Review of the Sampling and Analysis Plan and Benthic Primary Producer Habitat Report (SKM 2007)

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SUMMARY

The SAPBPPH report documents investigations into:

- water and sediment quality;
- biological assessments of the potentially impacted areas; and
- assessment of the potential loss of BPPH due to the proposed dredging activities.

While the review has highlighted a number of concerns about the methods used or the interpretation of the results, the key findings are:

With respect to Sediment quality investigations:

1. The methods used were in accordance with the National Ocean Disposal Guidelines for Dredged Material (NODGDM);
2. Silver and mercury concentrations exceeded the NODGDM screening levels in Dredge area 3, and were investigated further to assess their bio-availability. This review concludes that the method used to evaluate bioavailability was too limited to provide certainty of bio-available metal concentrations under real dredging conditions.
3. A more appropriate range of testing, including elutriate test, may result in different concentrations of bio-available forms of metals and that these could approach or breach level of habitat protection criteria set for Dredge Area 3.

With respect to the biological assessments:

1. The methods used for habitat mapping were appropriate.
2. The qualitative nature of the reef and epifauna sampling, and the limited temporal coverage of the sampling, renders the data inadequate as baselines for any scientifically robust assessment of impact in the future or as baseline data for monitoring or auditing purposes. Subsequent discussions have indicated that this was not the primary purpose of the surveys, and that they were only intended as a guide to the local benthic habitats. If this is the case, then the qualitative surveys are adequate but they do not form the baseline of any future monitoring or auditing.

With respect to estimating the impacts on Benthic Primary Producer Habitat:

1. This is a difficult task that was approached in a clear and logical way. Due to the complexity of the task, a large number of assumptions had to be made; much of the necessary data did not exist and had to be estimated from previous studies in other locations. The approach and the confidence in the predicted impacts is highly dependent on:
   - Understanding the minimum light requirements (MLR) of the BPP (seagrasses);
   - The predicted distribution and concentration of TSS plumes during dredging;
   - The relationship between TSS concentrations and the light attenuation coefficient (LAC).

2. The assumptions underlying the MLR are generally acceptable. However, recently published data suggest that the MLR value of 8% applied to *Posidonia sinuosa* could

be at the lower end of the possible range when correcting for epiphyte cover on the leaves. A value up to 14% may be more appropriate, with the implication that the seagrass requires more light to survive than is assumed in the modelling. This could have significant implications for the model outputs and it is appropriate that the issue be addressed.

3. Other recently published data suggest that the threshold light level for permanent loss of seagrasses has been set too low. Again, this would result in an under-estimation of impact for a given reduction in light availability in the model.

4. The relationship between TSS and LAC is central to the predictions of impact on BPPH and a number of assumptions, experimental or analytical approaches were used which affect either the validity of the relationships derived or the conclusions drawn. Key amongst these are:
    a. The mathematical approach used to derive light attenuation coefficients from the experimental data is unusual and, given the fundamental importance of these estimates, require a more coherent explanation and justification. Subsequent independent assessment indicated the approach is mathematically valid, but confirms that the explanation is poor;
    b. The coefficient used to estimate LAC from a given TSS is estimated from pooled data rather than one derived from individual dredging zones. This has the effect of reducing the resultant affect of TSS on LAC. It appears that this is a valid approach if dredging covers the full range of sediment types over short time scales (less than 3 hrs) but may under-estimate effects if dredging is confined to single locations for extended periods;
    c. The decision to estimate background TSS from published work in the Sargasso Sea rather than adjusting threshold values for seagrass survival using ambient LAC data which, according to the report, were gathered for the region as part of the SAP. SKM have subsequently indicated that the decision to use Sargasso Sea data was based on the comparability of water quality to Albany and the lack of appropriate water quality data for Albany. This implies that there are sufficient data available for Albany to provide this assurance of comparability and it would be appropriate for these to be referred to in the report.

5. While it is not clear what difference the above issues will make to the calculated loss of BPPH each has the potential to affect the outcome. In some cases the potential is to underestimate potential effects, while in others the assumptions are conservative and may over-estimate the impact on seagrasses. Overall, the approach taken is sound but the issues of detail raised above cumulatively reduce confidence in the outputs.

1. Introduction & Background

This document presents the results of a peer review of the Sampling and Analysis Plan and BPPH Impact report (SKM, 2007), which was prepared as part of the Albany Port Expansion proposal. As per communication on 20 August 2007, the review was to focus on:

- the methods and findings documented in the report; and specifically
- the methods used to derive the threshold levels for BPPH; and
- the series of investigations undertaken to predict and identify the zones of impact and influence.

As part of the approval process for the Albany Port Expansion proposal, a Sampling and Analysis Plan (SAP) was submitted to the Department of Environment & Conservation (DEC) in May 2005, and a Supplementary SAP was submitted in February 2006. The two SAP documents detailed a series of investigations into:

- water and sediment quality;
- biological assessments of the dredge areas, surrounding habitat and the potential offshore dredge spoil disposal areas;
- turbidity-light attenuation relationships;
- Benthic Primary Producer Habitat (BPPH) mapping; and
- assessment of the potential loss of BPPH due to the proposed dredging activities.

The Sampling and Analysis Plan and Benthic Primary producer Habitat Report (SAPBBPH) summarises the findings of those investigations.

For the purposes of this review, the main elements of the SAPBPPH report are grouped into: Sediment quality; Biological assessments; and BPPH impacts. While the Report includes water quality assessments with sediment quality assessments, these focus on determining total suspended solid – light attenuation relationships, which are central to the BPHH impact predictions. Therefore, these are considered in the review of the BPPH impacts section.

2. Sediment Quality

All sediment sampling was performed in accordance with the National Ocean Disposal Guidelines for Dredged Material (NODGDM). Appropriate QA/QC procedures appear to have been followed by the NATA-registered laboratories that undertook the chemical analyses. The report draws the readers' attention to some exceedences of the recommended criteria for permissible variation in split samples. However, even if the highest values were taken as representative, they would still be well below the NODGDM screening levels.

2.1. Metals

Silver and mercury concentrations exceeded the NODGDM screening levels in Dredge area 3, and were investigated further to assess their bioavailability. The Report acknowledges the three common approaches to determining the bio-available fraction of total metals in sediment (dilute acid extraction, AVS/SEM and porewater concentrations) but used only the porewater concentrations approach.

Restricting the analysis of bioavailability to porewater analysis potentially underestimates the bio-available fraction. The re-suspension of sediments into a water column can expose them to significantly different physico-chemical conditions, including redox conditions, which can affect the release of metals into the water column. It is common practice to use elutriate slurry test to determine the amount of desorption/adsorption of metals that may occur during re-suspension. In addition, it is acknowledged in the report that porewater concentrations may not be a useful indicator of potential metal bioavailability to organism that ingest sediment, and that acid extraction would be a better indicator of bioavailability of metals for these organism. A more appropriate approach would have been to use a variety of methods, including elutriate tests, weak acid extractable and porewater metal analyses. (Note: elutriate tests were performed for bio-available nutrient tests but no rationale was provided for not using these in the metal assessments).

Significance:
While the outcome of additional bioavailability tests is difficult to predict, some metals weakly bound to sediments may be released during resuspension, becoming potentially bio-available. In dredge area 3, the porewater concentrations were frequently at or above the 99% ANZECC/ARMCANZ level of habitat protection, and in one case approached the 95% protection level. The 95% protection level was set as the criteria for assessment in the Channel and Disposal areas. It is entirely possible that a slight increase in bioavailability under a more appropriate range of analyses would see the 95% level of habitat protection criteria approached or breached in Dredge Area 3.

2.2. Effects of Nutrient Liberation

The report concludes (pg 49) that any effects of liberated nutrients will not be long-lasting since:

1. the activity will occur in winter when epiphytes are quiescent,
2. there will be adequate mixing to prevent nutrients exceeding environmental guidelines; and
3. flushing of the area between the cessation of dredging and commencement of the summer (algal) growth season will remove nutrients to background levels.

The first assumption is invalid as epiphytic algae grow throughout the year and may achieve maximum biomass on seagrass leaves during winter (Kendrick et al 2000). Given this, there may, in fact, be a significant algal assemblage available to respond to nutrients. This is significant as later in the report the minimum light requirement for the seagrasses in the area uses the value based on seagrasses with low epiphyte biomass (8% of surface light) and not that for seagrasses with high epiphyte loads (14% of surface light). The validity of the other two assumptions about local hydrodynamics and flushing cannot be confirmed form the data presented in the report.

The MLR of seagrasses is a crucial component of the modelling of impacts on seagrasses (see section 4). Given this, any potential for nutrient release to enhance epiphyte growth and therefore increase the light requirement of seagrass should, ideally, be incorporated into the estimates of impact. A difference of 6% of MLR is likely to have a significant effect on the estimate of impact. It would be prudent to re-run the model with this scenario and confirm the extent of any difference in the predicted outcome.

3. Biological Assessments

3.1. Habitat Mapping

The habitat mapping was fundamental to the subsequent BPPH impact estimates. The methods applied for this mapping are standard and, without being able to confirm the quality of the photography on which they were based, appear appropriate. No indication is provided of the potential error in the maps. Since these maps form the basis of subsequent assessments of loss of seagrass habitat, a large error would be a concern. An indication of the potential error in the mapping would increase the confidence in the outcomes of BPPH impact assessment

3.2. Reef surveys

No rationale was provided for undertaking the biological surveys of the reef or disposal area assessments. In subsequent discussions with Dr Peter Morrison (SKM), it was indicated that the purpose of the surveys was not to provide a baseline data for future auditing or monitoring but simply to give an indication of the types of hia=bitat present in the area.

The reef assessments are entirely qualitative, comprising of written descriptions of the dominant biota and a series of photographs, which do not appear to be geo-referenced. The report clearly states that the use of quadrat sampling was considered inappropriate, though the reasoning is not provided. The qualitative data provided are a useful overall description of the reefs, and therefore meet the stated purpose (as per Morrison, above). However, the surveys will not provide adequate baseline data for any future assessment of impact.

3.3. Disposal area surveys

The infauna assessment had a reasonable degree of replication at each disposal site, though there is no understanding of temporal variation and this will restrict the capacity to undertake future assessments at the site. The assemblage may be quite different in other seasons. The assessment was confined to fauna greater than 1 mm, presumably because of the dramatic increase in time required to sort lower size classes. A 1mm cut-off is not an unreasonable compromise. However, numerous other studies in SW Australia (e.g. Brearley & Wells 2000) have shown that much of the biodiversity and a disproportionate amount of the faunal production in marine sediments occurs in size classes less than 1 mm. Given this, there is the potential for the survey to have underestimated the infauna biodiversity and abundance.

The epifauna assessment, like the reef assessments, is purely qualitative and has little value for future monitoring or auditing purposes. Again, however, subsequent communication with Dr P. Morrison of SKM, indicates that this was not the intended purpose of the surveys.

Significance:
The methods used to assess the biological communities of the reef and disposal areas are inadequate for use as a baseline in any rigorous monitoring programme. If it is intended to develop a baseline for future monitoring or auditing purposes, then additional surveys would be required.

4. Benthic Primary Producer Habitat Impacts.

The assessment of impacts on BPPH follows a logical approach, with the assumptions clearly stated. The approach is based on estimating the light requirement of the existing BPPH and then determining the likely change in light climate due to dredging. Where the change results in light levels falling below the minimum light requirement of the BPP, then a loss is anticipated. These losses are then clearly tabulated against the criteria formulated in the BPPH Policy.

Given the above, the accuracy of the approach and the confidence in the predicted impacts is highly dependent on:

1. Understanding the minimum light requirements (MLR) of the BPP (seagrasses);
2. The predicted distribution and concentration of TSS plumes during dredging;
3. The relationship between TSS concentrations and the light attenuation coefficient (LAC).

4.1. Minimum light requirements of seagrasses

The habitat mapping has identified 3 species of seagrass which may be affected: *Posidonia australis*, *P. sinuosa* and *P. coriacea*.

The MLR's of *P. sinuosa* and *P. australis* are derived from experimental shading studies reported in published works and are appropriate estimates. However, the work cited (Collier 2006) indicates that where the seagrasses are heavily epiphytised, the MLR could be higher than the 8.5% used here, possibly as high as 14%. This would increase the anticipated loss of seagrass. The report does not document the degree of epiphyte cover and it would be appropriate to confirm this. There is no reason to suspect that, under average conditions, the seagrasses in King George Sound would have epiphyte loads any higher than those present in Collier's 'normal' conditions. However, as described earlier, if nutrients liberated under dredging and spoil dumping stimulated algal growth, then the higher MLR may be a more relevant value. Again, it would be appropriate to compare the estimated impact on seagrasses using the 14% value to test the sensitivity of the model to this parameter.

Predicted Threshold Levels

The report then goes on to establish the threshold levels for seagrass health. These are based on percentages of the MLR.

Threshold level 2 is that at which some temporary loss of seagrass will occur. In the case of P. sinuosa, this is defined as 30% of the MLR during the dredging programme, since earlier work by Gordon et al (1994) showed that an 80% reduction in PAR to this species, at a depth of 3-4 m resulted in temporary loss of seagrass but significant recovery within 8 months. The 30% value was chosen to be conservative.

Threshold level 1 is that at which permanent loss of seagrass occurs, and set at 0 available light during the dredging programme, gain based on Gordon *et al*'s observations that there was significant recovery of seagrasses subjected to 99% light reduction.

While the approach is not unreasonable, it ignores some more recent data that could have informed the estimates and has some inherent assumptions, which are not justified and may affect the outcomes:

- Collier (2006) has undertaken more extensive shading experiments on *P. sinuosa*, which complement those of Gordon *et al* (1994). She imposed 7 months of shading and on seagrasses at different depth. In her study seagrasses at 4 m depth, which received 24% of the MLR showed significant losses and no recovery after 9 months. Plants at 8m depth which received 35% of the MLR showed no recovery after 13 months. These data suggest that the depth of seagrass is important to their recovery and that the assumption that 30% of MLR during the dredging period will allow significant recovery within 5 months may not be valid.

- Collier's data suggest a poorer capacity for recovery at the sorts of shading intensities being proposed in the report. Her data raise the possibility that plants in deeper water will also show significantly less (or no) recovery than those in shallow waters. Certainly her data do not support the assumption that permanent loss will only occur at 0% of MLR, since she has shown effectively permanent loss at values as high as 35% of the MLR in deep *P. sinuosa* meadows.

Thus, while the report has attempted to take a conservative approach, more recent work on *P. sinuosa* suggest that the assumptions made are not necessarily conservative, and that, at least, the Threshold 1 level is set too low.

4.2. Predicted Distribution of TSS

The report does not describe the model used to estimate the distribution of TSS. It is assumed that the model has been appropriately validated for the local conditions and takes into account the nature of the sediment particles likely to be resuspended. Modelling TSS distribution is an area outside my expertise. It would be valuable to confirm the appropriateness of the DRDGE3D model and its associated particle-tracking model used in the EIA with a suitably qualified physical oceanographer, and to confirm that the relationship of TSS suspension and transport has been validated for the types of sediments present in the dredge area.

4.3. The Relationship between TSS and LAC.

This relationship is central to the predictions of impact. The LAC in the impact area will be the result of background LAC (due to phytoplankton, other suspended organic matter, suspended sediments and dissolved coloured substances) plus the LAC due to TSS concentrations resulting from dredging. The relative importance of the source will vary with location.

The ambient LAC and TSS were determined from water quality monitoring. There are two concerns with these estimates:

1. They were based on a limited period in July – September 2006 (pg 3 of report). The report indicates additional ‘subsequent sampling’ was conducted with a light meter, but no dates are given. Phytoplankton concentrations are likely to be lowest in winter and highest in spring-summer, thus the measured values reported in the document may be at the lower end of phytoplankton contributions. Should dredging occur outside the July-September period, then the data used in the modelling may not be appropriate.
2. The LAC values were derived from Secchi disk depth measurements, later calibrated against photometer readings. Using a relationship from one time of year and applying it to SDD gathered at other times introduces the risk of error, since the relationship may vary over time and among observers. While SDD is a useful crude measure of water clarity it is not sufficiently quantitative for application in the sort of modelling being applied here. The report should clarify whether the data used in the modelling were based on the SDD data or the subsequent data collected using a quantum photometer. If the data are generated from a regression of SDD and LAC, then the strength of the relationship should be reported.

The relationship between the TSS generated by dredging and LAC was established using laboratory experiments. The approach is a useful one that improves the capacity to undertake light climate modelling. However, because of its central role in the entire modelling approach, the experimental determinations need to be rigorous. With this in mind, there are several aspects of the method that require comment or clarification:

1. The report details the type of sediment used in the test. This was collected from 4 geo-technical core samples. It is not clear if this sediment is representative of those that will be generated by dredging. In particular, will the dredging technique cut or in some other way change the nature of the sediment particles? If so, then it should be clarified whether this will affect either the persistence of TSS in the water column or the light absorbance characteristics.

2. The experimental tests were performed in freshwater. It is possible for dredged sediment particles to form flocs or physically bind with each other in ways that cause them to behave differently with respect to light absorption and re-suspension than

natural sand grains. Is the behaviour of the particles likely to be different in marine water than the freshwater used in the tests? If so, the significance of this for the TSS-LAC relationships needs to be clarified.

3. The experimental approach uses a point light source. As such, the Beer-Lambert Law (which is used to derive the LAC) is not applicable, since that law only applies in situations of a diffuse light source. On page 31, the report documents a mathematical normalisation that appears to be designed to deal with this incompatibility and to allow the generated PAR values to be used in the Beer-Lambert law. However, the explanation provided in the SAPBPPH Report is not sufficient to provide any confidence that this approach is valid. In fact, the experimental data can be used to generate an extinction coefficient according to following relationship which is applicable to point light source data:

$$I_z = \frac{I_0}{1 + Kd_z + (Kd_z)^2}$$

and it is unclear why this equation was not used to generate estimates of light extinction.

Given the fundamental importance of these estimates to the impact prediction, a more coherent explanation of the approach and justification of its validity should be included. Subsequent discussions with Optek, who undertook this work, has confirmed that the approach used was designed to correct for non-diffuse source of light but rationale for the data normalisation is not clear. Following initial advice, Ecologia contracted an applied mathematician to review the original Optek report. On the basis of Dr Farrow's review, it appears that the approach is valid, though not well explained.

4. The data generated by the experiments were used to produce linear relationships between TSS and LAC, for each dredging zone and for the data from all zone pooled. The slopes of the relationships for different zones or pooled data ranged from 0.022 (pooled) to 0.072 (VC06 sample). Consequently, the choice of coefficient to apply will dramatically affect the predicted LAC. For example, when sediments form zone VC06 are suspended, each mg will cause a 0.07 increase in the LAC, while for the pooled data set an increase of 1 mg of TSS will only produce a change of 0.022 in the LAC. With this in mind, there are two important concerns:
   - The pooled relationship only extends over the TSS range 0-80 mg/L yet the individual dredge zone relationships cover the range 0-250. This suggests the pooled data are only a sub-set of the full data set. Subsequent discussion with Optek staff has confirmed that the pooled regression was based on less than 100 mg/L data, at the request of SKM. The rationale for this is not given, though presumably SKM believe that concentrations of TSS in excess of 100 mg/L will not occur. This sub-sampling of the data set needs to be justified, since the pooled data set predicts less effect on LAC for a given increase in TSS than most of the zone-specific relationships.
   - The report subsequently applies the pooled relationship in the modelling of light climate during dredging. The pooled coefficient produces a reduced effect on LAC than would any of those derived from zone-specific relationships

(as explained above). The justification given for this pooling is that dredging will not treat discrete areas separately, but will liberate sediments from across the entire dredging area. In subsequent discussions with Grange Resources and SKM it was indicated that the dredge would cover the entire range of sediments sampled within a 1-3 hour timescale and, therefore, the suspended sediments would be a mixture of those from all four sediment tests. On this basis an average TSS-LAC relationship was applied. So long as dredging occur with this spatial and temporal design, then the assumption seems reasonable. However, were dredging to occur in specific areas, the effect on LAC will be determined by the sediment characteristics of that area.

Both of these considerations affect the model outputs and have the potential to under-estimate the resultant LAC. The justification for the first issue should be addressed in the report and it is important to recognise the potential effect of changing the design of the dredging operations (issue 2).

5. Having generated the above relationships, they are then applied in the model to estimate the LAC at given places where seagrass occur. The LAC at a given location is derived by the model overlaying turbidity onto the system. The wording of the report is confusing, but after subsequent discussions with Dr P. Morrison of SKM, it appears that the contribution of background (non-dredge) turbidity is accounted for by reducing the threshold values for seagrass loss by the ambient TSS concentration. Thus, if the threshold TSS at a given location is, say, 20 mg/L, then a background concentration of 4.4 mg/L would be removed resulting in an allowable additional TSS from dredging of 15.6 mg/L. (Note: this is an interpretation based on discussions with the report author and is not completely clear from the report itself).

   The ambient LAC is likely to include a range of particles with quite different light absorbing characteristics to those used in the experimental tests, such as phytoplankton with light harvesting pigments. Often it is these particles that contribute a disproportionately high amount to the total LAC, which is why ambient relationships between TSS concentration and LAC are often highly scattered. It is inappropriate, therefore, to assume the same TSS-LAC relationship to the background turbidity, rather than apply the ambient LAC directly. Unfortunately, while the TSS-LAC relationship was not applied, nor were local LAC values used.

   Instead, the report goes on to approximate background LAC by deriving it from Smith et al's (1998) work in the Sargasso Sea. This area, renowned for its exceptionally high water clarity, had an LAC of 0.098 and if this is applied in the TSS-LAC relationship derived in the experimental work, then it would suggest a TSS in King George Sound of 1.96 mg/L, remarkably similar to the measured value of 2 mg/L measured in this study. It is then concluded that 2 mg/L TSS is would have minimal effect on modelled output. This raises several questions:

   a) according to the equation given in the report (page 70) an LAC of 0.098 yields a TSS of 4.4, not 1.98. Presumably, there is a mix up here between LAC and the light extinction coefficient, where Smith *et al*'s value must be an extinction coefficient based on Ln of PAR rather than the LAC (Log_{10} of PAR). In any case, the 1.98 mg/L value looks to be incorrect and should be 4.4 mg/L (more than double that currently being used).

b) even allowing for the above, there is no logical justification for using a TSS value derived from the Sargasso Sea to then generate an LAC value, when local empirical data, far more relevant and robust LAC data for the region could be applied than a value derived from the Sargasso Sea, are available. SKM have subsequently indicated that the decision to use Sargasso Sea data was based on the comparability of water quality to Albany and the lack of appropriate water quality data for Albany. This implies that there are sufficient data available for Albany to provide this assurance of comparability and it would be appropriate for these to be referred to in the report.

Overall

It is not clear what difference the above issues will make to the calculated loss of BPPH. However, each of the issues has the potential to affect the outcome and, cumulatively, they reduce certainty and confidence in the outputs.

5. Application of the BPPH

The application of the data to the BPPH Policy appears to conform to the principles of the policy. The spatial scales of the management units approximate those recommended in the Policy. Two issues that warrant mention:

1. The historical losses are clearly documented and take a conservative approach, in the sense that they tend towards the higher estimates of historical losses. The absence of any historical losses in King George Sound is reasonable except for some small losses likely to have occurred within aquaculture farms. A study by Eyres (2005) found no large-scale losses of seagrass associated with aquaculture, but his visual observations suggested that scouring due to the movement of anchoring devices does produce losses of the order of up 10s to 100 m2 in some farms. The cumulative impact of these losses has never been quantified, but it should be possible to include a conservative estimate in the report.

2. The predicted losses given in Tables 46 and 47 do not specify the BPPH. Presumably this is all seagrass, however that is not clearly stated. The intent of the policy is to report on each BPPH. In this case, reefs are present in the area but it is not clear from the report whether any reef area is affected.

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