REVIEW OF THE SYDNEY TAR PONDS REMEDIATION PROJECT MARINE ENVIRONMENTAL EFFECTS MONITORING PROGRAM YEAR 1 RESULTS

Context

On February 4, 2011, Fisheries and Oceans Canada's (DFO) Environmental Assessment and Major Projects Division (EAMP), Maritimes Region, requested that DFO Science, Maritimes Region, provide advice regarding the Year 1 results of the Sydney Tar Ponds Remediation Project Marine Environmental Effects Monitoring Program (MEEMP), as well as the potential affects on MEEMP of dredging and infilling of Sydney Harbour that may be undertaken in support of the proposed Sydport container terminal. The request for science advice supports DFO EAMP's involvement as an expert authority in the Sydney Tar Ponds Remediation Project pursuant to the *Canadian Environmental Assessment Act*. Specifically, DFO EAMP asked:

1. Are the conclusions of each Sydney Tar Ponds Remediation Project marine monitoring method valid based on the Year 1 monitoring results and baseline observations?

2. Should the marine monitoring methods be changed, based on the Year 1 monitoring conclusions, to better improve the monitoring program?

3. Is the proposed dredging and infilling of Sydney Harbour, which may be undertaken in support of the proposed Sydport container terminal, likely to affect the marine monitoring methods and future results of the Sydney Tar Ponds Remediation Project MEEMP? For each MEEMP method where potential effects from Sydney Harbour dredging and infilling are likely to occur, should the MEEMP method continue as proposed, be re-designed, or be discontinued? If re-designed, provide suggestions and/or recommendations for a revised MEEMP method.

A Science Special Response Process was used to provide DFO Science advice on these questions due to a requested deadline to provide the advice by February 18, 2011. This Science Response is based on the results of DFO Science research that has been undertaken in Sydney Harbour, as well as the knowledge gained from the Sydney Tar Ponds MEEMP in Year 1.

The major conclusions of this Science Response are:

- Polycyclic aromatic hydrocarbon (PAH) levels in surface sediments have increased by factors of 2 to 10 at all sampling locations and for all individual PAHs in Year 1 of the MEEMP monitoring program compared to the pre-construction phase of the Tar Sands remediation project.

- The increases observed in sediment PAH, but not in metal and polychlorinated biphenyl, levels indicate they are associated with transport from the Tar Ponds remediation site into the harbour by water or atmospheric pathways. The detection of these PAH increases in harbour sediments attests to the general value and utility of the MEEMP.

- The recent increase in PAH concentrations observed in Sydney Harbour sediments is statistically significant and in excess of environmental quality guidelines. However, the elevated PAH levels observed in Year 1 of the remediation phase remain significantly lower than those typical of inputs to the sediments during the peak of industrial activities from the 1960s-1980s. Once Sydney Tar Ponds (STP) remediation activities are finished, natural capping or attenuation of contaminant concentrations in the sediments will probably resume. Under these conditions, the increased PAH inputs measured during the remediation phase would primarily be evident as a local concentration maximum in the sediment record and have minimal biological impacts.

- It is strongly recommended that sediment cores be collected and analyzed for contaminants as an integral component of the MEEMP. Coring will permit downcore analyses of PAH concentrations and reveal the recent history of PAH contamination of the harbour. The latter will provide critical information on the source and magnitude of recent PAH inputs to the harbour and permit more accurate and realistic modeling of PAH transport.

- The higher PAH values measured by the Slo-Corer in comparison to the Grab sampler at several stations suggests that the Slo-Corer is more effective at collecting recently deposited, surface “fluff” material. The Slo-Corer (or a similar, alternative device) should continue to be employed in the monitoring program, as it is able to provide both quality control and sediment core collection.

- PAH water concentrations may have increased at some locations. The characterization of this effect is constrained, however, by experimental detection limit issues, potential biasing of water concentrations through the presence of highly contaminated suspended sediments, and possible quality control problems.

- It is recommended that filtered and unfiltered water samples be compared to determine the extent to which PAH levels may have been affected by the presence of highly contaminated, suspended sediments.

- The sampling protocol for the intertidal benthic community monitoring is considered to be inadequate to capture the natural variability at each site. It is recommended that this component be discontinued in its present form. To be most effective, it is recommended that the protocol be changed to include replication at each site adequate enough to fully characterize patterns in natural variability.

- It is recommended that the sample preparation protocol for the crab tissue component be modified in order to lower the analytical detection limit for PAHs by, for example, pooling together the legs and claws of 5 to 10 crab samples.

- The Sydney Harbour dredging and terminal construction projects will substantially affect benthic communities owing mainly to the generation of turbidity plumes resulting in particle transport into the South Arm. Continued monitoring of benthic communities is recommended to establish a new, post-dredging, environmental baseline against which future effects of Tar Ponds remediation can be evaluated.

- Since the sediments due to be excavated are mainly silts and sands and distinguished by low contaminant levels, it is anticipated there will be minimal transport of contaminants into the inner harbour as a result of dredging. The principle effect will be to bury the more highly-contaminated surface sediments with coarser-grained, less contaminated material thereby further remediating sediments of the inner harbour.

- It is recommended that caged bivalve studies and crab tissue sampling be discontinued during dredging, but recommence thereafter.

- To accommodate dredging activities, it is suggested that benthic sampling stations 2-1, 2-2, and 2-3 should be relocated to the east side of the harbour.

- It is considered unlikely that dredging operations or container terminal construction will produce environmental signals that will significantly interfere with the interpretation of the longer term monitoring results for the Tar Ponds remediation project.

- It is recommended that the MEEMP monitoring program be continued despite any environmental perturbations associated with the dredging/terminal construction projects. In particular, the trend of increased sediment PAH levels associated with the Tar Ponds remediation should continue to be monitored and associated biological effects fully characterized.

Background

Prior to commencement of the Sydney Tar Ponds Remediation Project, a Panel reviewed and approved the Project pursuant to the *Canadian Environmental Assessment Act* (refer to Environmental Assessment No. 05-05-8989 on the Canadian Environmental Assessment Agency Registry for more information on the Environmental Assessment 'Sydney Tar Ponds and Coke Ovens Sites Remediation Project'). A recommendation of the Panel was that a long-term monitoring program be developed to track changes in the state of the environment of Sydney Harbour as remediation of the tar ponds proceeds. The Government of Canada agreed in principle to this recommendation and committed DFO to providing expert advice on the marine component of the monitoring program, known as the Marine Environmental Effects Monitoring Program.

In January 2011, Public Works and Government Services Canada (PWGSC), the federal authority responsible for overseeing the monitoring program for the Sydney Tar Ponds Remediation Project, informed the Sydney Tar Ponds Environmental Management Committee that it intends to cancel the MEEMP. PWGSC's rationale for this proposed decision is that the results collected to date indicate that the Sydney Tar Ponds Remediation Project has had little to no negative effect on the state of the marine environment of Sydney Harbour relative to its pre-project baseline conditions.

PWGSC also believes that the proposed dredging and infilling of Sydney Harbour in support of the proposed Sydport Container Terminal may affect the MEEMP methods in a manner that makes it difficult to interpret future results of the MEEMP (refer to Environmental Assessment No. 08-01-40366 on the Canadian Environmental Assessment Agency Registry archive for more information on the Environmental Assessment 'Sydney Harbour Access Channel Deepening and the Proposed Sydport Container Terminal.' The project has been reposted on the Canadian Environmental Assessment Agency Registry, due to the identification of a new *Canadian Environmental Assessment Act* trigger, as Environmental Assessment No. 10-01-59106).

As an expert federal authority that is to advise on the MEEMP, DFO EAMP, Maritimes Region, requested advice from DFO Science, Maritimes Region, regarding results of the Year 1 monitoring program and the proposed discontinuation of the MEEMP due to the proposed Sydney Harbour dredging. The advice from DFO Science will be provided to PWGSC and the Sydney Tar Ponds Environmental Management Committee. A decision to discontinue the marine monitoring component of the Sydney Tar Ponds Remediation Project monitoring program is at the discretion of PWGSC.

Analysis and Response

The Sydney Tar Ponds Remediation Project MEEMP is designed to address the main concerns associated with contamination of Sydney Harbour that may result from Tar Ponds remediation efforts. The initial Year 1 monitoring results associated with the construction phase of the Tar Ponds remediation project is outlined in the Year 1 Construction/Remediation Marine Monitoring - Final Report (Dillon Consulting, 2011). This science review of the draft Dillon Consulting (2011) report (the Report) will address the five main elements of the Tar Ponds marine monitoring program: 1) marine water quality; 2) sediment composition and quality; 3) caged bivalves; 4) crab tissue; and 5) benthic community assessment. The questions posed by EAMP will be addressed consecutively, with a focus on individual sections of the Report.

1. Are the conclusions of each Sydney Tar Ponds Remediation Project marine monitoring method valid based on the Year 1 monitoring results and baseline observations?

The following science analysis and response to this question is organized in line with the applicable sub-sections of the Year 1 Construction/Remediation Marine Monitoring - Draft Report (Dillon Consulting, 2011):

4.1 Marine Water Quality

The Report notes:

> *With the exception of phenanthrene, anthracene, fluoranthene and pyrene, PAH concentrations were below laboratory detection limits across assessment areas (RDLs (reportable detection limits) varied from 0.01 to 0.05 L/L). For those PAHs that were above detection limits, the highest values mainly occurred within Area 1 (often collected by the 24 h composite sampler near Muggah Creek and also included samples collected by hand at the marine stations in Area 1). These findings are comparable to pre-construction/baseline findings* (Dillon Consulting, 2011, p.36).

Reported water concentrations for pyrene, phenanthrene and fluoranthene (Dillon Consulting 2011, Table 4-2) levels in Area 1 (the area closest to the remediation site) are slightly elevated in Year 1 construction monitoring compared to pre-construction/baseline results. It is difficult to determine the magnitude of the increase, as it depends on the method used to evaluate measurements below the detection limit.

It is difficult to understand the significance of the average values and other parameters reported in Tables 4-3 to 4-6, as the methodology used to evaluate values below the detection limit is not clearly stated.

Values of some PAHs (e.g. fluoranthene; Table 4-7; Figure 4-16) for the Battery Point 24 hour sampling increased by a small amount during the Year 1 construction period.

Although the post-remediation PAH water column levels are still only slightly elevated above pre-remediation phase values, these apparent increases are important to note, as they may be indicative of a longer-term trend.

It should be noted that four-ring compounds such as pyrene are produced by incomplete combustion and are insoluble in the water phase. The presence of pyrene in water samples is likely due to the presence of resuspended sediments in the unfiltered water samples. The absence of a filtering protocol may prevent the concentrations of dissolved water PAHs from being obtained, as water samples may contain trace amounts of sediments (possibly highly concentrated in particle reactive PAHs) in the water samples. Further, from an environmental risk perspective it is also important to know contaminant levels in the particulate phase, because different biota (e.g. filter feeders) discriminate between aqueous and particle phases for food uptake.

4.2 Sediment Composition and Quality

4.2.1 Grab Samples

The Year 1 monitoring results for surface sediments (Table 4-9) indicate increases in PAH concentrations by factors of 2-10 compared to pre-construction levels. These increases are observed at all sampling stations and are apparent for all individual PAHs. In several cases, increased PAH concentrations have elevated sediment concentrations above the effects range medium (ER-M). By definition, organisms within sediments that exceed the ER-M are very likely to be negatively affected by the presence of a contaminant (Jones et al., 1997). These results suggest that there has been a statistically significant discharge of PAHs into Sydney Harbour during the construction phase of the Tar Ponds remediation project. Of primary concern, however, is determining the sources and transport mechanisms for the PAH inputs.

The Report indicates:

> *The increase in total PAH concentrations in surface sediments during Year 1 monitoring could have occurred because of on-site releases as a result of remediation activities in the STP area, but the expected signature from a point source such as the STP would have resulted in a more localized sediment PAH concentration increase (i.e., at stations in area 1), rather than at all stations as evidenced in our results* (Dillon Consulting, 2011, p.78).

Figure 4-34, however, indicates a decreasing PAH concentration gradient with distance from the Tar Ponds with the exception of anomalously high levels at station 2-1. This decreasing concentration gradient is also noted (correctly) on page 77 of the Report, "*the total PAH concentrations in surface sediments decrease sharply with increasing distance from Muggah Creek, with the lowest PAH concentrations (<5 µg/g) at both far-field stations in area 3, in the Northwest Arm"* (Dillon Consulting, 2011, p.77). This decrease in PAH concentrations with distance from Muggah Creek is consistent with the STP being the source of recent inputs to the harbour.

The Report also notes that, "*one possible explanation for the increase in total PAH concentrations in surface sediments across all stations during Year 1 monitoring could be caused by resuspension or an uncovering event of contaminated sediments previously* *deposited in the Harbour as a result of a major storm event"* (Dillon Consulting, 2011, p.78). However, the Report notes that metal concentrations are not significantly different in post-construction compared to pre-construction surface sediment samples. Because concentrations of PAHs and metals (Pb, As), identified as steel industry contaminants, strongly co-vary in harbour sediments (Smith et al., 2009), the absence of observed increases in these metals in the Year 1 sampling phase indicates that the redistribution of sediments already deposited in the harbour is not considered the source of the enhanced PAH levels. Instead, these discharges likely originated from the Tar Ponds sediments where metal levels are proportionally lower compared to the PAH levels.

Transport of the PAHs into the harbour from the STP could occur by water or atmospheric transport. A considerable quantity of heavy equipment has been involved in remediation efforts and despite strenuous efforts to keep vehicles clean and avoid the atmospheric dispersion of contaminants, some atmospheric transport of PAHs into the harbour will inevitably occur. Air monitoring results for the Tar Ponds (All-Tech Environmental Services, 2011) show significantly elevated PAH levels at the site boundaries closest to the harbour during the Year 1 construction phase compared to pre-operational levels. Atmospheric transport of PAHs into the harbour helps to explain the wide spread contamination observed during the Year 1 monitoring phase, even at the more remote, far field stations in Area 3.

Similarly, despite the closure of the Muggah Creek estuary, runoff from the watershed will likely transport PAHs into the harbour. The Report notes that mass balance modeling (Appendix H) indicates that calculated fluxes of PAHs from the STP, based on water column sampling at Battery Point, are insufficiently low, by almost an order of magnitude, to account for the PAH increases observed in harbour sediments in Year 1. It is difficult to quantitatively collect particulate material using water sampling bottles in dynamic hydrological regimes due to the short residence times of suspended material in the water column. As a result, it is likely that the inventory of particle-reactive PAHs leaving Muggah Creek will have been under sampled. The mass balance modeling is discussed in more detail below under the heading, Appendix H.

Specific comments:

The Report states, *"PAH concentrations were detected in each assessment area in Sydney Harbour and were higher than baseline results, but absolute concentrations were* *<u>very low</u>"* (Dillon Consulting, 2011, p. 74).

This statement appears contradictory to Figure 4-34, which indicates PAHs exceed the ER-M at several stations. A similar statement with respect to PCBs and metals made in following paragraphs is correct:

> *Overall, ranges of total PAH concentrations in surface sediments measured in Sydney Harbour in 2009 and 2010 (1.4-64.9 µg/g) were several orders of magnitude lower than ranges (200-500 µg/g) determined by Smith et al. (2009) from geochrononolgies of sediment cores that represented total PAH concentrations from the 1960s-1980s* (Dillon Consulting, 2011, p. 78).

and:

> *Additional comparisons to our monitoring data were made using total PAH concentrations in surficial sediments (0-0.5 and 0-1 cm) collected in 1999 and 2000 from cores by Smith et al. (unpublished data) which were found to be several orders of magnitude higher when compared to approximate locations of seven*

stations used in this study: 1-1, 1-2, 1-3, 1-4, 2-2, 3-1 and 3-2) (Dillon Consulting, 2011, p. 78).

In each case, it is more accurate to say that the Smith et al. (2009) results were greater by an order of magnitude (not several orders of magnitude).

The Report states, "*Year 1 increases in PAHs in harbour sediments are most probably a small and predictable blip in the general trend of decreasing PAH concentrations that have been documented by others*" (Dillon Consulting, 2011, p.78).

The increase in PAH concentrations is predictable if the Year 1 remediation activities in the Tar Ponds have specifically led to PAH inputs to the harbour. The increase in PAHs deposited in surface sediments during the construction phase of remediation activities will likely be "smoothed" out by natural remediation and sediment capping once the Tar Ponds remediation project is completed.

The Report states that, "*It is also possible that results from 2009 baseline sediment sampling could have been "unusually" low as a result of burial from less contaminated sediments, again caused by major storm activity"* (Dillon Consulting, 2011, p.79).

While this possibility cannot be dismissed, it would be unusual for all of the different sediment regimes in the harbour to be effected simultaneously in the same manner.

The Report *states, "A further complicating factor in the variation in total PAH concentration may be the presence of coal dust observed in some sediment samples, particularly those close to the bulk coal unloading pier at Whitney Pier which is located approximately 400 m from the mouth of Muggah Creek"* (Dillon Consulting, 2011, p.79).

There is no evidence, either in this report or elsewhere, that the bulk coal unloading dock at Whitney Pier has been a significant contributor to PAH concentrations in Sydney Harbour. Loading and transport of coal generally produces far less PAH contamination than combustion of coal. Methods that can assess whether there are other likely sources of PAHs (Stout and Emsbo-Mattingly, 2008) involve assessing the fingerprint patterns generated by biomarkers, such as hopanes and steranes. The unique profiles generated by these compounds can aid in distinguishing possible PAH sources. If there is evidence of other PAHs sources, this technique is the best option. Otherwise, it must be concluded that the major source of PAHs in this region is from the coal tar.

The Report states, "*Therefore, the detection of these changes attests to the effectiveness of this marine EEM program*" (Dillon Consulting, 2011, p.80).

The detection of these changes attests to the scope and comprehensiveness of the program; its effectiveness depends on its capability to accurately characterize the source of the PAHs and potential biological impacts.

The Report states, *"Historical inputs of metal contaminants in the Harbour were likely derived from atmospheric sources from coal combustion when the coking and steel facility was operating (J. Smith personal communication, March 17, 2011)"* (Dillon Consulting, 2011, p.84).

This comment pertains to some (e.g. lead and arsenic) but not all contaminants. Silver, for example, is derived mainly from runoff and sewage inputs.

4.2.2 Slo-Corer Sediment Samples

The comparison between the Slo-Corer and Grab sampler sediment results suggests that the Slo-Corer is collecting the most recently deposited, contaminant laden, “fluff” surface sediment layer more efficiently than the Grab sampler. Assuming that there has been a recent increase in PAH delivery to the sediments within the past year, as indicated by the sediment results elsewhere in the report, then increase in PAHs would tend to be concentrated in the surface fluff layer. The higher PAH values measured at stations 4-1 and 1-3 for the Slo-Corer compared to the Grab sampler suggests that the former is more effectively collecting this recently deposited, surface fluff material. The absence of an increase in PAHs measured by the Slo-Corer compared to the Grab sampler at station 1-2 may result from PAH levels being elevated at this station, which is closer to the mouth of Muggah Creek compared to the other stations. In addition, fluff layers are also easily resuspended and transported at low current velocities and may move in the direction of mean current flow. In areas where shear stress is low, <0.04 Pa, fluff layers can deposit and begin to be incorporated into the sediment itself during the consolidation process.

Specific comments:

The Report states, “*Overall, the 2 sampling methods are not considered different, meaning that the SLO-CORER is not necessarily an improvement on the careful deployment of the grab sampler under current conditions in Sydney Harbour”* (Dillon Consulting, 2011, p.89).

Similar metal and PCB concentration in samples collected by the Slo-Corer and Grab sampler indicates that both devices are collecting representative samples for the upper few centimeters of sediment. However, metal and PCB results do not reflect the efficiency of collection of the fluff layer. There is no indication of recent inputs of these contaminants to the system and, accordingly, the fluff layer will not be particularly enriched for these contaminants. The report supports the notion that the Slo-Corer is likely collecting the surface “fluff” layer more efficiently than the grab sampler, making the above statement somewhat misleading.

4.3 Caged Bivalves

Specific Comments:

Page 96 – Estimates of variance (preferably 95% confidence levels) should be provided for mussel (and other) data. In addition, water depths and the depths of deployment of mussels should be provided for each site.

Page 101 – The rationale for the variable transformation prior to ANCOVA is not clear. It is also unclear whether a comparable set of analyses (see Table 4-22) was performed on a subset of mussels prior to deployment. This comparison is necessary to determine if changes observed were due to the mussels deployed or a result of differences between the four sites at which they were deployed.

Page 103 – The experimental methodology is considered inadequate to properly evaluate the effects of pollution. For example, if mussels at sites 3 and 4 are slower to reproduce or obtain less food due to their location, then this will affect body weight (Figure 4-38), mantle weight (Figure 4-39) and any other index associated with these or other related condition indices.

Page 105 – Environment Canada's caution is considered appropriate; however, it should not preclude the use of statistical analysis. For example, the qualitative description of data in Figures 4-40 and 4-41 is insufficient.

Page 106 – Survivorship is a poor indicator in toxicity testing except under the most extreme (acute) circumstances. The absence of differences in survival of mussels between stations or assessment areas is a strong indication of the lack of acute, not chronic, effects, which should be the focus of this assessment.

The Report states, "*there appears to be no obvious differences between juvenile mussels deployed at the reference stations and those from other stations*" (Dillon Consulting, 2011, p.108). The log transformation of data plotted on the y-axis makes it difficult to detect differences between measures. It is recommended that statistical comparisons be used to make quantitative evaluations.

Page 112 – It is not clear where the egg diameter data appears in the report.

4.4 Crab Tissue

Specific Comments:

The Report states, "*there appears to be a subtle increase in PCB concentrations during Year 1 at the three near-field stations*" (Dillon Consulting, 2011, p.115). To ensure statistical comparisons of parameters across site and sample period are achieved, the use of 2-way ANOVAs should be considered. This type of analysis would allow the results to be scientifically defensible when under review.

PAH concentrations were below the detection limit for crab tissues, under both pre-operational and post-operational conditions. Thus, it was not possible to determine whether a temporal trend in crab tissue contamination existed. It should be noted, however, that PAHs are lipid soluble compounds and are therefore unlikely to be found in crab claws and legs. These compounds are more likely to accumulate and be found in the digestive glands (fatty tissue) of crabs.

4.5 Benthic Community Assessment

4.5.1. Assessment of Benthic Sub-tidal Communities

The Report primarily provides a qualitative description of several aspects of sub tidal benthic communities, including abundance, biomass, diversity, and richness. These parameters and the experimental design are appropriate for the detection of changes in benthic community structure related to the Tar Ponds remediation project. Information provided in the Report indicates that differences in benthic community parameters among stations and sampling years are apparent. However, the lack of data concerning the benthic community assessment prevents a critical assessment of these conclusions. Figures and/or tables of the data should be provided in the Report. Some values of biomass, abundance, and diversity at each station are provided in the text; however, the data are provided without an estimate of variance. It is unclear whether these values are means of the five samples at each station or sums across all five samples. Most importantly, no indication of environmental variability is given. The absence of data in the report for this component make it difficult to comment on the results.

Comparisons that state that parameters differ between stations, because one number is higher than the other, are not considered informative in the absence of any consideration of variance among replicates. Soft-sediment benthic communities are highly, spatially variable, and adequate replication is required to capture this feature. A good estimate of variability among replicates is essential when making comparisons among stations and sample years. The data are available to do this. The Report indicates that statistical analyses among stations and years showed statistical differences, yet no statistical analyses are reported. The Report would benefit from presentation of the results of all statistical analyses completed, and figures and tables of the data, instead of the current general description. This would allow a full comprehensive review of the data and, more importantly, allow evaluation of any changes observed over time.

4.5.2. Assessment of Benthic Intertidal Rocky Shore Communities

This section of the Report is comprehensive with all relevant data provided. However, as previously stated in a previous DFO Science Response to the Tar Ponds baseline monitoring report (DFO, 2010), the experimental design deployed at each site is inappropriate for detection of changes in intertidal benthic communities over time or among stations. The sampling of subsections of one quadrat does not provide independent replicates that will adequately capture the natural variability at each site.

5.0 Summary of Year 1 Construction Monitoring Results

5.2 Assessment of Potential Sources of Sediment PAH Variation

The Report outlines various hypotheses to explain the increased PAH concentrations in the sediments in Year 1 of the STP remediation phase. While most of these have been discussed in Section 4.2, additional specific comments are provided here.

Page 139 - Hypothesis 2. The Report suggests that increased sediment loadings are unlikely to be from the Tar Ponds because, *"a mass balance and efflux calculation … independently estimated that approximately 100 kg/yr PAHs were estimated to have left Muggah Creek during 2010, which is considerably lower than 777 kg/yr efflux estimated by JDAC (2002), and much lower than would be required to cause PAH increases observed in Year 1"* (Dillon Consulting, 2011, p.139).

The mass balance modeling is a useful tool; however, the uncertainties associated with the results are rather large. Further, this calculation is based on water column monitoring that may not accurately sample the entire inventory of PAHs leaving the Tar Ponds site. This modeling is discussed further under Appendix H below.

Page 140 - Hypothesis 3. The Report suggests that atmospheric inputs of PAHs from the Tar Ponds are unlikely because (1), "*the Tar Ponds air monitoring program reportedly did not detect concentrations of PAHs in air exceeding human health guidelines,*" and (2) that, "*water column concentrations would be noticeably elevated for an extended period which contradicts water quality data"* (Dillon Consulting, 2011, p.140).

As noted under Section 4.1, air monitoring results for the Tar Ponds (All-Tech Environmental Services, 2011) show significantly elevated PAH levels at the site boundary for samples collected during the Year 1 construction phase of the STP remediation compared to pre-operational levels. While these levels did not exceed human health guidelines, they may still contribute significantly to harbour inventories of PAHs in the sediments. With regard to (2), the deposition of particle-associated PAHs in the water column via an atmospheric pathway would be difficult to detect by water monitoring due to the very short residence time of this particulate material in the water.

It is recommended that a mass balance calculation, using air monitoring data and literature values of PAH deposition velocities be completed to determine if the atmospheric pathway is a significant source of contamination for Sydney Harbour sediments.

Page 140 - Hypothesis 4. The Report suggests, *"There was an increase in PAH concentrations in sediment - The increase was due to aberrantly low 2009 data rather than addition (al) inputs"* (Dillon Consulting, 2011, p.140). This hypothesis is the only one that does not require a recent increase in PAH concentrations in the water column. Although there is evidence of some sediment slumping and turbidity transport in Sydney Harbour sediments, the type of wide spread slumping required for this hypothesis would be an extremely rare event, as acknowledged in the Report.

Page 140-141 - Hypothesis 5 and 6. These hypotheses suggest that elevated PAH levels are associated with sediment resuspension of more highly contaminated underlying sediments deposited during the period of high PAH inputs during the 1960s-1980s. In addition to PAHs, underlying sediments are also enriched in metals such as lead (Pb) and arsenic (As) that were co-deposited with the PAHs. However, the increase in PAH concentrations observed in 2010 was not accompanied by an increase in metals. The only PAH source in the region where high PAH levels are not accompanied by correspondingly high metal concentrations is the Tar Ponds. Thus, the Tar Ponds likely represents the source of recent contamination in Sydney Harbour.

Pages 142-145 - Hypotheses 7-14. These hypotheses all suggest that the elevated levels of PAHs measured in Year 1 of the remediation phase of the project were caused by inputs from sources (coal storage areas, sewage, tank farms, urban run off, etc.) other than the Tar Ponds remediation site. Although there are surely multiple sources of PAHs for Sydney Harbour, including ones mentioned in the Report, there is no rationale to explain why these sources should suddenly begin to cause major contamination throughout Sydney Harbour beginning in 2010. The only known significant event associated with PAH sources for Sydney Harbour that occurred in 2010 was the initiation of remediation activities in the Tar Ponds. In the absence of compelling evidence to the contrary, it is reasonable to conclude that these remediation activities are responsible for elevated levels in harbour sediments. The main unresolved issue is the exact nature of the transport mechanism.

Appendix H

The mass balance calculation presented in this section is beneficial as it provides a sense of the magnitude of the various inputs and sediment inventories. However, there are a number of parameter estimates that may have been over or under estimated. For example, PAH concentrations at stations 3-1 and 3-2 are unlikely to be representative of the entire Area 3. Sediments become considerably coarser-grained in outer harbour sediment regimes and PAH concentrations will be much lower in these outer harbour, sandier sediments. As a result, PAH inventories have likely been over estimated in Area 3. The assumption, that the 1 cm surface layer of sediments represents 1 year of deposition, is also considered problematic. In the event of a large influx of material, recently contaminated sediments could reach a depth of several cm or more, in which case, the PAH inventory will have been under estimated. Conversely, if the sedimentation rate is very low (< 0.4 cm/y) at a given location, PAH inventories will have been over estimated.

Another concern with the mass balance calculation is the difficulty associated with identifying pulsed inputs of particle-reactive PAHs to the harbour. Water sampling at Battery Point is based on composite samples (40 ml collected hourly for 24 hours), thus a pulsed input of PAHs can be easily missed. Further, the particle reactive, PAH laden material may travel closer to the sediment water interface than can be effectively sampled using water sampling bottles without collecting resuspended sediments. Water bottle sampling is effective in identifying the transport of dissolved constituents, but provides very mixed results when applied to the transport of particle-reactive contaminants.

In this regard, a sensitivity exercise which would provide an estimate of the uncertainties in the mass balance calculation is recommended. Nevertheless, water monitoring at the entrance to Muggah Creek does not appear to be measuring a sufficiently large flux of PAHs which may explain sediment inventories in Sydney Harbour.

Summary

The water and sediment components of the Sydney Harbour MEEMP program are providing effective monitoring to the extent that they are identifying changes in the contaminant fields that have occurred during the Year 1 construction phase of the STP remediation. The increases in PAH concentrations by factors of 2-10 in harbour sediments compared to pre-construction, baseline levels indicate atmospheric or water transport of PAHs from the STP remediation site. However, the Report suggests that there are other explanations for the increased PAH levels in sediments. These arguments are considered unconvincing for the reasons outlined above. The measurement of PAH concentration profile in sediment cores would help resolve this issue.

The higher PAH values measured at several stations for the Slo-Corer compared to the Grab sampler suggests that the former is more effective at collecting recently deposited, surface “fluff” material. The Slo-Corer is considered a more reliable device for collecting surface sediments compared to a Grab sampler and it is recommended that it continue to be employed in the monitoring program. If logistical challenges preclude the use of a Slo-Corer, then a simpler gravity corer is recommended.

The recent increase in PAH concentrations observed in Sydney Harbour sediments is statistically significant and in excess of environmental quality guidelines. However, the elevated PAH levels observed in Year 1 of the remediation phase remain significantly lower than those typical of inputs to the sediments during the peak of industrial activities from the 1960s-1980s (Smith et al., 2009). Once Sydney Tar Ponds (STP) remediation activities are finished, natural capping or attenuation of contaminant concentrations in the sediments will probably resume. If this proves to be the case, then the increased PAH inputs measured during the remediation phase would primarily be evident as a local concentration maximum in the sediment record and have minimal biological impacts.

It is recommended that mass balance modeling be applied to the STP air monitoring results to determine whether atmospheric transport of PAHs from the STP remediation site can account for the Year 1 increase in sediment contamination in the harbour.

On a cautionary note, it is reported that some of the water Quality Control (QC) samples did not meet the laboratory’s data quality objectives within Section 4.5 (Laboratory QC samples) of Dillon Consulting (2009). This suggests that some of the water measurements may not have been accurately evaluated.

The experimental design of the sub-tidal benthic community monitoring program appears to be adequate; however, the absence of data within this component of the Report makes it difficult to constructively comment on the results. The experimental design of the inter-tidal component of the benthic community monitoring is considered flawed, as the sampling protocol is considered unlikely to capture the natural variability at each site.

2. Should the marine monitoring methods be changed, based on the Year 1 monitoring conclusions, to better improve the monitoring program?

The following science analysis and response to this question is organized in line with the applicable sub-sections of the Year 1 Construction/Remediation Marine Monitoring - Draft Report (Dillon Consulting, 2011).

4.1 Marine Water Quality

There is a lack of detailed information on the protocols used in this section. The method employed for PAH analysis is unclear, however, it is assumed that gas chromatography coupled with mass spectrometry has been used. If so, the laboratory should be using internal and surrogate standards, typically ^{13}Carbon or predueterated PAHs and the values for these compounds should be reported as part of the QC requirements. Finally, filtering of water samples is highly recommended. The potential for highly contaminated suspended solids to be collected in unfiltered water samples does not allow the dissolved phase to be accurately monitored, nor does it permit accurate monitoring of suspended material, both of which are important for environmental risk analysis.

4.2 Sediment Composition and Quality

It is unclear how the magnitude of the recent increase in PAH inventories in Sydney Harbour sediments could be determined from grab sampling alone. Assessment of PAH sediment inventories and fluxes can only be accomplished through the collection and analyses of sediment cores. Therefore, it is strongly recommended that the Slo-Corer continue to be employed in this program. The higher PAH values measured in samples collected by the Slo-Corer in comparison to the Grab sampler suggest the former is more effective. More importantly, cores can be analyzed for PAHs and metals at one cm intervals beginning at the sediment surface in order to determine the depth distributions of contaminant concentrations. PAH sediment depth distributions will provide critical information on the overall magnitude of recent PAH inputs to the harbour and on the input function, itself. This information will permit more accurate modeling of PAH contamination of Sydney Harbour. If the Slo-Corer is deemed to be too demanding from a logistics perspective, then the use of a simple gravity corer is recommended.

4.3 Caged Bivalves

Improved statistical analyses should be undertaken for the mussel data as outlined in Section 4.3 under Question 1 above. In particular, estimates of variance should be applied to data where at all possible.

4.4 Crab Tissue

It was not possible to determine if there were changes during Year 1 since PAH concentrations were below the detection limit for crab tissues, both in pre-op and post-op conditions. However, if the use of crabs as a sentinel organisms continues, it is suggested that the detection limit for PAHs be lowered, possibly through the collection of a larger number of organisms.

It is suggested that the lab incorporate the pooling of tissues from 5 to 10 crabs as part of their sample preparation protocol with the legs and claws pooled together and the digestive glands separately. This technique may provide sufficient sample mass to improve method detection limits and would also reduce the variability associated with individual crab sampling. However, it is also recognized that the laboratory may not be able to handle a larger sample size due to analytical method loading problems.

4.5 Benthic Community Assessment

4.5.1. Assessment of Benthic Sub-tidal Communities

For a full comprehensive review of this section and to detect changes in benthic communities over time, it is strongly recommended that the mean and standard deviation of all five samples at each station be presented. Results of statistical analyses should be presented. Recalculation of data will allow more meaningful comparisons of parameters among stations and times. The experimental design is strong and does not need to be altered.

4.5.2. Assessment of Benthic Intertidal Rocky Shore Communities

The experimental design deployed at each site is considered inappropriate for the detection of changes in intertidal benthic communities over time or among stations. The use of multiple replicate quadrats per intertidal zone (10-20 per zone), where flora and fauna in the entire quadrat are enumerated, is recommended. The mean and standard deviation for each intertidal zone at each site could then be calculated and compared. Statistical analyses would be conducted using each quadrat as a replicate. This protocol is commonly used for monitoring programs, and allows the natural variability of the site to be characterized. This enables meaningful conclusions about the impacts of remediation activities to be formulated. Conclusions drawn in the report based on one quadrat in two intertidal zones at each site are not considered robust and may simply reflect the natural variability at each site. In addition, methods to determine if differences detected between sites or years are related to the remediation activities or simply reflect site variability are suggested. For these reasons, the intertidal benthic program is considered ineffective and should be discontinued, as suggested in Table 5-4 of the Report.

Although the methods used to sample benthic communities at each site are considered inadequate to quantify the parameters of interest, the overall experimental design is well suited for detection of change in intertidal communities. Sampling five sites that span the near-field and far-field influence of the remediation project is a good approach and requires no modification. It is, therefore, recommended the intertidal benthic monitoring be strengthened by maintaining the five sites and expanding sampling within each site to include multiple replicate quadrats. This will permit biologically meaningful comparisons among sites and years, permit robust estimates of benthic community parameters, and provide enough statistical power to determine whether a measurable effect associated with the Tar Ponds remediation project is present.

Summary

It is strongly recommended that sediment cores be collected and analyzed for contaminants as an addition to this program. The Report has proposed a number of explanations for the Year 1 construction phase increase in sediment PAH concentrations that can only be accurately addressed through core analyses. Coring will permit downcore analyses of PAH concentrations and provide insight into the recent history of PAH contamination of the harbour. The latter will provide critical information on the overall magnitude of recent PAH inputs to the harbour and permit more accurate and realistic modeling of PAH transport.

PAH water concentrations may have increased at some locations, although the characterization of this effect is constrained by experimental detection limit issues and possible sample contamination by suspended sediments. Therefore, it is recommended that PAH concentrations in filtered and unfiltered water samples should be compared to determine whether highly contaminated suspended sediments are present. This will indicate true dissolved PAH levels in the water column and the partitioning of PAHs between dissolved and particulate phases.

It is suggested that the detection limit for PAHs in crab tissue be lowered, possibly by collecting a larger number of organisms.

The experimental design of the inter-tidal component of the benthic community monitoring is considered flawed. The program is unlikely to capture the natural variability at each site and the program should, therefore, be discontinued as proposed in Table 5-4.

3. Is the proposed dredging and infilling of Sydney Harbour, which may be undertaken in support of the proposed Sydport container terminal, likely to affect the marine monitoring methods and future results of the Sydney Tar Ponds Remediation Project MEEMP? For each MEEMP method where potential effects from Sydney Harbour dredging and infilling are likely to occur, should the MEEMP method continue as proposed, be re-designed, or be discontinued? If re-designed, provide suggestions and/or recommendations for a revised MEEMP method.

The proposed Sydney Harbour dredging program involves the excavation of a 142 ha channel in the Seaward Arm to Sydney Harbour to provide access to the deeper water of the South Arm (Jacques Whitford, 2009). Dredging will be undertaken by a self-propelled vessel equipped with suction pipes with centrifugal pumps. Sediments are loosened and removed from the seabed by suction and discharged into the vessel's hopperwell. The vessel is then connected to a pipeline about 300 m offshore at one of the confined disposal facilities (CDFs) where it is pumped into the reclamation area. Approximately 3.5 - 4 million cubic metres of dredged materials will be removed from the seabed and two waterlots will be infilled using CDFs (structures designed to receive dredged sediments and safely contain the materials). Approximately three months will be required to complete the dredging.

Background levels of suspended sediments in the harbour are generally less than 10 mg L^{-1}. A coupled three-dimensional hydrodynamic and sediment transport model (Jacques Whitford, 2009) was used to assess the dispersion of the turbidity plume during and after dredging operations. In the channel, settling time for a plume generated during one cycle is estimated to be 8-10 hours; thus, the cumulative impacts of several cycles are considered to be limited. The model suggests that the plume would primarily stay in the centre of the Seaward Arm within a 1.5 km wide track. At the proposed container terminal, results indicate that the plume and its subsequent re-deposition would be primarily confined to the South Arm (Jacques Whitford, 2009).

Above-background turbidity (i.e. suspended sediment) levels from a 24-hour continuous dredging period is expected to last for approximately 4-5 days. The model was also used to obtain order-of-magnitude estimates of natural, wave and current-induced turbidity peaks during storms. Results suggest that a 1-year return storm would have a greater turbidity footprint than that generated during dredging in the Seaward Arm, except along the narrow centerline of the channel where turbidity may be up to 10 times higher during dredging. For the marine organisms whose habitat spans both the shallow and deeper waters of the harbour, turbidity from the dredging operations in the channel may be comparable to that from an extended period of back-to-back storms with the exception of much lower turbidity close to the shoreline during dredging.

Approximately 80% of the sediments to be dredged are sands, while mainly fine silts and clays cover the interior of the harbor. Subsurface grain size distributions at the entrance to the harbour are similar to those at the surface. Therefore post-dredging, geotechnical parameters should be similar to those that presently prevail. Contaminant inventories in Sydney Harbour are mainly confined to the fine-grained silts and clays that cover the inner South Arm of Sydney Harbour (Smith et al., 2009) and are low in the sandy regimes that will be excavated during the dredging operation. It is, therefore, anticipated that the dredged material will have low concentrations of metals, PCBs, and PAHs.

The discharge of the material during dredging, transport further into the interior of the harbour in turbidity plumes, and deposition in interior sediments will likely result in a decrease in contaminant concentrations in surface sediments of the South Arm. Therefore, the net effect of the dredging operation will likely be the continued remediation or “capping” of the contaminant inventories in the harbour interior, a phenomenon that is already being driven by natural processes. This assumes that minimal dredging will be undertaken in the fine sediment regimes in the basin adjacent to the planned location of the container port where significant inventories of contaminants presently reside.

Within the dredge footprint, sedimentation rates are less than 0.5 cm y^{-1} (Smith et al., 2009), indicating that ambient sedimentation will result in little infilling of the channel. If there is minimal bedload transport of sand during storm events, then little maintenance dredging of the channel will be required. Therefore, the environmental impacts of the dredging are expected to be confined to the approximately 3 month period of the dredging operation itself. The following science analysis and response is organized in line with the applicable sub-sections of the Year 1 Construction/Remediation Marine Monitoring - Draft Report (Dillon Consulting, 2011).

4.1 Marine Water Quality

Water sampling will be affected during the three month duration of the dredging operation through the enhanced suspended particle concentrations generated within the water column. However, the dredging operation should not lead to significantly enhanced contaminant concentrations in the water column, as the dredged, sandy sediments have low contaminant concentrations themselves. Once a new steady-state in the suspended particle field has been established following the cessation of dredging operations, water sampling associated with the post construction phase of the Tar Ponds remediation can and should be continued.

It is recommended that sampling locations 2-1, 2-2, and 2-3, presently positioned at the site of the new container pier, be relocated. It is recommended that they be relocated to the east side of the South Arm at approximately the same latitude.

4.2 Sediment Composition and Quality

The main effect of the dredging operation in the main channel on the sediment contaminant field will be to further bury or cap contaminant inventories by a layer of sediment associated with any turbidity layer transport that occurs from the dredging and CDF construction sites. The additional, deposited sediments will likely be distinguished by lower concentrations of contaminants compared to the underlying sediment regime, so the net effect will be one of further remediating the contaminated sediment regime. However, it should be noted that 80% or more of the sediment in the outer harbour is sand and has a modal diameter of approx 180-200 μm (Stewart et al., 2001). At this size the fall velocity, W_s, (≅ 25 mm/s) would result in the majority (>50%) of the sediment being deposited in approximately 30 minutes. Using average current velocities for Sydney Harbour, it is estimated that the maximum horizontal distance of travel for 180-200 μm sands in approximately 18 m of water would be approximately 200 m during the dredging process. Therefore, the net effect of turbidity current transport into the inner harbour is anticipated to be minimal.

The particle size of the newly deposited sediments will likely be greater (depending on the distance of the sediment regime from the site of the dredging operations) than underlying sediments. Thus, distinguishing the timing of the dredging event in the sediment record based on sediment texture alone is expected to be achievable in the future. Similar textural anomalies are evident in the twentieth century sediment record of Sydney Harbour, and are associated with phenomena such as storm events (Smith et al., 2009).

It is anticipated that sizable quantities of sediments will be removed from the inner south arm of the harbour, the majority of which will be removed from the area designated for the Sydport terminal. Sediments in that region have 10-20 cm thick layers of contaminated sediments deposited during 1960-1990 period (Smith et al., 2009). Contaminated sediments dredged from that area may be dispersed over parts of the South Arm. Most of the sediment is expected to be confined to the area of dredging, but the small grain size of this material and the affinity for PAHs to bind with the <16 μm grain size fraction suggests that there could be some contaminant transport farther into the South Arm, resulting in some elevation of contaminant levels in surface sediments and the easily transported fluff layer. However, this effect will likely be small owing to the dilution of the relatively small volume of contaminated sediments in the vicinity of the future terminal site by the large volume of dredged material.

The dredging operation will result in a new and possibly lower contaminant baseline against which future changes associated with the post-construction phase of the Tar Ponds remediation should be compared. In this regard, the results for the sampling conducted during the first year following dredging may prove somewhat difficult to interpret if contaminant levels are lower or unchanged, since they will register the combined effects of both the dredging and Tar Ponds remediation. However, if there is an increase in PAH levels, either in the sediments or water column, and no accompanying increase in metal concentrations, then this can be assumed to be an effect associated with discharges from the Tar Ponds remediation site, as this is the only operation that will produce enhanced contaminant loadings of this nature. The dredged or resuspended sediments in Sydney Harbour that are contaminated with PAHs (discussed above) will also register a proportional increase in particle-reactive metals, such as lead and arsenic.

4.3 Caged Bivalves

Separation of the perturbation due to dredging versus the remediation project may be difficult for cages located close to the predicted plume footprint and particle deposition region. Cages located further from the dredge impacted area (i.e. station 3-1 and 3-2) may not be affected. However, this precludes the comparison of tissues at sites near the remediation and further away during the period of dredging. It should be noted that the dredging is not expected to lead to increased contaminant levels in bivalves, so the effect of the dredging on this component of the monitoring program should be minimal. However, it is recommended that the caging study be discontinued during the dredging operation and resume once operations have been completed.

4.4 Crab Tissue

Remarks similar to those for the cage bivalves study also apply to the crab tissue monitoring. Dredging is not expected to result in increased contamination of crabs, although physical effects may affect their distribution patterns. The crab tissue studies should be scheduled to resume once the dredging operations have been completed.

4.5 Benthic Community Assessment

The proposed dredging and infilling of Sydney Harbour is expected to affect the benthic monitoring program for the Sydney Tar Ponds Remediation due to the release of sediment plumes.

Studies have shown that abundance, biomass, and diversity of benthic communities at dredge sites recover relatively quickly from the initial disturbance (i.e. 1-4 years; reviewed in Bolam and Rees, 2003). Parameters of benthic communities located away from the dredge sites (i.e. 100 m or more) are either not affected or recover quickly (i.e. a few months; McCauley et al., 1977; Newell et al., 2004). Modeling results indicate intertidal transects 3, 4, 5 will be marginally affected by the dredging plume. It is recommended that these transects be maintained.

Intertidal transects 1 and 2, which are closest to possible remediation impacts, are directly in line with sediment deposition from port construction. For these intertidal transects, separating the perturbation from the dredging versus the remediation may not be possible if they operate on the same time scales. However, literature studies indicate that the dredging effects may occur on a short time scale, and they may only influence benthic communities in the short term. This is particularly true for unstable environments, such as Sydney Harbour, which is frequently subjected to various types of disturbances. Monitoring of the benthos may reveal a perturbation that can be attributed to dredging, while long term data may reflect impacts from the remediation project.

Although there is possible value in continuing the remediation monitoring of intertidal transects, particularly if the project has a longer time scale than the dredging, it should be recognized that, if benthic changes are apparent, definitive separation of the effects of the two different disturbances may not be possible. Clear separation of the effects of the two disturbances depends on the length of dredging, number of times dredging will re-occur, length of the remediation project, and stability of the benthos (i.e. are fauna well adapted to adjusting to disturbances).

For the subtidal benthos, modeling results indicate that stations 3-1 and 3-2 will not be impacted by the dredging and the resulting sediment plume. These stations remain useful as reference stations. However, the remaining stations in the South Arm (i.e. 1-1, 1-2, 1-4, 1-3, 2-1, 2-2, 2-3, and 4-1) may be significantly impacted by deposition from the sediment plume. It is recommended that stations 2-1, 2-2, and 2-3 be relocated due to their proximity to the new container pier. Relocating these stations to the east side of the arm would subject them to less deposition from the sediment plume (according to the modeling results). The degree of impact on the subtidal benthos at all of the stations depends on a number of factors. Separation of the effects of the two different disturbances (i.e. dredging and remediation) may be possible if they operate on different time and spatial scales, but only direct monitoring will show this with certainty.

Summary

The Sydney Harbour dredging program for the proposed Sydport terminal is expected to have a substantial impact on the monitoring program during the actual period of dredging. This impact will be primarily stem from mechanical interference with bottom communities and the generation of turbidity plumes resulting in particle transport into the South Arm. However, since the sediments due to be excavated are mainly sands, distinguished by low contaminant levels, the transport of contaminants into the inner harbour is expected to be minimal. It is anticipated that the principle effect of the dredging will be to further cap or bury the more highly-contaminated sediments of the inner harbour with coarser-grained, less contaminated material. Therefore, the effect of the dredging will be to further remediate sediments of the inner harbour. In this regard, any post dredging increases in contaminant levels in the water column or sediments will almost certainly be due to increased discharges from the Tar Ponds remediation project.

The dredging project is highly likely to have impacts on water column and benthic communities at the dredge site and at sites within close proximity to the dredge site and terminal construction as outlined above. It should be recognized that it may prove difficult to definitively separate the effects of dredging from Tar Ponds remediation during the dredging operation itself. Therefore, caged bivalve studies and crab tissue sampling should be discontinued during dredging but should recommence thereafter. Continued monitoring of the benthic communities is considered necessary to establish a new, post-dredging environmental baseline against which future effects of Tar Ponds remediation can be evaluated. The principle changes that should be made to accommodate the post-dredging regime are to relocate sampling stations 2-1, 2-2, and 2-3 to the east side of the harbour as noted above.

The MEEMP should be continued despite the possibility of environmental perturbations associated with the dredging and container terminal construction in Sydney Harbour. This generally well designed monitoring program has identified a trend of increased contaminant inputs to Sydney Harbour, presumably associated with the Tar Ponds remediation project. This trend should continue to be monitored and any associated biological effects should be identified and fully characterized. It is unlikely that the dredging operations or container terminal construction will produce environmental signals that will drastically interfere with the interpretation of the longer term monitoring results for the Tar Ponds remediation project.

Conclusions

PAH levels in surface sediments have increased by factors of 2 to 10 at all sampling locations and for all individual PAHs in Year 1 of the MEEMP compared to the pre-construction phase of the Tar Sands remediation project.

The increases observed in sediment PAH levels, but not in metal or PCB levels, indicate that they are associated with transport from the Tar Ponds remediation site into the harbour by water or atmospheric pathways. The clear, unambiguous detection of these PAH increases in harbour sediments attests to the general value and utility of the MEEMP.

The recent increase in PAH concentrations observed in Sydney Harbour sediments is statistically significant and in excess of environmental quality guidelines. However, the elevated PAH levels observed in Year 1 of the remediation phase remain significantly lower than those typical of inputs to the sediments during the peak of industrial activities from the 1960s-1980s. Once Sydney Tar Ponds (STP) remediation activities are finished, natural capping or attenuation of contaminant concentrations in the sediments will probably resume. Under these conditions, the increased PAH inputs measured during the remediation phase would primarily be evident as a local concentration maximum in the sediment record and have minimal biological impacts.

It is strongly recommended that sediment cores be collected and analyzed for contaminants as an integral component of the MEEMP. Coring will permit downcore analyses of PAH concentrations and reveal the recent history of PAH contamination of the harbour. The latter will provide critical information on the source and magnitude of recent PAH inputs to the harbour and permit more accurate and realistic modeling of PAH transport.

The higher PAH values measured by the Slo-Corer compared to the Grab sampler at several location suggests that the former is more effective at collecting recently deposited, surface “fluff” material. The Slo-Corer should continue to be employed in the monitoring program, as it is able to provide sediment core collection and essential quality control.

PAH water concentrations may have increased at some locations. The characterization of this effect is constrained, however, by experimental detection limit issues, potential biasing of water concentrations through the presence of highly contaminated suspended sediments, and possible quality control problems.

It is recommended that filtered and unfiltered water samples be compared to determine the extent to which PAH levels may have been affected by the presence of highly contaminated, suspended sediments.

The sampling protocol for the intertidal benthic community monitoring is considered to be inadequate to capture the natural variability at each site. It is recommended that this component be discontinued in its present form. To be most effective, it is recommended that the protocol be changed to include replication at each site adequate enough to fully characterize patterns in natural variability.

It is recommended that the sample preparation protocol for the crab tissue component be modified in order to lower the analytical detection limit for PAHs by, for example, pooling together the legs and claws of 5 to 10 crab samples.

The Sydney Harbour dredging and terminal construction projects will substantially affect benthic communities owing mainly to the generation of turbidity plumes resulting in particle transport into the South Arm. Continued monitoring of benthic communities is recommended to establish a new, post-dredging, environmental baseline against which future effects of Tar Ponds remediation can be evaluated.

Since the sediments due to be excavated are mainly silts and sands and distinguished by low contaminant levels, it is anticipated there will be minimal transport of contaminants into the inner harbour as a result of dredging. The principle effect will be to bury the more highly-contaminated surface sediments with coarser-grained, less contaminated material, thereby further remediating sediments of the inner harbour.

It is recommended that caged bivalve studies and crab tissue sampling be discontinued during dredging but should recommence thereafter.

To accommodate dredging activities, it is suggested that benthic sampling stations 2-1, 2-2, and 2-3 be relocated to the east side of the harbour.

It is considered unlikely that the dredging operations or container terminal construction will produce environmental signals that will significantly interfere with the interpretation of the longer term monitoring results for the Tar Ponds remediation project.

It is recommended that the MEEMP be continued despite any environmental perturbations associated with the dredging/terminal construction projects. In particular, the trend of increased sediment PAH levels associated with the Tar Ponds remediation should continue to be monitored and associated biological effects fully characterized.

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