INDEPENDENT EXPERT GROUP ADVICE ON POMC'S ENVIRONMENTAL MANAGEMENT PLAN, 6 SEPTEMBER 2007

BACKGROUND

The Inquiry considering the Channel Deepening Project (CDP) has asked the Secretary DSE to seek advice from the Independent Expert Group (IEG) on the Port of Melbourne Corporation's (PoMC) Environmental Management Plan (EMP) (Revision C) on:

1. "…any issues which you believe the Inquiry should be made aware of regarding the EMP"
2. "…an overall assessment of the EMP's robustness as a workable document".

In responding to the Inquiry's request, DSE has asked the IEG to comment on the adequacy of the EMP using the same format as the IEG's May 2007 Advice on the Supplementary Environment Effects Statement (SEES) that were the focus of:

1. The overall conceptual and technical basis of the EMP;
2. The adequacy of the EMP to protect marine ecological assets, especially seagrass. Specific comment is sought on the proposed Environmental Limits and monitoring strategy; and,
3. The feasibility of implementing the Channel Deepening Project as proposed on the basis of the EMP.

Note that the IEG is providing advice on the Entrance scour reports separately to this advice.

IEG ADVICE ON THE EMP

EXECUTIVE SUMMARY

The EMP (Revision C) (i.e. the "EMP") contains considerably more detail on Bay-wide monitoring in Annexure 8 (than the EMP exhibited with the SEES). The Bay-wide monitoring program considers most of the areas raised as matters to be addressed by the EMP in the IEG's May 2007 advice. Annexure 8 contains some detail on each of these monitoring programs to provide an indication of the overall approach and amount of effort planned.

The IEG notes that the EMP is an evolving document, and consistent with other projects of this nature, will not take its final form until after the conditions for any project approvals are incorporated. In finalising the EMP, the following matters need to be addressed in Annexure 8:

- Specification of response levels or Environmental Limits, informed by statistical analysis, which might be used to guide management decisions.
- The provision of sufficient details of the statistical methods which will be used to analyse the data resulting from these monitoring programs,.
- Clarification of how the monitoring programs are intended to separate the effects of the CDP from those of other events in the Bay.
- Further explanation of the justification for the levels of augmentation proposed for existing programs.
- Explanation of the links between actual, rather than predicted, turbidity plumes, the spatial pattern of potential impacts, and the monitoring to address these effects.

The IEG strongly commends the statistical approach adopted in setting the turbidity Environmental Limits for seagrass, and regards it as a model for other aspects of the EMP. The IEG has sought clarification of the Environmental Limits for seagrass, before it advises on the soundness of these specific limits.

For the proposed monitoring of the plume intensity and extent to be adequate to capture the possible variations in the plume during the CDP, it would be appropriate for additional plume monitoring to be conducted during major activity blocks in the dredging schedule. Satellite imagery, and/or regular (e.g. weekly) aerial photographs of the plume, would suffice for the additional monitoring.

In relation to sediment transport, the proposed monitoring program consists of a single LIDAR bathymetric survey prior to dredging. To address potential sediment transport issues, an assessment of the Sands region following dredging is also required. The IEG supports recommendations made by PoMC's expert consultant, Prof. Terry Healy in June 2007 in relation to the need for monitoring and modelling of the Sands region, and suggests that these recommendations are incorporated in the EMP.

In relation to the Entrance dredging, the IEG acknowledge that it is not practical to accurately quantify rock spill (i.e. material not retrieved by the dredger or clean-up processes) once it has moved either into the canyon as "rockfall" or south of the Rip Bank. Consequently, it would seem prudent that the EMP includes a method to optimise the dredging and clean-up process to minimise rock spill. While the IEG does not comment on rock scour in the Entrance and its allied effects in this advice, it notes

that it may be critical to retrieve as much rock spill as possible, irrespective of where it is, to reduce both the extent and the impact of any rock scour processes, and rock fall and its associated ecological impacts, by:

- Determining the quantity of rock spill not being retrieved during the dredging and clean-up process; and,
- Optimising the clean-up process to minimise the rock spill and rock fall;

Estimation of rock spill may be achievable through multi-beam echo sounding campaigns, similar to those reported in the Rock Scour reports. Clarification may be needed on the use of Stone fishing to retrieve rock spill, and the proposed "soft" startup procedure for the hydrohammer to protect marine fauna.

The IEG considers it would be prudent to assess the implications of the EMP for the timely and cost-effective implementation of the CDP, and that this should be addressed in finalising the EMP.

The Inquiry asked the IEG for, "an overall assessment of the EMP as a workable document." The workability of the document can only be fully assessed once the details outlined above are incorporated.

1. THE OVERALL CONCEPTUAL AND TECHNICAL BASIS OF THE EMP

The IEG's May 2007 advice on the SEES supported the approach adopted and the general conceptual design of the EMP exhibited with the SEES, but noted that the design of the medium- and long-term and post-construction monitoring need to be developed, beyond a broad commitment to Bay-wide monitoring and six-monthly management reviews. In particular, the IEG noted in its advice that for the Bay-wide monitoring programs:

> "It will be important that these monitoring programs:
>
> - Include indicators for key environmental assets at potential risk;
> - Include any additional indicators required for diagnosis of cause and effect; and,
> - Provide adequate spatial and temporal coverage and resolution to reliably detect and diagnose change at agreed levels.
>
> The design of management and monitoring programs has three steps:
>
> 1. Outlining the conceptual basis;
> 2. Specifying the way in which the concepts will be translated into a detailed design and assessment model; and,
> 3. Development and implementation of the final technical design to be used for each of the monitored variables."

The IEG also noted that:

> "It is important that the [EMP] monitoring design, and assessment and management responses, for the medium term (six-month) and post-construction phase, are developed as soon as possible."

The IEG's response to the EMP (Revision C) (i.e. the "EMP") focuses on the Bay-wide monitoring programs component. It is recognised, however, that the adoption of particular Environmental Limits for the protection of Bay-wide assets may have implications for process and operational components of the EMP.

The EMP now contains considerably more detail on Bay-wide monitoring in Annexure 8 (than the EMP exhibited with the SEES). The EMP proposes monitoring programs in eight areas: seagrass, water quality, nutrient cycling, plume intensity and extent, contaminants in fish, algal blooms, little penguins and fish stocks. Some of these programs are existing programs, which are to be augmented where deemed appropriate. This set of programs covers most of the areas raised as matters to be addressed by the EMP in the IEG's May 2007 advice, and more recently in its 18 and 31 July 2007 Advice to the Inquiry. The EMP, in most cases, also includes an explicit commitment to post-construction monitoring.

Annexure 8 contains sufficient detail on the Bay-wide monitoring programs to provide an indication of the overall approach and amount of effort planned. In most cases, it provides at least indicative locations of sampling stations, temporal frequency and variables to be measured. (Refer to Appendix A for further comments on the Bay-wide programs.) The IEG understands that the detailed statistics and other approaches for interpretation, analysis and response are still under development, and that monitoring programs outlined in Annexure 8 may be refined as these are developed. Further, response levels or Environmental limits which might be used to guide management decisions are also still under development.

Accordingly, the EMP, particularly Annexure 8, does not yet provide the necessary detail for its effective implementation. Generally, the justification for the levels of augmentation proposed for existing programs needs to be strengthened. Further, for many of the augmentation monitoring programs, the link between the proposed locations to be sampled and information needs to effectively inform management of the CDP require clarification. For example, the links are unclear for the recreational fisheries program. The IEG acknowledges a broader benefit of building on existing long-term monitoring programs, but there should be a clear indication of which monitoring programs:

1. Contribute to long-term information about the Bay;
2. Are intended to identify large-scale effects of the CDP; and,
3. Focus on important, spatially restricted local effects of the CDP.

For a substantial number of the proposed programs, it is not yet clear which of these purposes is to be met. Without such clarity, it is not possible to assess whether the monitoring is appropriate. For example, the monitoring of key species in seagrass beds appears to have been designed independently of the changes that might occur as a result of the CDP. The issue of interest here is whether those species are affected by the loss of seagrass, and for these locations to be appropriate, one would think that they should cover a mix of seagrass areas, both affected and unaffected.

The IEG's May 2007 advice emphasized the importance of an integrated approach to monitoring design, assessment and management responses: "Experience has shown that the development of the monitoring design, assessment model and management response strategy need to proceed in an integrated way. Adopting a monitoring design, and then developing analysis and interpretations post-hoc is rarely successful.". As mentioned above, Annexure 8 has yet to provide details of the statistical methods which will be used to analyse the data resulting from these monitoring programs. In the absence of any formal analysis or statistical design, it is not possible to comment on the statistical rigour, confidence and power with which the proposed monitoring programs will be able to detect change, and particularly difficult to comment on the ability to attribute change to dredging or other causes.

The SEES notes that factors external to the CDP will influence the indicators included in the Bay-wide monitoring program (p. 17-45). The IEG agrees, but suggests it is therefore important that prior to project implementation consideration be given how to attribute changes due to dredging from changes due to other factors, rather than have to resolve such questions at the time they become an issue.

A well-designed monitoring program would allow:

1. Identification of its purpose, relative to the required protection or management objectives for environmental assets.
2. Understanding of its scientific basis with respect to impact pathways.
3. Consideration of the program’s empirical basis in terms of:
    - the locations of potentially affected assets;
    - availability of background data;
    - temporal sensitivity of impact indicators; and,
    - statistical model of detection.

The IEG provides further discussion of the framework for monitoring, and attribution of cause and effect of environmental changes in Appendix A of this document.

2. THE ADEQUACY OF THE EMP TO PROTECT MARINE ECOLOGICAL ASSETS, ESPECIALLY SEAGRASS. SPECIFIC COMMENT IS SOUGHT ON THE PROPOSED ENVIRONMENTAL LIMITS AND MONITORING STRATEGY

(i) Environmental Limits for turbidity to protect seagrass.

The proposed Environmental Limits for turbidity to protect seagrass have been revised to a limit of 15 nephelometric turbidity units (NTU) as a 2-week moving average, and to a limit of 25 NTU as a 6-hourly moving average (EMP, p. A4-89). The EMP specifies management actions to be undertaken if turbidity exceeds numerical 'response levels' one or two, or the overarching Environmental Limits. However, the response levels are still being developed (EMP, p. A4-91). The IEG understands that the revised Environmental Limits for seagrass are based on analyses by Prof. David Fox, as presented in his reports: "Statistical Aspects of Turbidity Monitoring – Setting Environmental Limits", and "Control Charting". These Environmental Limits are designed to ensure that the following ecological objective put forward by Mr Chidgey is met in seagrass beds: "The incident light at 3 m should exceed 15% of surface irradiance for at least 50% of the time in any two week window." IEG is assuming that PoMC has derived this objective from Mr Chidgey's report, SEES Technical Appendix 50.

The approach adopted in setting Environmental Limits for seagrass has a number of positive features:

- Limits are related to a clearly-stated ecological objective;
- There has been a rigorous statistical analysis of experimental data and observations, to relate the ecological objective to statistical limits for turbidity;
- Historical background data and model predictions have been used to assess the likelihood of both Type 1 and Type II errors for proposed environmental limits.

The IEG strongly commends this approach, and regards it as a model for other aspects of the EMP. However, there are a number of technical aspects of the analysis for the proposed environmental limits, at least as presented in the reports and submissions by Prof. Fox, Mr Chidgey and PoMC, which the IEG finds ambiguous or confusing.

While there is much valuable analysis and interpretation in the reports by Prof. Fox, the IEG would like to see a clearer connection between the ecological objective in Mr Chidgey's report, the statistical analysis in Prof. Fox's reports and the Environmental Limits for turbidity in the EMP. Prof. Fox's statistical reports do not recommend a specific environmental limit. The report, "Statistical Aspects of Turbidity Monitoring – Setting Environmental Limits", states explicitly that both reports address only statistical issues (p. 1), and other considerations will have to be taken into account in setting limits. Neither report analyses the specific Environmental Limits for seagrass actually proposed in the EMP. Given the technical ambiguities and issues outlined below in Appendix B, the IEG finds it hard to evaluate whether the proposed Environmental Limits for turbidity will ensure compliance with the ecological objective. Moreover, the EMP (p. A4-91) states that response levels for seagrass have not yet been established, and without those, it's not possible to determine whether compliance with the proposed Environmental Limits is likely to be achieved.

The EMP proposes to generate data that will provide a better picture of the relationship between NTU and light on the seabed by simultaneously deploying light and turbidity meters during the first year of dredging. It would be appropriate to monitor at the selected sites before dredging in order to eliminate any future debate about background levels of turbidity, particularly as some of the limits are related to undefined background levels. This simple data collection could have been initiated much earlier, and would have greatly simplified the analysis of Environmental Limits undertaken by Prof. Fox. PoMC should consider the advantages of such a deployment at one or more key sites, so that information is available in advance of the commencement of dredging. In addition, PoMC could examine trends that have already been identified from historical data to provide some synthesis of the current background conditions.

On the basis of the information before it, the IEG is not currently in a position to conclude its advice on the proposed Environmental Limits, but has sought clarification which will be the subject of supplementary advice to the Inquiry in the near future.

The IEG provides further discussion of seagrass turbidity limits in Appendix B of this document.

(ii) Bay-wide monitoring for water quality, nutrient cycling and algal blooms.

These programs, although described separately, are strongly inter-related. The proposed water quality monitoring program builds on the EPA's long-term monitoring program, augmented by other sites based on proximity to dredging and/or assets, which have been sampled as part of baseline monitoring for CDP. The variables measured relate primarily to nutrients, phytoplankton production and oxygen consumption, and heavy metals. If cost-effective instrumentation is available, it would be desirable to add Photosynthetically Available Radiation (PAR) to the set of variables to be measured in depth profiles, as this provides a more rigorous assessment of changes in light attenuation and availability.

The nutrient cycling program proposes to monitor benthic nutrient, oxygen and carbon fluxes twice per year at 2 sites, and 4 times per year in Hobson's Bay. This will allow assessment of long-term changes in sediment respiration rates and denitrification efficiencies. A key issue here will likely be the extent to which such a limited set of sites and times can provide the statistical power to detect changes in regional fluxes and denitrification efficiency. This may partly depend on the detailed experimental design of measurements within sites i.e. the number of 'landers' deployed. An analysis of this should be undertaken before dredging commences in the area.

The nutrient cycling program also involves continuous monitoring of 'chlorophyll a' (presumably fluorescence), Dissolved Oxygen (DO), temperature and salinity using moored sensors at two depths at four sites, including the three benthic sites. The algal bloom monitoring effectively consists of the monthly water quality monitoring for chlorophyll, and the continuous monitoring. The continuously logged data will be assessed fortnightly in Hobson's Bay during dredging, and monthly at other sites / times.

A key question here, given the spatial and temporal patchiness of algal blooms, will be the power of the proposed monitoring program to detect changes in bloom frequency, extent or intensity. One would imagine that this could be assessed rigorously, based on a statistical analysis of historical data from the EPA, and possibly the CSIRO Port Phillip Bay Environmental Study. Observations could also be supplemented from other sources, such as ad hoc observations from survey-vessel skippers.

The SEES identified risks with respect to the composition of blooms, and in fact the risks associated with impacts of toxic algal blooms rated higher than those associated with general increases in primary production and bloom frequency and intensity. Given this, it may be possible to monitor phytoplankton species composition. If the cost of an exhaustive taxonomic analysis of each sample is deemed to be disproportionate to the risks, an assessment of each sample to look for abundant toxic or nuisance bloom species should be feasible and helpful. It is conceivable that this assessment could be triggered by chlorophyll levels exceeding a given response level.

Attribution will be a key issue for these monitoring programs, given high levels of natural variability in these variables in response to other forcing (river loads, STP loads, seasonal cycles, etc). This is discussed further in Appendix A.

(iii) Monitoring (or mapping) of the plume intensity and extent

Generally, a key purpose of a plume monitoring program is to be able to characterise the plume during dredging so that any observed changes in the ecosystem can be either attributed to the plume or to other natural or anthropogenic factors in the Bay. In the absence of this knowledge of the plume, judgments about the effects of the plume cannot be made.

The EMP proposes a monitoring program to map the plume intensity and extent to detect differences between the modelled plume predicted in the SEES and the observed plume during project implementation (p. A4-138). The program is proposed to be conducted on at least one day in the first week of each of the major dredging activities in Project Areas 1, 2, and 3.

The plume monitoring program addresses a question raised in the IEG's May 2007 advice, noting that the assessment of risk to nutrient cycling and other environmental assets depends on the accuracy of predictions about plume extent and intensity. The plume monitoring program compliments the continuous monitoring of turbidity at ecological assets proposed in the EMP; this is effectively 'near real time' adaptive management. While plume monitoring is to be based on underway vessel transects, supported by satellite imagery where possible, only a very limited number of satellite images of the plume are to be required under the EMP. Indeed, if no images become available in 6 months, only one set of aerial photographs will be taken. The IEG considers that satellite imagery, and/or regular (e.g. weekly) aerial photographs of the plume, would effectively map the plume extent during dredging, particularly during calm weather.

The proposal to conduct the plume monitoring program on at least one day in the first week of each of the major dredging activities raises a questions in relation to the dredging schedule that indicates that dredging in the South Channel and in Williamstown Channel will take place in major blocks, separated in time, and potentially in different seasons. The IEG's May 2007 Advice raised questions about whether one might expect the source term from dredging to change over time, during prolonged periods of dredging, and that this uncertainty should be resolved through the EMP. For both these reasons, it would seem inappropriate to restrict monitoring of the plume intensity and extent to the first week in which dredging occurs in each project area. It would be appropriate for some plume monitoring in each major activity block, and preferably some monitoring to occur say half-way through as well as near the beginning of each block, in order to address this issue. If satellite monitoring, referred to above, proves to be robust it may be that satellite monitoring alone would suffice for these additional times.

Further, if the plume monitoring is to be used in some way to define "substantial departures" (EMP, p. A4-127, 138) from the modelling presented in the SEES, it would be important that this monitoring is conducted after several days of continuous dredging in reasonably calm conditions i.e. during low wind when the plume is most stable. This would enable both dredging and non-dredging sources of turbidity (e.g. natural re-suspension) to be identified.

Further clarification of the following aspects of the plume monitoring would assist to improve its effectiveness:

- The planned "forecast" of "the location and intensity of the plume and expected turbidity levels to inform management actions." (p. A4-92). The EMP is not clear on the types of forecast to be undertaken and their use.
- The quantitative specification of a "substantial departure" (p. A4-127) in "plume intensity and spread" (p. A4-138), and how this is to be utilized in combination with the NTU limits at selected locations (Table A4-6-16, p. A4-89).
- A clear basis for differentiating "Indicative Turbidity Conformance Locations" and "Other Turbidity Locations". (p. A4-89)

(iv) Monitoring of turbidity at assets

For protection of ecological assets, the EMP proposes a turbidity monitoring program which focuses on continuous monitoring of turbidity at key sites or assets, supplemented by monitoring of the plume. The selection of EMP monitoring sites is related to the plume intensities and extent predicted in the SEES modelling and the associated exposure of vulnerable environmental assets.

Further clarification of the following aspects of the turbidity monitoring would assist to improve its effectiveness:

- Derivation of the response levels in the context of protective Environmental Limits (p. A4-91); and,
- The "additional monitoring" in the event of a Level 1 exceedance, taking account of how rainfall events would affect the plume (p. A4-91).
- Need for additional turbidity monitoring sites at key assets (e.g. the Marine National Park at the Entrance).

(v) Monitoring of the stability the Sands region including the southern Bay beaches

The IEG's May 2007 Advice highlights the need to monitor and model the stability of the Sands region. The EMP proposes a single LIDAR bathymetric survey prior to dredging (p. A4-54). .

The IEG consider the proposed monitoring program in the EMP is not adequate to assess potential medium- to long-term impacts on sediment transport in the Sands region, including erosion to beaches, or to inform management decisions including whether remedial action may be required. The IEG supports the recommendations made by PoMC's consultant, Prof. Terry Healy in his Expert Witness Statement in June

2007, in relation to the need for additional monitoring and modelling of the Sands region including beaches, and supports the incorporation of these recommendations in the EMP.

In order to detect significant changes to the Sands region, monitoring surveys would need to be conducted during and after the dredging and linked to scheduling of future maintenance dredging campaigns. (Refer to IEG May 2007 and July 2007 Advice for further details.) While the SEES modelling of sediment transport in the Sands was unable to accurately predict the sediment fluxes, a model could be calibrated against the LIDAR surveys, multi-beam surveys, maintenance dredging volumes and hence channel infilling rates. Such modelling would allow predictions of the longer-term effects on the Sands region of the capital dredging, and therefore would be a desirable component of the EMP.

If monitoring and/or modelling points to long-term changes, for example in the depletion of sediment within the Sands region, remedial action could be taken by placement of dredged sands within this region.

(vi) Monitoring of dredging and rock spill at the Entrance

The EMP Annexure 4 proposes controls for dredging and clean-up operations to minimise rock spill (Table A4-6-7, p. A4-64). Conformance with these environmental controls is specified in a project delivery standard (PDS), where the frequency of spill clean-up is related to the quantity of material dredged and the predicted sea state (i.e. storms). A systematic method for ensuring that the dredging and clean-up operations are carried out approximately over the same locations is presented. However, a method is not yet proposed to gauge the quantity of spill that has either occurred or been recovered by the clean-up operations.

The IEG acknowledges that, once rock spill not retrieved by the dredger has moved into the canyon as “rockfall” or south of the Rip Bank, it would not be practical to quantify this material. Considering the ecological impacts of rockfall, it would seem prudent to include in the EMP a method to optimise the dredging and clean-up to minimise the rock spill, having regard to the cost effectiveness of available methods.

Since the trial dredging at the Entrance, extensive surveys and investigations have been conducted (refer Rock Scour reports[1]). These reports indicate that there may be aspects of the dredging that will cause further physical and ecological impacts on the Entrance in the future through rock scour and erosion processes, after the dredging has been completed. In addition, it is evident that some loose material not retrieved by the dredger has moved a considerable distance away from the Trial Dredge area and into the surrounding Great Shipping Channel (GSC).

Consequently, it may be critical to retrieve as much rock spill as possible, irrespective of where it is, to reduce both the extent and the impact of any rock scour and erosion processes, and rock fall and its associated ecological impacts.

The IEG considers that there would be considerable benefit to be gained by:

- Accurately determining the quantity of rock spill not being retrieved during the dredging and clean-up process; and,

[1] IEG will comment in detail on the Entrance rock scour issue in separate advice

- Optimising the clean-up process to minimise the rock spill and rock fall.

In the Rock Scour report (Section 1, p. 3) the comparison of two multi-beam echo sounding campaigns demonstrates that there is very little loose material on the seabed in the GSC. This degree of survey accuracy suggests that it could be used to determine the dredged volume over a period of time. During both the dredging and clean-up cycles of the dredger, the on-board instrumentation may be used to determine the additional tonnes of rock removed and hence, assuming in situ densities of rock and sea water, the volumes removed. By subtraction, an estimate figure of the amount of rock spill not retrieved may be made. While use of this method to estimate rock spill is crude and subject to inaccuracies (due to variability in rock density and survey tolerance), it could possibly be used to identify large rock spill losses if they should occur.

With respect to the clean-up operations, there appear to be two potential areas where improvements might be considered. First, the EMP is concerned with ensuring that the correct areal extent of clean-up has been achieved, irrespective of whether the clean-up has actually removed all the material left behind by the dredging operations. It would therefore be prudent to include, in the early stages of the work an analysis of the effectiveness of picking up spilt rock as the clean-up proceeds. This would demonstrate whether clean-up runs, as presently specified in the PDS would be beneficial and cost-effective, and whether more or less were appropriate.

Second, it is clear that some rock spill is moving away from the dredging areas under the influence of currents, waves and gravity. In the IEG's view this demonstrates the necessity of developing some method of detecting this movement and re-directing the clean-up operations to the requisite zone. The most effective method identified so far is the multi-beam surveying, augmented wherever possible by diver or remotely controlled video footage of the seabed. To some extent this is foreshadowed by the procedures described (EMP, p. A4-66), but it would seem appropriate for these procedures to be carried out more frequently and that they are associated with a management response that is dependent on their outcome.

Stone fishing operations are mentioned in this table under "Application" (EMP, p. A4-64), but do not seem to feature thereafter. The EMP should clarify whether they are an adjunct to dredging operations or to clean-up operations.

(vi) Hydrohammer noise control

The EMP describes the start-up procedure for the hydrohammer as "either intermittent use or gradual increase in the hammer energy during the initial 10 minutes of use (p. A4-68). As the IEG understands it, this procedure indicates that "intermittent use" is at normal or full power.

The Technical Report on Underwater Noise (SEES, Appendix 64) includes a number of recommendations for use of the hydrohammer to minimise potential impacts (p. 7-9). This report recommends a "soft" start to the operations in order to enable marine fauna to move away from the noise source where prolonged exposure to could cause injuries. The recommendation states:

"A soft start may allow animals close to the source to move away. This can be done by using the lowest power possible and hammering at a low rate during the first 20-30 minutes before ramping up to the target power and hammering rate."

The IEG considers that intermittent use of the hammer at normal or full power is not consistent with the recommendation(s) of Appendix 64, and therefore would not be protective of marine fauna. If a low power start-up is not a feasible option for the hydrohammer, it might be possible to consider use of some alternative noise producing device initially to encourage fauna to leave the area.

(vi) Effects on biota of the Bay

Effects on the biota, including seagrass, fish, and penguins, are addressed through a series of "Bay-wide" programs, which are described in Annexure 8. As discussed earlier, the IEG is satisfied with the range of programs to be established, although there is at least one program that needs to be clearly linked to the major risks of the project. The rationale for the DMG marine pest inspection programs is not clear, and this monitoring does not appear related to an identified important risk (EMP, p. A4-23).

As mentioned above, for the other programs, there is presently limited information for the IEG to assess the robustness of the monitoring. In particular, the logic behind the choice of sampling times and locations needs to be strengthened, and information provided to explain the adequacy of the sampling programs. In particular there needs to be a clearer indication of the kinds of changes to the Bay that the monitoring will detect. These issues are described in Appendix A.

3. THE FEASIBILITY OF IMPLEMENTING THE CHANNEL DEEPENING PROJECT AS PROPOSED ON THE BASIS OF THE EMP

The IEG's May 2007 advice highlighted that it would be prudent to assess the potential risk of the EMP to the timely and cost-effective implementation of the CDP. Put simply, if the CDP could be halted or delayed whenever adopted environmental limits in the EMP are exceeded, then it would seem appropriate to consider how often this may occur, what kinds of delays could result, and what would be the expected impacts on CDP completion and costs.

The IEG has not yet seen any formal quantitative analysis of these risks. The risk assessment conducted in the SEES has focused on assessing and managing risks to environmental, social and economic assets, rather than risks to the delivery of the CDP. In the case of the environmental monitoring programs for noise and turbidity, where Environmental Limits and responses have been specified, it is presumably possible to undertake such an analysis. The analysis provided by Prof. Fox for turbidity does contain information directly pertinent to the likelihood of exceeding environmental limits, although it has not been assessed from this perspective. In the case of the Bay-wide monitoring programs, given that the framework for interpretation and assessment has yet to be specified, it is probably not possible to carry out a quantitative evaluation of these programs at this time.

It could be argued that since the SEES has identified for the most part that risks to environmental assets from the CDP are low, and has adopted a conservative approach in assessing risks, it should follow that the risk to the CDP from adopting an EMP which protects those assets is also low. However, that is not necessarily guaranteed as it will depend in practice on the extent to which the EMP adopts a precautionary approach in protecting assets, and the ability of the EMP to distinguish impacts of dredging from other pressures on assets.

Appendix A - Bay-Wide Monitoring Programs – Discussion of a Broad Framework of Monitoring, and Attribution of Cause and Effect

Important aspects of the EMP's Bay-wide monitoring programs are to detect change and determine whether this change differs from that which is observed historically or is predicted to occur as a result of the CDP.

(i) Short-term monitoring during project implementation

The technical approach to development of monitoring programs varies between a projects' implementation and post-construction stages.

The approach to monitoring during project implementation focuses on environmental parameters that allow quick responses, and the emphasis of sampling is on detecting anomalies in time – unexpected behaviour that may result in, or raise the risk of exceeding a particular environmental limit. This approach uses frequent sampling (e.g. 15-minute rate using NTU meters), and requires statistical tools capable of detecting important signals from long time series of data.

(ii) Medium- to long-term monitoring including post-construction

In contrast, medium- to long- term monitoring, including post-construction, would be expected to include sampling for several purposes:

- Verify that the impacts are no greater than predicted in the SEES;
- Detect or quantify flow-on effects to other Bay assets;
- Determine rates of recovery of important assets;
- Provide a check against effects that are unlikely, but of major consequences (e.g. algal blooms, effects on nutrient cycling); and
- Provide a check against possible effects on other Bay assets that are not of themselves ecologically important, but are of great public concern (e.g. penguins.)

Some of these are Bay-wide issues, while others focus on specific areas of the Bay (e.g. areas directly under the plume, parts of the Entrance, DMGs), discussed below.

The important aspects of medium- to long- term monitoring, including post-construction are to: (i) estimate the size of any change, and (ii) to determine whether such change is attributable to the CDP or reflects other natural or anthropogenic factors in the Bay. Achieving this requires different approaches to short-term monitoring programs controlling day-to-day operations, as many key assets do not respond quickly, so a temporal comparison is usually not possible. The focus in this case shifts to spatial comparisons, comparing the state of assets in areas putatively affected by the CDP to the state of assets in areas outside this influence. It is also helpful to be able to compare the state of assets before and after dredging occurs, and the best monitoring information typically involves collection of both spatial and temporal data. In many cases, however, we do not have extensive data prior to dredging in the parts of the Bay that will be of most concern, and it is possible that, for example, the plume will not behave as we currently expect. It will be necessary, therefore for post-construction monitoring to have a strong focus on spatial comparisons. Again, the most robust decision-making comes when we have data from several locations with and without dredging “impacts”.[2] In general, the more places that can be examined, the greater the chance of soundly attributing cause to any observed change.

Using this approach means that it is important to assess the state of Bay assets in locations at which impacts are predicted. The EMP provides details of those locations, mainly in Annexure 8. Some of the predictions are specified; for example, the DMG locations are specified, and PoMC has developed models to predict where any rock not retrieved by the dredger will fall in the Entrance. For other assets, particularly where the plume is involved, the SEES provides *indicative* predictions – it predicts the locations of impacts as long as weather during the actual dredging program does not differ too markedly from that used in the modelling, and as long as the source term is described accurately. In reality, local weather at the time might result in the plume behaving in different ways, and differences in the source term could also have non-trivial effects.

(iii) Approaches to monitoring assets

In the presence of these uncertainties (e.g. turbidity modelling predictions), there would appear to be two approaches to monitor assets.

First, by using information in the SEES, key locations could be selected for each asset, and these assets monitored during and after the dredging program. This approach would require monitoring at a substantial number of locations, and carries the risk that the locations chosen are not the right ones, given plume behaviour. This could result in the monitoring of many locations, some of which are not appropriate, and attribution of cause may rely on the supporting information that comes from continuous environmental monitoring at each location (e.g. using NTU meters). In the EMP, there is limited information for either the locations nominated, or the total number of locations nominated.

Second, by characterizing the plume behavior during the dredging program, and using this information to target areas that were subject to high levels of turbidity, and those that escaped the plume. These areas could be identified by direct measurement (e.g. remote sensing through airborne sampling or satellite data, or a network of turbidity sensors), or by the model if it could be used. The change in asset condition at these impacted and non-impacted sites could then be evaluated. However, it is not generally clear from the EMP whether monitoring sites are chosen on the basis of impacted and non-impacted locations.

(iv) Approaches to monitoring the physical environment

While the effects of the CDP are mostly physical, the flow-on effects relate to assets. The IEG considers that these flow-on effects cannot be soundly assessed without monitoring of the physical processes to determine the size of changes observed. A key priority during dredging is the monitoring of the turbidity plume, as discussed above. Other physical parameters may also warrant consideration, for example, to confirm the SEES predictions and to inform medium- to long-term environmental management:

[2] It is common in the literature to talk about “impact” locations, or impacted areas. This is not intended to pre-judge the monitoring results, but is a convenient shorthand to reflect areas of interest where significant impacts *could* occur.

- Sea levels at sites around the Bay integrate all physical circulation impacts into a single measurement, and therefore warrant monitoring.
- Currents in the South Channel are a relevant indicator of the effects of the project on matters such as flushing, residence times, larval transport, fish recruitment and likely changes to the Sands morphology. Current meter stations could be established in the South Channel and inside the Entrance following the completion of dredging.
- The monitoring of sediment movement in the Sands region could inform decisions to place material from maintenance dredging back into the Sands region in order to stabilize its morphology.

(v) Considerations for monitoring of 'Local assets'

The approaches detailed in (ii) above are appropriate for monitoring assets for which any impacts are likely to be localized and/or associated with the plume (e.g. seagrass, seagrass-dependent fish, snapper recruitment), and sampling programs should be capable of separating effects of the CDP from other causes. For this reason, the EMP should provide clear justification of either the locations chosen for sampling, or the number of locations to be sampled, to achieve this.

(vi) Considerations for monitoring of 'Bay-wide assets'

Some impacts could be Bay-wide, such as effects on denitrification, and PoMC correctly identifies the difficulties in attributing cause and effect relationships. For these effects, there are no possible "unimpacted" areas outside the Bay for comparison. In this case, the focus of the monitoring must be on time series, ensuring enough sampling to accurately represent the state of a particular Bay asset at a given time. The technical details required here are a justification of the number of measurements (e.g. denitrification sites, returning penguins) that are needed for an accurate snapshot, and a critical assessment of the time series necessary to be able to distinguish CDP effects from background. As with other monitoring components, the concept behind the monitoring is sound, but the current EMP does not provide enough information about the capacity of the existing programs to suit the purpose of CDP monitoring.

(vii) Considerations for monitoring of 'recovery of assets'

The final monitoring purpose for ecological assets is to assess recovery of impacted assets. These monitoring programs are only outlined in the EMP, and there is insufficient information for the IEG to comment on the technical robustness. In this case, particularly for seagrass and Entrance biota, the scale of the monitoring will depend on the magnitude and extent of the actual, rather than predictable impacts, so it is reasonable for detailed designs to be developed later.

APPENDIX B – TECHNICAL DISCUSSION OF SEAGRASS TURBIDITY LIMITS

Analyses linking the ecological objective to turbidity statistics are presented in Prof. Fox's report "Statistical Aspects of Turbidity Monitoring: Setting Environmental Control Limits".

The report derives regression relationships for Port Phillip Bay between Total Suspended Solids (TSS) and nephelometric turbidity units (NTU), and between Kd and TSS, based on observations and experimental results. The report uses the standard exponential function to convert Kd into % surface light as a function of depth. The report then constructs probability distributions for NTU and Kd at site 2006 in the south of the Bay, with and without dredging, based on observed time series at the site, and the output of the turbidity model. Care is taken to adequately represent uncertainty in deriving these distributions.

The report concludes that the objective of 15% of surface light at 3 m would be met 62% of the time over an entire dredging period of ca 300 days, and about 70% of the time in the absence of dredging. The report notes that, provided background and modelled data are both accurate and representative**,** light at 3 m will exceed 15% of surface irradiance more than 50% of the time, over the entire dredging period. The report notes that the ecological objective requires this criterion be met in any two week period. However, it implies (p. 13) that, were it not for this additional constraint, intervention aimed at limiting peak NTU levels would not be required. But the EMP exists at least partly to provide insurance against unacceptable impacts in the event that the turbidity model is wrong. Concluding that no intervention is required if the model is correct seems to miss the point. It is also appropriate when there is scientific uncertainty about whether average conditions, or short periods of more extreme conditions, are more important to seagrasses. The 2-week criterion provides protection against this uncertainty, by providing protection against brief periods of very turbid water.

In any case, the report goes on to assess whether the ecological objective will be satisfied in rolling two week periods within the dredging period, based on the modelled NTU time series. It concludes that there are multiple periods where it would not be met. The report concludes that the ecological objective can be met provided turbidity is capped at 15 NTU. More detail is required to justify this conclusion. It is unclear from the report (p. 17) whether this cap is to be imposed on instantaneous NTU, or on some other statistical property. This is critical in setting a realistic environmental limit for turbidity. It is exceedingly unlikely that dredging can be managed in such a way as to control instantaneous values of turbidity below such a cap. The EMP proposes an environmental limit of 15 NTU for the running two week average turbidity, not the instantaneous turbidity. It is possible that the discussion on p. 17 of the report and Fig. 12 actually refers to the running two week average turbidity. But this certainly isn't stated in the report.

To summarise, the IEG has two key concerns / questions around this report. The report seems to base parts of its analysis and conclusions on the assumption that the turbidity model is correct, yet the point of setting Environmental Limits in the EMP is to protect against the model proving incorrect. The report suggests that the ecological objective can be met if turbidity is capped at 15 NTU, but it is unclear whether this refers to instantaneous values of turbidity, or some other statistic.

It seems as though a more direct, model independent approach to translating the ecological objective into an environmental limit might have been taken here. A value of 15% surface light at 3 m corresponds to Kd = 0.63. The ecological objective is equivalent to stating that the median Kd in any two week period must be less than 0.63. One might suppose that it would be logical to set an environmental limit for the median, rather than the mean, value of turbidity in any two week period. The question then is what median value for turbidity would correspond to median Kd <= 0.63. Using the TSS vs NTU and Kd vs TSS mean regressions in the report, Kd = 0.63 corresponds approximately to turbidity = 10 NTU. Given the variability in these relationships, one might want to choose a more conservative limit for median turbidity.

The analysis undertaken in this report does allow an assessment of the probability of exceeding a given environmental limit in the presence and absence of dredging. While the report addresses the likelihood of exceeding the limit in the presence of dredging (assuming the model is correct), it does not specifically address the probability of exceeding the limit in the absence of dredging. It would be very interesting to see a repeat of Fig. 10 or its equivalent using a rolling median, in the absence of dredging.

The second report by Prof. Fox on Control Charting addresses the practical issues associated with establishing a monitoring and assessment program to manage performance against proposed environmental limits. The report considers the noise associated with continuous monitoring of turbidity, and recommends that the instantaneous data be aggregated in 6 hourly periods. It is unclear from the text (p. 9) whether these aggregates are medians or means. It is also unclear whether this period resulted from comparisons of a substantial number of alternative “windows”, and whether some relatively simple alternatives (e.g., computing the median of each 2½ minute “burst” of samples, and then using those medians for the rolling 2-week assessments) were considered.

The report proposes to use control charting as a way of tracking performance, by plotting an indicator statistic on a chart which also shows warning limits and control limits. The report recommends the use of an Exponentially Weighted Moving Average as the statistic to be plotted. Examples are given based on simulated data for a site in Hobson’s Bay, and site 2006 in the south of the Bay. The IEG is left with a number of questions about these examples.

- The cited Environmental Limits for turbidity are those given in the EMP exhibited with the SEES , not the EMP (Revision C).
- The plotted statistics are EWMAs with relatively short decay times. But the Environmental Limits prescribed in the latest version of the EMP relate to two week moving averages.
- Response levels set to 99.9 and 99.99 %iles are proposed for EWMA in Hobson’s Bay. But at site 2006, it is suggested that 15 NTU might be used as a response level, assuming the environmental limit is 25 NTU. The relevance of these plots to the limits and statistics proposed in the latest version of the EMP is unclear.

A key issue for the EMP is whether it can practically ensure compliance with the ecological objective and environmental limits, without incurring unacceptable costs through shutting down dredging unnecessarily. Even if the environmental limit corresponds directly to the ecological objective, so compliance with one ensures compliance with the other, one would only know about non-compliance in retrospect, when it is too late to prevent it. One can try to avoid this by setting response levels inside the environmental limit. The report suggests a risk-based approach might be adopted, in which a running probability of future non-compliance is computed, and action triggered when this probability exceeds an acceptable level. This approach looks interesting, but it does not seem to be carried through to a point where it can be applied. Moreover, it’s unclear in the examples provided (Fig. 18-20) what compliance time period has been assumed. Again, the IEG understands that the compliance period in the EMP is a rolling two week period.

In addition to the statistical aspects considered in the report, there are operational and physical issues which presumably need to be considered. How quickly is it feasible to cease dredging once an environmental limit or response level is exceeded? And how quickly will turbidity levels decline once dredging ceases? As noted above, there is also a question as to whether non-compliance could result from elevated background turbidity, in which case ceasing dredging may have little effect.

The report also undertakes an analysis of spatial correlation structure in background turbidity. It concludes that turbidity time series at sites in the south of the Bay are strongly correlated, over spatial scales of 5 km or more, and concludes that monitoring at intervals less than 5 km is not warranted. This is potentially an important conclusion for the design of the turbidity monitoring network. However, for this conclusion to be applied to the network design, it needs to be valid not just for background turbidity, but for turbidity resulting from dredging. The practical question is whether Environmental Limits could be exceeded at points between monitoring sites, without triggering response levels at monitoring sites.