such that the pre-disposal and the two post-disposal surveys all give different results.

The monitoring is undertaken by sampling from locations adjacent to the edge of the disposal site together with control sites to the north-west of the disposal site. Sampling from additional stations may be required.

The purpose of the sediment chemistry monitoring at locations surrounding the disposal site to determine if contaminated sediments from the disposal cells have moved e.g. through wave dispersal, outside of the disposal site. This analysis is made possible by the enrichment of the dumped sediments in a number of chemical components i.e. trace metals and trace organics relative to the native sediments of the disposal area. As such, this is a reasonably designed test protocol for this particular disposal situation in that it provides some degree of sensitivity for detecting sediment movement after disposal. This method may not be applicable to the disposal of sandy uncontaminated sediments or may not be applicable to other disposal sites.

2.2 Biological Monitoring

This part of the monitoring programme does address key questions relating to impact on benthic communities. However, the Panel considers there may be scope to simplify the monitoring without undermining the purposes of the programme. The benthic sampling programme at the disposal site generates more information than is used in the appraisal and offers the possibility of employing other multivariate methods to examine possible community-wide responses to spoil disposal.

The biological monitoring will, in itself, generate valuable data on spatial and temporal variability of benthic populations. Few studies of this type have been undertaken in New Zealand.

The degree to which the disposal ground is a containment site clearly has implications for the design of the monitoring programme. It is possible though, that the benthic community at sampling locations in the vicinity of the disposal site may be able to cope with considerable dispersal of dredge spoil without exhibiting clear signs of stress.

The REMOTS[2] monitoring, while not part of the conditions of the water right, provides useful information on the sediment profile. The purpose of the REMOTS surveys is to monitor the rate of recolonisation of the dredge spoil on the seabed. The technique depends on photographic interpretation and deducing the stage of succession from the animal-sediment characteristics that are observed. It will be valuable to have this information on the pattern of recolonisation but there is no requirement for parallel biological information to help interpret the images. There is scope to improve the coordination of the REMOTS work with the biological work.

An appreciation of the nature and extent of benthic recolonisation would be assisted by taking box-core samples from within the disposal site.

Although it is not a requirement of the special conditions of the water right, some biological sampling has since been carried out at the disposal site.

Inclusion of the Noises ecological monitoring arises from the concern that 'sensitive' habitats may be exposed to impacts. The relevance and provision of this type of monitoring will be largely site-specific. The measured currents and the depth of the disposal site both indicate that the concentrations of any toxic material will be highly diluted after travelling over 3.5 km between the spoil site and the Noises. Biota vary naturally at annual and inter-annual time scales. The surveys at the Noises may ultimately provide ambiguous results on the environmental effects of spoil disposal at downstream locations.

A repetitive photographic survey has been voluntarily undertaken by the New Zealand Underwater Association (NZUA). The Association has photographed along a transect in deeper water (18 to 22 metres) than the quadrat surveys in the monitoring programme. NZUA suggest that the shallow sites are too prone to regular wave activity for turbidity to have an impact. If sedimentation does occur at greater depths, it will be disturbed less frequently due to lower wave energies at depth, and therefore any excessive turbidity due to the dredging may have a bigger impact on biota.

2.3 Bioaccumulation Monitoring

The intended purpose of this monitoring appears to be to demonstrate whether or not contaminated sediments or leached contaminants can be transported from the disposal site and subsequently affect biological organisms at a typical adjacent site (in this case the Noises).

Although this monitoring programme is part of the conditions of the water right, the Panel has some doubts as to its effectiveness in assessing whether the arrival of sediment at the Noises can be attributed to the dredge spoil disposal.

2.4 Sediment Monitoring

The sediment monitoring is an important part of the overall monitoring programme. The principal means of monitoring is by bathymetric surveys. The surveys use soundings which are accurate to ± 100 mm in absolute levels and are repeated using the same techniques each time. These surveys will provide some reasonable estimate of the volume changes of the spoil and will check the containment capability of the site. If the adjacent seabed is stable, the mound of spoil will show up as a perturbation above a natural datum and repetitive surveys should show volume changes, including consolidation of the material. The accuracy of the results should be specified.

The predicted height of the mound after disposal was up to 7 metres. The height after spoil disposal was nearer 900 mm. The high water content of the spoil may be responsible for the difference between the prediction and the reality. The other explanation is that some sediment has been lost from the site.

Turbidity monitors on the spoil disposal site and on any adjacent control site would have identified any differences in sediment load. Simultaneous measurements of currents and wave orbital motion would have provided essential data needed to place the results in the context of the annual tidal, wave and weather patterns. If storms occurred during the critical period of spoil consolidation, large amounts of sediment could be lost from the site.

A more detailed time series of weather during the monitoring programme should be obtained as the weather on the day of the surveys is not a sufficient indicator of the dynamics of the coastal environment.

Some current meter data has been obtained at the disposal site. Data was collected before the spoil was disposed and during the time the sediment plumes from the disposal operation were being tracked. Current meter data is not being collected during the monitoring programme.

3.0 GENERAL ISSUES

3.1 Design of the Monitoring Programme

In the absence of any New Zealand guidelines for monitoring the environmental effects of spoil disposal, the consultants have considered carefully the problem of a suitable framework for evaluating potential effects. The relevant procedures adopted by international and national agencies have been critically assessed and the tiered approach, particularly to characterisation of the sediment requiring dredging, has much to recommend it.

The Panel understands that the monitoring programme is based on the assumption that the disposal site is a depositional site. The seabed material in a depositional area may be subject to resuspension and, in extreme conditions, transportation but overall, it should accumulate material (i.e. the amount of material leaving the site is less than the amount of material entering the site). A containment site should be located in a depositional area. Both verbal and written evidence that this is so was presented to the Planning Tribunal hearing. The site is in deep water (about 30 metres) which is less affected by swell and wind-driven flows. The site is in an intermediate tidal flow category.

Once the nature of the disposal site was accepted as providing containment, the primary concern was not verification of this finding but verification that the physical, chemical and biological characteristics of the area surrounding the disposal site remained unaffected by the disposal operation. The studies were directed at downstream impacts because the disposal site was assumed to be a containment site.

The degree to which the disposal ground is regarded as a containment site has basic implications for the design of the monitoring programme including the position of sampling locations.

The issue of whether the disposal site is a containment site has been raised by the Panel. At the end of the monitoring programme, the Panel considers that questions of whether most of the material has remained on site and been recolonised will be of great interest to all stakeholders.

3.2 Permissible Levels of Change

One of the problems with any biological monitoring programme is what is the acceptable level of change that can be tolerated and that is ecologically meaningful. It is rare to find with benthic communities, for example, that sufficient information about spatial and temporal variability of populations is available to indicate the amount of change that might be considered abnormal.

Even if it is possible to attribute a difference in some biological index (e.g. abundance or diversity) to human impact, what level of change is acceptable, both in extent and duration?

There is a similar dilemma in considering what is an acceptable level of resuspension of spoil material after dredging compared to that which can occur during storms at sea.

4.0 SUMMARY

The purpose of the Panel's first meeting was to gain an appreciation of the dredgings disposal monitoring programme and the considerable discussions on the issue that had taken place over the past two years.

The initial evaluation is that the monitoring programme has been carefully constructed and does address most of the key questions in assessing the biological and sediment chemistry impacts of the spoil disposal. The lack of monitoring for sediment dynamics as to what is happening to the mound of spoil appears to rest with the assumption that the disposal site is a containment site.

The Panel noted possible changes to some of the conditions that might be able to be achieved within the framework of the present statutory monitoring programme to improve the outcome of the programme. These included:

- refining the biological monitoring programme,
- coordinating the REMOTS camera work with the biological monitoring,
- the use of general automated systems for collecting data.

These issues will be further discussed at the Panel's second meeting in August 1993.

1 New Zealand Underwater Association Incorporated and Maruia Society Incorporated v The Auckland Regional Council and Ports of Auckland Ltd. Decision No a 131/91. Planning Tribunal.

2 The REMOTS camera photographs vertical slices of the surface sediment layer of deposited material.

Appendix 2:

DREDGINGS DISPOSAL IN THE HAURAKI GULF

SECOND REPORT OF THE TECHNICAL REVIEW PANEL

Office of the
PARLIAMENTARY COMMISSIONER FOR THE ENVIRONMENT
Te Kaitiaki Taiao a Whare Pāremata

PO Box 10-241, Wellington, New Zealand

February 1994

REVIEW PANEL

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Dr K Black:	Principal Research Scientist, Victorian Institute of Marine Sciences, Melbourne, Australia
Dr K Hunter:	Associate Professor of Chemistry, University of Otago, Dunedin
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ACKNOWLEDGEMENTS

The Commissioner wishes to thank the staff of Ports of Auckland Ltd and their consultants, staff of Auckland Regional Council and members of the New Zealand Underwater Association for their assistance.

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CONTENTS

1. INTRODUCTION

The Parliamentary Commissioner for the Environment established a Technical Review Panel in late 1992 to assist the Auckland Regional Council (ARC) and Ports of Auckland Ltd (POAL) to review the monitoring programme established as part of the water right granted for the disposal of dredgings from the Port of Auckland to a site in the Hauraki Gulf.

The Panel met in February 1993 and a report of that meeting is contained in its first report (Parliamentary Commissioner for the Environment, August 1993).

The second meeting of the Panel was held in August 1993 and this report summarises that meeting.

2. PURPOSE OF SECOND MEETING

The purpose of the second meeting was to review the monitoring carried out between February and August 1993 and to make recommendations to ARC and POAL for any changes to Condition 11 (as allowed for in the granted water right).

The monitoring programme includes physical, biological and chemical monitoring at sites located up to 750 metres upcurrent and downcurrent from the disposal site as well as biological and water quality monitoring at The Noises Islands and at a control site. The full programme is outlined in Appendix 1.

Survey Three was conducted in April 1993 and included: a biological survey including a bioaccumulation survey and a survey of benthic biota; a sediment chemistry survey and a physical survey including bathymetry and particle size analysis of sediment. Biological surveys Five and Six at The Noises and Tiritiri Matangi Island were conducted by January 1993 and by March 1993 respectively. The report on Survey Five was made available to the Panel and a briefing on the results from Survey Six was given to the Panel members at the meeting.

3. REVIEW OF MONITORING PROGRAMME

The Panel's findings on the monitoring programme are as follows:

- There have been no obviously damaging effects on the benthic community surrounding the disposal site.

- A loss of fine sediment from the disposal mound has been indicated but the amount or extent is not clear. Results have been within the errors of the measurements making their interpretation difficult and uncertain.

- The decreased concentrations of copper, lead and zinc in the surrounding sediments do not seem to be significant.

- The results of the analysis of the DDT components in the sediments indicate a problem of contamination has arisen during sampling or analysis.

3.1 Monitoring in the Vicinity of the Disposal Site

The Panel considers the programme of benthic biological monitoring undertaken in the vicinity of the disposal site has progressed satisfactorily. Results of the core sampling around the disposal site indicate that to date there have been no obviously damaging effects on the benthic community.

Similarly, whilst the monitoring of sublittoral rocky epibenthos and (predominantly) sandy gravel infauna at The Noises Islands and Tiritiri Matangi Island has revealed changes in species diversity and abundance, these appear to be consistent with an expected degree of natural variability.

The purpose of studying the sediments from the disposal mound is to determine that the material actually deposited at the site has a chemical composition similar to the average composition of the dredged material. This has been established in Survey Three. The chemical surveys outside the disposal site have not identified any significant changes.

3.2 Monitoring on the Disposal Mound

Chemical Analysis

Chemical analysis shows reduced concentrations of some of the components that are enriched in the Port sediments. Although this might point to a loss of fine material, the picture is not consistent across all of the components. Pollutants such as the trace metals and trace organics are commonly supposed to be present largely in the fine (i.e. mud) fraction of harbour sediments but this has not been demonstrated for the sediments from the Port of Auckland.

Copper, lead and zinc all show concentrations towards the lower end of the range found in Port sediments. For both copper and zinc there have been problems of consistency in the analytical results from different surveys possibly as a consequence of the effects of sample handling and processing. This is a very common problem in sediment analysis for trace metals and is neither unique to this monitoring programme nor an adverse reflection on the quality of work conducted. It is therefore difficult to attach any significance to the decreased concentrations of copper, lead and zinc. The results could indicate a loss of up to 30% of dredged material if the fine material was enriched in these elements. However, without information on the actual concentrations of copper, lead and zinc in both the sand and mud fractions of the fine material, this estimate of loss remains imprecise.

For mercury (and lead), fewer problems with consistency were observed in previous work. The mercury results of Survey Three are essentially the same as the dredged sediments. This is not consistent with a major loss of fine material if it was enriched in mercury.

The organic components are, by and large, more sensitive tracers. Polynuclear aromatic hydrocarbons (PAH) are enriched in the Port sediments by a factor of about 13 relative to the disposal site (pre-disposal), while the factors for PCB and DDT are 32 and 100 respectively. For both PAH and PCB, the disposal site concentrations are essentially the same as those of the Port sediments. DDT is the most sensitive tracer. However, the results presented in the Appendix (to the Draft Survey Three Report) indicate that a problem of contamination has arisen during processing and analysis of the samples.

In conclusion, the most sensitive tracers (organics, mercury) suggest that the dumped sediment has the expected composition based on studies of the Port sediments before disposal. There are unexplained features with the results for the other trace metals that probably arise from analytical variations.

Bathymetric Analysis

The bathymetric surveys indicate that the initial spoil volumes of 262,000 m^3 may have reduced to 202,000 m^3 and 176,000 m^3 in two subsequent surveys. However, the process of consolidation of the spoil and errors in the survey accuracy make these estimates unreliable. Some loss of fine material is obviously to be expected either during the disposal operation or as winnowing off the mound from the top layers of spoil but the extent of the loss is difficult to demonstrate.

Textural Analysis

Textural analysis of sediment on the mound has been carried out on a limited number of samples. Because only the top approximately 6 cm of a sample was analysed, it cannot be assumed that these samples are fully representative of the texture of the mound overall. The results give a sediment composition of 57 ± 14% mud and 42% ± 13% sand in the disposal zone. The draft of Report 24 (Survey Three results) describes this as lower than expected, as the average mud content of sediment in the Port is 81% to 84%. The reduction in the percentage mud in the spoil at the disposal site could indicate a loss of sediment from the disposal mound of up to 31%, if the sample results applied to the whole mound and if it is assumed that only mud is lost by dispersion and winnowing.

4. REFINEMENTS TO MONITORING PROGRAMME

As a result of evaluating the results of the monitoring programme, the Panel considered possible amendments to the programme.

4.1 Benthic Community Monitoring

The second post-disposal monitoring survey of macrobenthos outside the disposal site, which is due to be carried out in October 1993, 12 months after the completion of the disposal of dredged material, could be deleted.

Differences in species diversity, total abundance, brittlestar abundance, and biomass for samples collected around the disposal site appear to be consistent with expected natural variability and, in particular, sedimentary gradients. The period of greatest potential physical disturbance to the benthos, the disposal operation, occurred without obvious impacts on benthic community structure in areas adjacent to the disposal site.

It is unlikely that significant changes in benthic community structure due to dredgings disposal will become evident around the disposal site during the second post-disposal monitoring survey unless there is a sudden and major movement of sediment off the disposal site, or there is some chronic sublethal effect of disposal on adjacent sediment benthos which begins to manifest itself. These possibilities are not likely because of:

- the local hydrodynamic and sedimentary environment is well characterised,
- the deposited sediment is likely to have increased in stability, and
- there has already been rapid recolonisation at the disposal site .

4.2 Benthic biomass

Determining biomass of sediment macrobenthos would seem to be of limited value and could be deleted from future surveys.

Biomass is sometimes used for monitoring, probably most effectively by employing the Abundance Biomass Comparison method which takes account of the distribution of biomass among species. The rationale for this approach is that sediment benthic communities in early successional stages of recovery tend to be characterised by a few small short-lived species which can reach high population densities. By contrast, the mature community is typically more diverse and contains more longer lived species that attain larger body size but at smaller population densities. Consequently at early successional stages biomass is distributed among a large number of individuals of few species, but as the community recovers biomass becomes distributed among more species of higher individual body weight. To use biomass data in this way, however, would entail a considerable increase in laboratory time.

The monitoring programme specifies that biomass is to be determined for benthic macrofauna to at least the level of class. In the reports on physical and biological monitoring of the dredgings disposal site, biomass data are given for species (in the case of the abundant echinoderms, the heart urchin *Echinocardium cordatum* and the brittlestar *Amphiura rosea*), and for the trophic group (in the case of the major annelid and molluscan classes). This degree of resolution may provide some indication if the community had been knocked back to an early successional stage. One would, for instance, expect to see an abundance of small surface deposit-feeding polychaetes and few of the dominant sub-surface echinoderms. But such changes would be revealed in the abundance data, and it appears doubtful if the biomass data in the form specified in the water right conditions provide useful monitoring information. The results from the biological monitoring indicate that the distribution of the biomass can be strongly influenced by large individuals.

4.3 Chemical Analysis

There seems to be little point in repeating the on-site chemical analysis. It has been established that the deposited sediment has the expected chemical composition. Little would be served by repeating the measurements. The variations in results for copper and zinc are probably a result of procedural factors and only confuse the essential issues. However, the problem of the DDT results must be resolved as DDT is the most sensitive tracer. If it is shown that the present set of samples are themselves contaminated, it may then be necessary to resample for DDT analysis.

The off-site chemical measurements could be usefully simplified by focusing on a more restricted range of tracers. Taking into account the nature and costs of the analytical methods used, reductions in the measurements could be made without significant loss of information quality. The PCB and PAH analyses could be deleted from the next off-site programme. Although the trace metals copper, lead and zinc are less sensitive tracers than the organics, the analytical methods involved are much simpler and less prone to contamination artifacts. Moreover, removing one or two of the metals from the list would not result in a significant cost reduction given the common sample preparation needed for each analysis. Thus it does not seem useful to change the trace metal component of the measurement programme.

5. ADDITIONAL MEASUREMENTS

The issue of whether the disposal site is a containment site which was raised at the Panel's first meeting in February 1993 has been a subject of discussion among Panel members and staff and consultants of ARC and POAL. The Planning Tribunal was presented with a considerable body of evidence on the issue of containment. The monitoring programme focused on the effects of the dredging disposal on the surrounding environment.

Even if it has been determined, on the basis of evidence available before disposal, that a site has the physical properties that will ensure containment of most of the disposed material, the Panel considers it is sensible, prudent and reasonable to include in the monitoring programme an investigation of possible sediment transport into areas surrounding that site.

The purpose of undertaking additional measurements suggested by the Panel is to assist in more clearly defining the sediment movement, within the spoil ground, which has been suggested by the latest results.

5.1 Cores Within the Disposal Mound

The existing programme could be replaced with two sets of measurements. In the first, cores could be collected within the disposal site. The cores should extend through the dumped sediments into the original sea bed and analysed to provide:

(i) information about the volume of spoil remaining on site;

(ii) the overburden pressure causing consolidation of the spoil and compression of the existing sea bed under the weight of the new sediments;

(iii) the grain size composition through the core to examine any changes in sediment particle size of the deposited sediment. This could assist in providing evidence of any recent loss of fines from the disposal site.

The aims of the work will be achieved by recording:

- thickness (and calculated volume) of the spoil
- bulk density
- percentage mud.

Thus a series of sub-samples would need to be taken from each core at least at the surface, mid-depth and above the bottom interface. The bottom interface may be visually obvious. However, it may be necessary to undertake chemical analyses, presumably looking for one common, easily-measured chemical, which exists in significantly different concentrations in disposal mound sediments and original Gulf sediments, to identify the bottom interface. The REMOTS camera should aid this process in the locations where the dredge spoil was thinly spread. Extreme care will have to be taken to ensure that the core is not altered during sampling.

Secondly, the coring should include some adjacent sites on the edge of the disposal site. At least 20 cores would be recommended in a spatial arrangement suitable for the calculation of volumes. Sediment on the disposal site may be moving to the east and so some cores should also be taken from the east of the main area of dumping.

5.2 Recolonisation by Benthic Fauna

Although not specified under the water right conditions, some macrobenthic sampling has been carried out within the disposal site during the first post-disposal survey. Samples taken from the central portion of the disposal site, seven months after completion of disposal, indicate rapid recolonisation to a community stage very similar to that occurring around the disposal site.

There is very little information on the rate, pattern and methods of recolonisation for this type of infaunal community in New Zealand and there is an opportunity here to obtain useful information on the response of infaunal macrobenthos to disposal of dredge material and mode of recolonisation. In particular, examination of cores taken from the disposal site (penetrating to below the original sediment surface) and from adjacent control sites, could also indicate if the burrowing fauna at the disposal site had been able to keep pace with the deposition of dredged material and ultimately regain the new sediment surface. If this had not occurred, one could expect to find a stratum rich in skeletal remains (notably from the dominant echinoderms) as evidence of recent catastrophic burial.

5.3 Fate of Fine Sediment

The indications from the results of Survey Three are that some fine sediment may have been lost from the mound of disposed dredgings either during the dredging disposal operation or subsequently as storms occurred in the vicinity. There are presently two means of identifying to what extent the sediment may have moved. One is to use those chemical components that are enriched in the sediments dredged from the Port relative to the original disposal site sediments as tracers for post-disposal movement of sediment off the site.

The other means is the bathymetric measurements taken over the disposal site. One of the difficulties with the present monitoring programme is the inherent lack of accuracy in the bathymetric surveys notwithstanding the care taken in conducting these surveys. While these surveys are indicating a net loss of sediment from the site, errors in the depths make volume calculations unreliable. As such, a datum and a more direct measure of bed levels is needed. In particular, the direct measure should account for consolidation, if it is still occurring. There are some highly technical instruments, including bottom mounted depth sounders and bed level sensors, which would give an accurate measure of the sediment levels. The cheapest option may be "stakes hammered into the sea bed". A diver would measure bed level changes on the stakes but it should be noted that this technique will provide a limited data set.

5.4 Sediment Deposition at The Noises

A photographic transect of the rocky sublittoral benthos at water depths of 18-22 m off The Noises has been surveyed by New Zealand Underwater Association (NZUA) divers, once before disposal (June 1992), and (to date) on five post-disposal occasions (from August 1992 to August 1993). Results show that on the pre-disposal sampling date the transect was relatively free of deposited material whereas on the subsequent sampling occasions a significantly greater amount of deposited material was evident. The New Zealand Underwater Association divers have, however, surveyed only this one transect, and there appear to be no measurements available to indicate natural spatial and temporal variability of deposition episodes to be expected at these water depths within the Hauraki Gulf. Thus it is difficult to judge to what extent these results might be regarded as abnormal.

There is a need for meteorological records to be examined for possible relationships between weather events and sediment resuspension and deposition. It would also be helpful, if opportunities arose, to examine other rocky sublittoral areas at similar water depths in this part of the Gulf to see if there is more widespread evidence of sediment deposition. The monitoring programme specified in the water right has used transects at 8 m and 12 m at The Noises Islands.

The Panel considers that it is important that representative samples of the material deposited on The Noises are obtained for chemical and physical characterisation. Chemical analysis should determine whether the material is primarily organic or inorganic in nature, and, if inorganic, whether it originates from the disposal zone.

5.5 Identification of Other Techniques

The Panel has indicated that other, more expensive, techniques are available to track sediment movement and these techniques may be suitable for consideration for any future monitoring programmes. These include the use of fluorescent tracers to identify the location of dredged material. The tracer could be placed on the sea bed at the disposal site and tracked through Hauraki Gulf. Other methods are:

- Long-term underwater video observations (placed on the sea bed adjacent to a wave recording current meter) would show when and if the sediment is being moved;
- Long-term measurements of waves, currents and turbidity on the spoil ground would quantify the sediment movement and the conditions when transportation takes place;
- Electromagnetic and acoustic devices which show the bed levels over several months are available with automated logging systems.

SUMMARY

The Panel reviewed the results of Survey Three carried out in April/May 1993 and concluded that monitoring the disposal site surroundings has to date not identified any adverse effects.

The Panel considered the monitoring programme could be modified where the water right conditions allow change, and could include additional measurements on the disposal site to help resolve questions that have arisen since the granting of the water right.

Suggestions have been made to POAL and ARC to refine parts of the present monitoring programme by deleting some measurements. Additional measurements to enable a better assessment of the fate of fine sediments at the disposal site to be identified have also been suggested.

The Panel will meet again at the conclusion of the monitoring programme.

APPENDIX I Special Conditions of the Water Right Relating to the Monitoring Programme

Appendix C

Programme to Monitor the Effects of the Disposal of Dredged Material at the Hauraki Gulf Disposal Site.

1. Sample Sites

i Standard Sampling Locations
- 2 pairs of sites located in the upcurrent and downcurrent boundary zone (a 250 m zone around the disposal site) respectively.
- 2 pairs of sites located 300 m beyond the boundary zone upcurrent and downcurrent respectively of the sites specified above.
- 4 control sites located in areas comparable to the vicinity of the disposal site.

ii Additional Sampling Locations
- 2 pairs of sites located 750 m beyond the boundary zone, upcurrent and downcurrent respectively of the sites specified above.
- 4 further control sites, to ensure balance of design.

Minimum replicate number per site for i and ii = 4.

Where a statistically significant difference between pre- and post-disposal mean values at the standard sites for any parameter is detected, then sampling from the additional sites for this parameter will be carried out.

iii Bioaccumulation Sampling Locations
- between the disposal site and The Noises
- north of the disposal site;
- 2 control sites located in areas comparable to the vicinity of the disposal site

Minimum replicate number per site for iii - 3 (pooled)

2. Physical Monitoring

i A bathymetric survey of the disposal site and surrounding seabed.

ii Sediment samples collected from the standard sites analysed for particle size characteristics and the presence of anthropogenic materials. Precision of particle size analyses = 15%.

iii Samples collected and analysed in conjunction with the chemical monitoring of 4(iii) below.

3. Biological Monitoring

a Benthic biota:

i Samples collected from the standard sites analysed for the following: total abundance and biomass of all macrofauna separated to at least the level of class; abundances of the 5 major macrofaunal species. Precision for <u>Amphiura</u> sampling = 30%.

b Bioaccumulation:

i Scallops collected from the bioaccumulation sites analysed for copper, lead, zinc, mercury, the DDT group, chlordane, PCBs and PNAs. Precision has yet to be established by baseline monitoring.

4. Chemical Monitoring

i Samples collected from the standard sites analysed for copper, lead, zinc, mercury, organic carbon content, PCBs PAHs and chlordane. Analyses will be carried out on the <63 um fraction. Precision = 20% for copper, lead and zinc.

ii four replicate samples collected from each of half the cells used for disposal since the previous monitoring or baseline survey, analysed as above.

A comparison will be made between the pre-disposal chemical characteristics of the dredged material and the material at the disposal site. If the new analytical data show exceedances of a guideline concentration of the dredged material average, plus three standard deviations about that average, then supplementary analysis of the collected samples will be carried out. The new data will be compared to protocol screening guidelines, and if necessary the discharged sediment will be reanalysed and tested by bioassay and bioaccumulation procedures, and remedial action carried out.

A comparison will also be made between the pre-disposal chemical characteristics of the disposal site and post-disposal concentrations at the standard site. If the new data exceed a guideline concentration of the pre-disposal sediment average, plus three standard deviations about the average then a gridded sampling programme will be instigated around the site.

Appendix D

Programme to Monitor the Effects of the Disposal of Dredged Material on Water Quality at The Noises Islands.

1. **Sampling Locations**

a) i) 3 stations located not more than 1 kilometre north of The Noises Islands.
   ii) 3 control stations.

b) Depths

   i) 5 metres away beneath the surface of the water.
   ii) 5 metres above the seabed.
   iii) mid-way between the depths specified in 1(i) and (ii) above.

2. **Pilot Survey**

a) Prior to the commencement of disposal, water samples shall be collected from all stations at each depth specified in (1) above on at least 12 occasions during a representative range of weather conditions. The samples collected shall be analysed for non-filtrable residue and turbidity.

b) The Grantee shall then establish:

   i) a statistical relationship between levels of non-filtrable residue at The Noises stations and at the control stations, and
   ii) a sampling regime.

which are sufficient to permit the detection, during the period of disposal, of an increase in non-filtrable residue of 20 g/m^3 or greater at The Noises stations, above any increase which may also occur at the control stations.

3. **Impact Survey following commencement of Discharge**

a) Following the commencement of discharge the Grantee shall carry out sampling as determined in accordance with (2b) above, except that this survey shall include:

   i) sampling at all sites and depths on at least 7 occasions during disposal of the first 150,000 m^3 of dredged material, and then sampling at least once per week until the completion of the disposal operation.
   ii) Sampling following disposal on each day when winds in excess of an average of 17 knots and from a northerly direction as measured at the Whangaparaoa Meteorological Station (between NW and NE) have prevailed for at least 6 hours prior to disposal.

b) The timing of sampling shall relate to disposal events as follows:

   i) disposal during ebb tide or the first 3 hours of flood tide - samples shall be collected within one hour of the next high tide.

ii) disposal during the second three hours of flood tide - samples shall be collected within one hour either side of the second high tide following this disposal event. Provided that if monitoring is required during the official hours of darkness it may be delayed until the next succeeding high tide.

c) The samples collected shall be analysed for non-filtrable residue and turbidity. Wind and sea state conditions prevailing during the 24 hours preceding each sampling occasion shall be recorded.

Appendix E

1. Sampling Locations

a) Sites:

i) 3 vertical transects located on the rocky substrate of The Noises Islands, 2-3 sites on each transect.
ii) 3 vertical transects at a control location, 2-3 sites on each transect.

2. Survey Parameters

Each survey shall consist of photographs of the biota occurring within permanent guadrats established at each site. Digitising techniques will be used to quantitatively assess any changes in biota recorded by the photographs.

3. Survey Timing

The surveys will be carried out in accordance with the following programme:

i) three times prior to the commencement of disposal.
ii) during disposal, one survey, prior to the completion of dumping.
iii) 3, 6 and 12 months after the completion of the disposal operation.

AUCKLAND REGIONAL WATER BOARD

RIGHT IN RESPECT OF NATURAL WATER

WATER RIGHT NO. 907448

This right is issued pursuant to Section 21(3) of the Water and Soil Conservation Act, 1967, by the Auckland Regional Council, exercising the functions, duties and powers of the Regional Water Board (in this right called ' the Board').

DETAILS OF RIGHT

Grantee:	PORTS OF AUCKLAND LIMITED
Date of Expiration of Right:	2 years from the date of commencement of disposal operations.
Legal Description of Land:	N/A
Local Authority:	N/A
Purpose of Right:	To discharge dredged material from maintenance dredging of existing berths, basins and approaches within commercial areas of the Port of Auckland to waters of the Hauraki Gulf.
Works:	N/A
Site Address:	N/A
Map Reference:	The disposal area measures 2300 x 1700 m and is bounded by the lines joining the points defined by these coordinates:

36°38.92'S	174°58.12'E
36°39.18'S	174°59.29'E
36°39.78'S	174°59.09'E
36°39.52'S	174°57.93'E

Quantity:	The maximum total discharge during the term of this right shall not exceed 270,000 cubic metres of saturated sediment measured in situ plus an unspecified volume of carrier seawater.

SPECIAL CONDITIONS ON RIGHT:

1. That waste material shall not be discharged during the months of January, November or December in any year.

2. That the waste material shall be discharged according to the manner described in Appendix A.

3. That the grantee shall submit a sampling program for the approval of the Council, for the purpose of defining and characterising the material to be dredged and the dredging units. The sampling programme must be sufficient to reasonably characterise the material which is to be disposed of from each dredging unit.

4. That the dredging procedure include mechanical screening or some similar mechanism which guarantees that maintenance dredging material will be free of man-made rubbish.

WATER RIGHT NO. 907448

5. That daily disposal records shall be kept for each barge load of dredged material discharged at the site detailing:

- the dredging unit and locality within that unit from whence the material was dredged.
- the precise disposal locality as identified on the gridded disposal site plan.
- the volume discharged.

6. That the records specified in Condition 5 above must be available for inspection by staff of the Council, and a report on this information shall be prepared monthly and submitted to the Council by the last day of each month.

7. That no waste material shall be discharged at such a rate as to exceed current USEPA water quality criteria for the protection of marine organisms beyond the boundary of the disposal site.

8. That the acceptability for unconfined marine disposal of material from any dredging unit shall be determined in accordance with the protocol specified in Appendix B.

9. That the Grantee shall submit all results of investigations specified in Condition 8 above to the Council for confirmation of the acceptability of unconfined marine discharge of the dredging unit material to which the investigations relate, prior to the discharge of this material.

10. That no waste material determined by the protocol to be unsuited for unconfined marine disposal shall be discharged.

11. That the Grantee shall carry out a monitoring programme as specified in Appendix C. The physical and biological monitoring shall be carried out monthly during disposal activities and 6 monthly for the balance of the water right, provided that bioaccumulation monitoring shall be carried out at the end of disposal activities and six monthly for the rest of the term of the right. Chemical monitoring shall be carried out every 12 months during the term of the water right. All results an interpretation except those which relate to the analysis of synthetic organic chemicals shall be forwarded to the Council within two months of completion of each monthly, 6 monthly or 12 monthly programme. Results and interpretation of the synthetic organics chemical analyses shall be forwarded to the Council within four months of completion of the 12 monthly programme.

<u>April 1994 Review</u>

i) That the following monitoring requirements be deleted from future surveys:

   a) Bio monitoring
   b) Chemical analysis of sediments within the disposal site (except for those required as part of the Alternative Monitoring Provisions below).
   c) Analysis of organic carbon levels, lead and chlordane.
   d) Analysis of PAHs other than at a reduced number of sampling sites as approved by the Group Manager, Environmental Management Department, ARC.

ii) That, apart from the bathymetric survey required by Appendix C.2.i, the fourth survey previously scheduled for October/November 1993 be deleted from the monitoring programme and replaced with the 'Alternative Monitoring Provisions' below.

iii) That the following 'Alternative Monitoring Provisions' shall be employed by the Grantee on the area of the disposal site:

WATER RIGHT NO. 907448

a) That changes in the height of the disposal mound shall be monitored using an arrangement of sediment accretion/erosion pins measured at least once each six months from their date of installation. Final details of the number of pins, their design, their arrangement of the site and the measuring and reporting techniques to be employed shall be approved in writing by the Group Manager, Environmental Management Department, ARC.

b) That the available wind, wave, current and weather records shall be reviewed by the Grantee to provide conclusions on the times when conditions likely to cause mobilisation of sediment on the disposal site have occurred. This information shall be supplied to the Group Manager, Environmental Management Department, ARC within six months of the approval of this change of consent conditions.

c) That the Grantee shall collect and analyse core samples from the disposal mound to provide information on the mounds thickness, the mounds volume, the degree of compression of the original sea bed beneath the mound, the degree of fine sediment loss from the mound and the ability of fauna to survive the disposal operation and to burrow to the mound surface. Final details of the number of cores, their arrangement, and the analytical and reporting procedures shall be approved in writing by the Group Manager, Environmental Management Department, ARC.

12. That prior to commencement of discharge at the site, a baseline survey shall be carried out, at the standard, additional and bioaccumulation sites specified under Condition 11, which is sufficient to permit the detection of post-disposal change in physical, chemical and biological parameters at the respective statistical levels specified under Condition 11. Samples collected from additional sites may be archived for later analysis if post-disposal examination at these sites is triggered as described under condition 11.

13. That the programme specified in Condition 11 above may be reviewed after a period of twelve months by the Council but that in no case shall the program so reviewed require a level of monitoring higher than that stated in the program specified by the said condition.

14. i) That if at any time in the opinion of the Council the Grantee does not fulfil the conditions of this Right and/or the monitoring programme reveals measurable change in the abundance and/or well being of the aquatic biota and their habitat outside the disposal area, the Council may require the Grantee by notice in writing to cease the disposal of dredged material within 48 hours.

ii) That disposal of dredged material shall not commence after any such notice is given to the Grantee until such time as remedial measures which will redress detrimental impacts observed are implemented to the satisfaction of the Council.

15. That the Grantee shall submit a Closure Plan to the Council not later than three months prior to the expiry of the water right detailing the following:

i) assessment and description of the short-term (12 months) and predicted long term (5 years) characteristics the disposal site with respect to:

- bathymetry of the disposal site
- stability of the disposed material
- any other factors or characteristics of the disposal site which could result in detrimental impacts on the abundance and diversity of aquatic biota and their habitats beyond the boundary of the disposal site and the impacts of any such material and/or contaminant transfer.

ii) assessment of the residual long term risk to the marine community and its habitat.

iii) the steps proposed to ensure there will be no detrimental impacts on aquatic biota and their habitats outside the disposal area.

16. Prior to the expiry of the right, the Grantee shall take all such steps as may be directed in writing by the Council to ensure there will be no detrimental impacts of the kind described in Condition 15.

17. That the Grantee shall be bonded financially for performance of these conditions including monitoring standards and any remedial works required, the value and terms of which shall be determined by the Council. This condition shall not apply so long as 50% or more of the shares in the grantee shall be owned by a local authority or other public authority.

18. That the Grantee shall undertake a water quality monitoring programme in respect of The Noises as specified in Appendix D. Collection and analysis procedures used in this programme shall be in accordance with APHA (17th Edition) or equivalent as approved in writing by the Council. All data obtained in accordance with this programme shall be submitted in writing to the Council within 48 hours of sample collection. Final details of the programme shall be submitted to, and approval obtained from, the Council as follows:

i) the precise location of all stations, prior to the commencement of sampling.
ii) the weather conditions under which pilot survey samples are to be collected, prior to the commencement of disposal.
iii) the statistical relationship between levels of non-filtrable residue at The Noises stations and at the control stations, prior to the commencement of disposal.
iv) the sampling regime for the impact survey, prior to the commencement of disposal.

19. If on any sampling occasion following the commencement of disposal the level of non-filtrable residue in samples collected from The Noises stations exceeds by more than 20 grams per cubic metre the level established by the pilot survey as the baseline relationship between The Noises and the control stations (all samples having been collected and analysed in accordance with Special Condition 18) then the Grantee shall within 3 days of this sampling occasion consult with the Council as to the likely cause.

20. If on any sampling occasion following the commencement of disposal the level of non-filtrable residue in samples collected from The Noises stations exceeds by more than 50 grams per cubic metre the level established by the pilot survey as the baseline relationship between The Noises and the control stations (all samples having been collected and analysed in accordance with Special Condition 18) then the Grantee shall within 24 hours of this sampling occasion cease disposal and shall not resume until the Council has confirmed in writing the conditions under which the resumption of disposal may occur.

21. If on any sampling occasion following the commencement of disposal the level of non-filtrable residue in any one Noises sample shows an increase of more than 80 grams per cubic metre above the level established by the pilot survey as the baseline relationship between the Noises and the control stations (all samples having been collected and analysed in accordance with Special Condition 18) then the Grantee shall within 3 days of this sampling occasion consult with the Council, as to the likely cause.

22. That the Grantee shall undertake a biological monitoring programme as specified in Appendix E. Results and interpretation shall be submitted to the Council within 2 months of completion of each survey. Details of the precise location of all sites shall be submitted to, and approval shall be obtained from the Council prior to the commencement of sampling.