FINAL REPORT (20/07/99)

FOURTH REPORT OF THE OTML ENVIRONMENT PEER REVIEW GROUP (PRG) -

COMMENTS ON THE SCIENCE UNDERLYING THE HUMAN AND ECOLOGICAL RISK ASSESSMENT (HERA)

1.0 INTRODUCTION

In 1997 Ok Tedi Mining Limited (OTML) formed a Peer Review Group (PRG) to provide advice, recommendations and peer review related to a human and ecological risk assessment (HERA) of the terrestrial and aquatic ecosystems of the Ok Tedi/Fly River systems downstream of the mine. There are five members of the PRG:

Professor Margaret Burchett, University of Technology, Sydney
Professor Peter Campbell, Université du Québec
Dr. Peter Chapman, EVS Environment Consultants, North Vancouver (Chair)
Professor William Dietrich, University of California, Berkeley
Professor Barry Hart, Water Studies Centre, Monash University

The PRG was asked to attend and participate in the July 6-8, 1999 Ok Tedi Risk Assessment Workshop in Brisbane, and then provide their comments on the quality of the science underlying the HERA, specifically on the following reports:

1. Sediment Transport Model: Parker & Cui
2. Dieback Thresholds: Marshall & Rau
3. Dieback Modelling: Carroll & Moi
4. Copper Chemistry Model: Apte, Simpson & Webster
5. ARD Modelling Work: Miller
6. Food Web Report: Storey & Smith
7. Isotope Report: Bunn, Tenakanai & Storey
8. Fish Habitat Report: Figa, Bakowa & Tenakanai
9. Fish Toxicity Report: AWT
10. Phytotoxicity Report: Kerven
11. Dredged Sediments Nutrient Trials: Ila'ava

An additional report (Human Health Survey Report: Flew) was reviewed outside the PRG. [Foursight Associates Pty Ltd. 1999. Review of health and nutrition work for OTML. June 11, 1999. Incomplete draft.]

The requested comments on the quality of the science underlying the HERA are provided in Section 4 of this report. Sections 2 and 3 provide information on, respectively, the functioning and expertise of the PRG. In Section 5 we comment briefly on the preliminary draft HERA documents, and in Section 6 we provide general comments intended to further assist OTML's Environment Department in fulfilling their responsibilities.

2.0 FUNCTIONING OF THE PRG

2.1 Terms of Reference

The PRG's Terms of Reference have evolved to the following:

i. Advise OTML management on the HERA programme, with particular focus on the approach (conceptual basis and methodology), the screening level risk assessment (SLRA), and the final detailed level risk assessment (DLRA).

ii. Recommend additional scientific studies necessary to ensure that the HERA has an adequate information base.

iii. Review key reports and individual projects related to the HERA programme as referred to the PRG by OTML management.

iv. Provide further advice as requested by OTML management.

2.2 Previous PRG Reports

The PRG has produced three previous reports as follows in addition to numerous reviews, and has attended and commented at various meetings and workshops. Summary Minutes of these meetings have been provided where appropriate.

1. 29/08/97: First Report of the OTML Environment Peer Review Group - Comments on the Ok Tedi Fly River Chemistry and Biology Workshop.

This report followed from the first task of the PRG, specifically: participating in the above workshop (Melbourne 18-20/08/97); providing a report recording the key findings from that meeting, together with comments (and recommendations) on those and other relevant issues. In addition, detailed Minutes of the entire workshop were provided.

2. 23/07/98: Second Report of the OTML Environment Peer Review Group - Comments on the Ok Tedi Risk Assessment Workshop.

The PRG attended and participated in the above workshop (Brisbane 7-9/07/98). In addition to detailed Minutes of the entire workshop, the PRG provided a report addressing the following specific objectives set by OTML:

i. Review individual projects and the overall human health and ecological risk assessment (HERA) programme considering the benefits, limitations, and implications to management.

ii. Make recommendations and advise whether individual projects should proceed relative to the goals and time frame and, where necessary and appropriate, suggest alternatives.

iii. Comment on whether the HERA can add significantly to the output of the 1996 risk assessment, providing additional necessary information for management decisions.

iv. Advise how to efficiently focus throughout the project on the output and the final outcome.

v. Advise on how the process and output can be made auditable and defensible.

vi. Ensure that there are no fatal flaws in the programme

3. 24/02/99: Third Report of the OTML Environment Peer Review Group - Comments on the Ok Tedi Risk Assessment Workshop.

The PRG participated in this workshop (16-18/02/99, Sydney) and summarized the following relative to our understanding at that time of the effects of the Ok Tedi mine on the receiving environment: major concerns (dieback; fish biomass/richness declines; dissolved copper; acid rock drainage; human populations); other major issues (dredging; time lines; meetings); and, additional issues (dieback extent and thresholds; low dissolved oxygen; habitat; copper spikes; tie channels; material on the floodplain; aquatic sediments).

2.3 Forthcoming PRG Reports

4. This document comprises the fourth PRG report.

5. A fifth PRG report on the HERA Detailed Level Risk Assessment (DLRA) will be provided in October 1999 following completion and review of the DLRA. It is anticipated that this will be the final report by the PRG on the HERA; OTML has expressed their desire that this report include the PRG "signing off" on the HERA (i.e., determining that the HERA is adequate for decision-making and that there are no major flaws).

6. A sixth PRG report on OTML's current and future proposed environmental monitoring will be provided after the HERA is completed (see Section 6.4).

3.0 PRG EXPERTISE

As noted in our Second Report to OTML (23/07/98), "the present PRG members have expertise in ecological risk assessment, aquatic and terrestrial ecology, ecotoxicology, geochemistry, environmental chemistry and water quality, plant physiology, and hydrology / sediment transport / geomorphology". However, an important area where the PRG has limited expertise is in tropical human health. In our second report we suggested "that OTML management consider appointing one additional member to the PRG, with such expertise." We reminded OTML of this deficiency in our Third Report to OTML (24/02/98). In response, OTML retained Foursight Associated Pty Ltd. (Melbourne) to provide a peer review of human health and nutrition work (Foursight Associates Pty Ltd., 1999). To date we have only seen a preliminary, incomplete draft of this review.

The PRG remains concerned that the human toxicological aspects of the HERA have not been adequately reviewed. The PRG has done its best within the limits of our expertise, but the HERA remains vulnerable to criticism in this regard.

4.0 COMMENTS ON THE SUPPORTING DOCUMENTS

4.1 Introduction

As previously noted in our third report, the PRG are generally impressed by the quality of work which has been done and are also impressed by the increased linkages between the different disciplines. Overall, the work is of good quality; a number of the reports are world class, most are adequate for the HERA, and one is unacceptable (see Section 4.10). Peer-reviewed publication of appropriate portions of this work is highly encouraged (see Section 6.2).

The 11 individual reports supporting the HERA are reviewed below in terms of the following key questions:

> What does this study tell us ("more likely than not")?
> What does this study not tell us / what are the major uncertainties?
> How does this study assist with the HERA and/or deal with key uncertainties?
> What monitoring/investigative studies [key ones] are needed resulting from this study?

Each of the 11 reports was reviewed at least once in detail prior to the July 1999 Workshop. The review comments were provided to both OTML and the authors of each report and are to be addressed before the reports are finalized.

4.2 Sediment Transport Model: Parker & Cui

The sediment model underpins the HERA. The science behind this model is state-of-the-art and, although uncertainties remain, this model provides the best information to date on the present and future (under different scenarios) hydrology and fluvial transport of the Fly River system. Two model runs have been made, an initial one in January 1999 (the January model), and a later other in May 1999 (the May model). The following comprise the PRG's comments on the model. Separate, independent review of the model, commissioned by the OTML Board, is expected to be completed by July 22 and will be reported separately to the Board.

What does this study tell us ("more likely than not")?

> The river is overloaded with sediment and will remain so for decades.
> Elevated bed levels along the lower Ok Tedi and Fly River leading to accelerated floodplain deposition of mine derived sediments and increased flooding will continue for decades, even if the mine were to close in the year 2000. Suspended sediment concentrations, however, will decrease relatively quickly upon mine closure. Recovery to previous bed elevations will be slowed in the lower reaches by the continued arrival of sediment eroded from upstream.

What does this study not tell us / what are the major uncertainties?

> Major uncertainties are: the height of the sediment wave that will propagate down the middle Fly River during and after mine closure; tidal effects (flow reversals) and backwater effects of the Strikland River on the amount of sediment deposited in the

lower Middle Fly; bed sediment grain size distribution as a consequence of mine waste loading and the effects of changing size distribution on rates of sediment deposition in the channel.

This model does not tell us what may be the effects of aggradation on tie channels.

How does this study assist with the HERA (relative to the options) and/or deal with key uncertainties (relative to the options)?

The May model should be used for the HERA, acknowledging that the model appears to fail (i.e., seriously underestimate aggradation) in the lower Middle Fly.

Dredging offers several likely benefits similar to (but less than) closure (in the May case); the other options cannot be distinguished / separated.

Overbank deposition heights and amount of material going overbank can be predicted for different scenarios.

What monitoring/investigative studies [key ones] are needed resulting from this study?

Documentation of the amount of sediment deposited in the lower Middle Fly. This can be done through a combination of a repeat of the extensive Andrew Marshall 1997 survey and through cores of the river bed.

Grain size analyses of the river bed surface and subsurface sediments in the Fly River to document what grain size adjustments have occurred and what size sediment is being buried in the channel.

Sufficient data on the flow heights on the lower Strickland and below the junction with the Strickland (e.g., at Ogwa) to allow the Parker and Cui model to make improved predictions of lower middle Fly channel deposition.

Integration with the ARD model.

4.3 Dieback Thresholds: Marshall & Rau

Dieback is a term applied by OTML to stressed and highly stressed vegetation; it is assumed that the vast proportion of the affected vegetation will eventually die and be replaced by other vegetation. Dieback is one of five major concerns previously identified by the PRG (third report to OTML). Determining dieback thresholds is a key requirement for modeling future changes to dieback related to different scenarios. The report is detailed, thorough and convincing, and includes the history, extent and potential maximum increases in dieback areas. The authors have adequately addressed all of the PRG's comments and produced an acceptable final report.

What does this study tell us ("more likely than not")?

Maximum possible areas of dieback.

Dieback extent through to January 1998 has approximately doubled every year.

What does this study not tell us / what are the major uncertainties?

Species-specific thresholds.

The present extent of the "dieback front", particularly the downstream boundaries.

The impact on the grasses and the swamp areas in the lower zones.

The rate of future dieback.

Ecosystem and health effects of dieback (e.g., loss of biodiversity, loss of ecosystem function, loss of food resources, increased risk of malaria or other water related illnesses)

How does this study assist with the HERA and/or deal with key uncertainties?

Information is provided on the vegetation mosaic and its relative vulnerabilities to flooding.
Information is provided on the maximum possible areas of dieback in addition to historic information.

What monitoring/investigative studies [key ones] are needed resulting from this study?

Reassessment of the present extent of dieback.
Further, directed, judicious ground truthing with associated satellite/aerial imaging, including Irian Jaya.

4.4 Dieback Modelling: Carroll & Moi

The model predicts the following maximum extent of dieback, which could increase by up to 50% within the limits of the floodplain: pessimistic, 1350 sq km; likely, 900 sq km; optimistic, 700 sq km. The effort devoted to developing this model is creditable, but the PRG remain concerned regarding some of the assumptions made in the model. However, we agree that these assumptions cannot be further refined based on presently available information (from monitoring and other studies). Given the consequent high level of uncertainty regarding key assumptions, we recommend that a conservative approach be taken as regards possible environmental effects. Specifically, the pessimistic scenario (at least 1350 sq km dieback) should be considered as a very real possibility.

What does this study tell us ("more likely than not")?

At least half (approximately 700 sq km) of the maximum predicted dieback area above Mabaduamon the Fly River will actually suffer stress or high stress such that the majority of the vegetation will eventually die and be replaced by other vegetation types.
Dieback will continue past mine closure due to increased flooding resulting from the sediment wave predicted by the Parker and Cui model.
Recovery will be slow (timing cannot presently be quantitatively determined from the model).
Recovery to specific vegetation types that will be present can be generically predicted based on site specific conditions.
The major effect of continued mining would be slower recovery of dieback compared to closing the mine.

What does this study not tell us / what are the major uncertainties?

What happens to grasses of the middle Fly swamp forests.
On a site-specific basis, when recovery occurs and how similar the vegetation will be then to what is there now, in terms of percentage (or proportional) disturbances.
The true maximum extent of dieback.

Duration of flooding (which is a major determinant of dieback).

How does this study assist with the HERA and/or deal with key uncertainties?

It provides upper and lower bounds (within a factor of two: 700 to 1350 sq km) to the minimum possible extent of dieback above Mabaduan.

The extent of dieback between Wygerin and Mabaduan may be decreased by about 50% by early mine closure or by extensive dredging; closure is the best option followed by dredging in terms of the peak extent of dieback (the differences are relatively small).

What monitoring/investigative studies [key ones] are needed resulting from the present study?

Relationship between duration and flooding frequency to refine dieback predictions.

Continuing surveys of dieback on the Middle Fly (a prediction has been made which can be tested).

Effects of increased flooding frequency on grasses.

4.5 Copper Chemistry Model: Apte, Simpson and Webster

This model combines laboratory work and modeling and is intended to model current conditions and predict future conditions with an emphasis on "dissolved" copper (dCu; <0.45 micro-m). The PRG finds the work done to be of very high quality and technically defensible. The science involved is state-of-the-art.

What does this study tell us ("more likely than not")?

dCu concentrations are expected, based on the present mine plan, to plateau between the years 2000 and 2010 (e.g., at Ningerum at 16 micro-g/L dCu in 2006); at no sites are these levels of biological concern when based on an average annual concentration basis. However, annual average concentrations are not as biologically significant as dCu spikes.

The different mine options have very little effect on dCu annual averages; the major effect would be to shift the plateau by about 10 years (earlier) if the mine closed (TSS is not changed by dredging).

Spikes/pulses of dCu will occur, and much of this Cu will be biologically available.

What does this study not tell us / what are the major uncertainties?

Whether water column spikes/pulses of copper will cause toxicity/adversely affect the food chain (only bioavailability is predicted). If the spikes/pulses recorded to date are real, then more than likely some sensitive algae are already being killed, possibly affecting the food chain (see Section 4.8).

The reactivity of the material stored on the floodplain is unknown. Release of Cu from material stored on the floodplain is not considered by the model.

The model output assumes that river pH will not change; acid inputs to the river (e.g., from localized ARD) could change river pH and change Cu mobility.

The model will change if the mine plan changes (e.g., if cut off grades change).

The model does not include the off river water bodies (OWRBs) because information

on sediment inputs to OWRBs is lacking.

How does this study assist with the HERA and/or deal with key uncertainties?

The way that mining is conducted is important (e.g., major downstream changes [improvements or the reverse] could result from modifications to the mine operations).

There is little difference in annual average dCu concentrations between different options. Mine closure at the end of the year 2000 results in about a 30% decrease in dCu concentrations in the first four years followed by a gradual decline in dCu concentrations over the next 45 years (the time limit of the model). The time taken for the system to return to pre-mine dCu concentrations is predicted to be greater than 50 years. Closing the mine at the end of the year 2010 delays this process by 10 years.

What monitoring/investigative studies [key ones] are needed resulting from this study?

Dedicated monitoring to examine and track spikes/pulses of dCu (e.g., their existence, extent and significance). [Presently there is some uncertainty that the spikes are real; replicate samples would provide information as to whether the spikes are real or not. If such spikes exist, they could be very significant to the upper Fly River ecosystem].

Better information on the tailings and waste rock composition/loads.

Upgrading the model to a monthly and then a daily time step.

A dissolved organic carbon (DOC) model of the system; however, it is not expected that major changes will occur that will affect the model output.

Determining the reactivity of floodplain materials and the likelihood of Cu releases, especially during wet and dry cycling.

Including OWRBs in the model.

ARD study results need to be integrated into the model (see Section 4.6, below).

4.6 ARD Modelling Work: Miller

The question of acid rock drainage (ARD) was raised at the first PRG meeting in Melbourne (August 18-20, 1997) and is also one of five major concerns previously identified by the PRG (third report to OTML). However, the preliminary report provided to the PRG on June 29, 1999 represents the first serious treatment of this issue. This preliminary report was the subject of both written PRG comments and intense discussions at the July 6-8, 1999 Brisbane workshop. ARD modeling is in the preliminary stages with a great deal more work to be done. This is a critical piece of work relative to both environmental and mine management issues, and should have been done earlier. If risks from ARD and metal leaching from deposited material cannot be eliminated or at least minimized, the environmental consequences will be extremely grave. The PRG believe that, if comments provided previous to and during the workshop are adequately addressed, the proposed work program will be appropriate. We cannot comment further until the work is completed and a complete draft report submitted for review. The PRG again stresses the very serious nature of the ARD potential and the need for OTML to assign a very high priority to this work. Further, if mining continues with addition of limestone, it is critical that this only occur if: (1) there is no uncertainty as to OTML's ability to correctly neutralize the ARD potential of the waste and tailings; (2) there is no signficant uncertainty regarding possible subsequent release of dCu following deposition (in either the near- or long-term).

What does this study tell us ("more likely than not")?

There will be localized areas of deposited material with the potential for ARD. Signs of these already exist.

The preliminary work suggests that ARD will not affect the overall ecological system nor have a major ecological impact in the short-term, provided limestone additions and other mine management activities are followed, and areas with ARD potential are successfully targeted.

Based on analyses of river-bank material conducted to date, there will not be ARD on the Fly River floodplain from presently deposited sediments; this may not be true of the Ok Tedi floodplain.

What does this study not tell us / what are the major uncertainties?

The short-term is reasonably certain; the longer term (>5 years post-mine), is less certain due to ongoing sorting and development of potentially acid forming (PAF) zones.

This is only a preliminary investigation that involves a large number of assumptions.

Adsorption mechanisms for released dCu are not yet included in the ARD Cu chemistry module.

The Fly River floodplain is not included in the model. However, based on river bank samples the flood plain deposits are expected to be non-acid forming due to excess acid neutralizing content (ANC).

The mine pit is not yet included in the model and is likely to be PAF.

How does this study assist with the HERA and/or deal with key uncertainties?

Serious risks occur when limestone runs out in the absence of successful management activities.

The tailings are expected to be PAF for the life of the mine. Therefore land-based disposal options must consider the need to prevent oxidation of stored tailings. This will require a high level of design and diligence, with ongoing maintenance to prevent ARD and Cu leaching from land storage. In contrast, river disposal involving mixing and blending with mine derived limestone and natural sediments is predicted (based on the limited evidence available) to produce a non-acid forming (NAF) sediment within the Fly River floodplain.

What monitoring/investigative studies [key ones] are needed resulting from this study?

Sampling to date has been biased to finer samples; bulk sampling is required.

Geochemical modeling done by CSIRO needs to be integrated into these investigations (see Section 4.5, above).

The possibility of ARD on the floodplain needs to be fully considered.

Sensitivity analyses are required for the modeling.

Uncertainties include: acid-base characteristics of waste rock and tailings; waste rock production schedules (by rock type and S grade); tailings production schedules (by rock type and S grade); oxidation kinetics, lag period, Cu leaching (load); geochemistry of river deposited material - by location and particle size; refining the effects on dCu concentrations with CSIRO; moisture profiles in exposed materials;

exposed areas - now and trends (to the end of mining and following closure).

4.7 Food Web Report: Storey & Smith

This is a good summary of information derivable from stomach contents and a creditable effort to construct food webs. This report forms a necessary basis for the isotope report (Section 4.8, below).

What does this study tell us ("more likely than not")?

There are food web differences between the river and floodplain related both to dominant species and food supplies.

What does this study not tell us / what are the major uncertainties?

Consumption of detritus/mud was recorded in most stomachs. However, detritus/mud included material too difficult to identify, which probably includes algae.
No information is provided on links between plants and invertebrates and fish; the study was based only on fish stomach contents - it showed what they were eating, not what they were getting their energy from.
Fish consumed were not identified to the species level.
No information was provided on larval fish (only on adult and subadult fish caught in gill nets).

How does this study assist with the HERA and/or deal with key uncertainties?

It provides a basic framework for food chain/pathway analysis.

What monitoring/investigative studies [key ones] are needed resulting from this study?

Energy pathways, assimilation and food web components (which are partially addressed by the preliminary isotope analysis).
Appropriate monitoring of algae and benthic invertebrates.
Targeted study around the junction of the Ok Tedi/Fly to determine if there have been changes since these samples were collected some years previously. Condition indices, etc. would also be part of such a study.

4.8 Isotope Report: Bunn, Tenakanai & Storey

This is a well written report and a credible piece of work that draws a plausible conclusion - that most fish and invertebrates sampled from two sites (Kawok, upper Fly and Oxbow 6, Middle Fly) ultimately derive their carbon from algae. We strongly recommend publication of this study in the international peer-reviewed literature.

What does this study tell us ("more likely than not")?

There are four main energy pathways in the Fly River aquatic ecosystem; there are differences between the floodplain and channel food webs.
Algae are an extremely important food source, terrestrial grasses are not.
The loss of forest will be detrimental to aquatic food chains. For instance, in some

areas Macrobrachium prawns are a major food source which have some level of dependency on forest food sources; if dieback continues, the prawns will be adversely affected. Also, fruit eating species are now absent from the Ok Tedi.

What does this study not tell us / what are the major uncertainties?

Sources (river or also floodplain) of algal biomass eaten by fish resident in the river channel.
Quantitative evidence as to what is presently or may in future be affecting the food chain (e.g., dCu, habitat, TSS, etc.).
Relative proportions of the epiphytic versus water column algae food chains on the floodplain.

How does this study assist with the HERA and/or deal with key uncertainties?

The study does not differentiate among options, but does indicate the most important and vulnerable food chain links (e.g., some algae are particularly sensitive to dCu).

What monitoring/investigative studies [key ones] are needed resulting from this study?

Differentiating between the epiphytic and planktonic algae as food sources.
More information on other lower trophic (food chain) levels, in particular the benthos.
What mine-related issues most affect algae and other important bases for the food chains (e.g., dCu, TSS, abrasion).
Dietary study as per the food web study above (see Section 4.7).

4.9 Fish Habitat Report: Figa, Bakowa & Tenakanai

This report provides useful background information, but does not address the key site-specific uncertainty, specifically, whether or not declines in fish biomass and diversity are due to aggradation effects on habitat.

What does this study tell us ("more likely than not")?

Physical habitat attributes can strongly affect diversity and biomass of fish communities in streams.
There will be some effect on Fly River fish communities from physical habitat attributes.

What does this study not tell us / what are the major uncertainties?

Influences of the fish-habitat relationship from: microhabitat conditions, water quality, interactions with other biota (e.g., competition, predation, food availability).
The relationship in the Fly River between habitat and aggradation related to fish communities.

How does this study assist with the HERA and/or deal with key uncertainties?

This study is a literature/information review only; it provides no convincing

information related specifically to the mine.

What monitoring/investigative studies [key ones] are needed resulting from this study?

Field studies to determine the relationship between specific components of habitat and aggradation (for fish and other key ecosystem components).

4.10 Fish Toxicity Studies: AWT

This study was disappointing. The methodology, reporting and report in general are inadequate and do not resolve the issue.

What does this study tell us ("more likely than not")?

The 96-h LC50 is in the range of 200 ug/L of 0.45 um filtered Cu; juvenile barramundi are unlikely to be at acute risk from present dCu concentrations in the Fly River.

What does this study not tell us / what are the major uncertainties?

The study is flawed; the exact sensitivity of barramundi to dCu is unknown. Additionally, although not the subject of this study, the sensitivity of *Nematolosa* herring to dCu remains unknown. Such studies have been previously recommended by the PRG.

How does this study assist with the HERA and/or deal with key uncertainties?

It provides rough estimates of Cu toxicity to Australian barramundi.

What monitoring/investigative studies [key ones] are needed resulting from this study?

Repeat the study to determine the acute toxicity of dCu to barramundi..
Determine sensitivity of herring from the Fly River to dCu (as recommended by the PRG in our second report).

4.11 Phytotoxicity Report: Kerven

The study is acceptable but limited in terms of the information provided, as noted below.

What does this study tell us ("more likely than not")?

Tailings are not acutely toxic to the tested plant species, corn.

What does this study not tell us / what are the major uncertainties?

The toxicity of tailings to other species, life-cycle effects, or possible chronic effects.
Any adverse effects of low nutrient concentrations in tailings.

How does this study assist with the HERA and/or deal with key uncertainties?

The tailings will not be acutely toxic to corn.

What monitoring/investigative studies [key ones] are needed resulting from this study?

The toxicity of tailings (acute and chronic) to other species including life-cycle effects.

4.12 Dredged Sediments Nutrient Trials - Ila'ava

The study is acceptable but limited in terms of the information provided, as noted below.

What does this study tell us ("more likely than not")?

Dredged sediments are not acutely toxic to the tested plant species, corn.
Plants can be grown on the dredged sediments but nutrient additions are required.

What does this study not tell us / what are the major uncertainties?

The toxicity of dredged sediments to other species, life-cycle effects, or possible chronic effects.

How does this study assist with the HERA and/or deal with key uncertainties?

The dredged sediments will not be acutely toxic to corn; revegetation of dredged sediments placed on land is possible.

What monitoring/investigative studies [key ones] are needed resulting from this study?

The toxicity of dredged sediments (acute and chronic) to other species including life-cycle effects.

5.0 HERA Documents: Parametrix & URS

Both the incomplete draft screening level risk assessment (SLRA) and the incomplete draft detailed level risk assessment (DLRA) were subject to numerous comments from the PRG. Final submission of these documents addressing the PRG comments is pending. Once the PRG's comments on the SLRA are addressed, the SLRA will be considered complete and will not be further reviewed. The DLRA will, however, be reviewed again since only an incomplete draft has been submitted for review to date (in contrast, the SLRA has been reviewed twice by the PRG).

We remain of the opinion that the HERA is eminently worthwhile; this opinion is supported by the substantial progress in our understanding of the ecosystem which has occurred as a result of the HERA process compared to the 1996 risk assessment. In the second PRG report we cautioned that "...given the very restrictive time-frame, the HERA will contain many more caveats and uncertainties (and larger uncertainties) than if the time-frame were more appropriate to the level of complexity of this issue." This caution has been proven true. The DLRA will not be a "world class" risk assessment given the major uncertainties remaining (e.g., reasons for fish biomass/diversity declines - habitat and aggradation relationships are suggested but to date comprise only a hypothesis which remains to be tested). However, it is

still our opinion that the DLRA will be a useful document for decision-making, i.e., a comparative risk assessment.

Key issues which must be fully discussed and assessed in the DLRA include the following five major issues identified by the PRG in their third report and which comprise our present understanding of the key issues to date:

> Terrestrial Dieback/Loss of Population and Systems Biodiversity: Localized loss of biodiversity will occur, associated with the loss of rainforest due to dieback.
>
> Fish Biomass/Diversity Declines: Declines have been documented since the early 1990s.
>
> Bioavailability of Cu (Cu spikes): As previously noted, if these spikes are real, they are likely killing sensitive algal species, and algae form the basis for the food chain.
>
> Human Populations: Health issues and social implications of changes to the environment need to be adequately addressed.
>
> Acid Generation and Cu Leaching: Potential adverse impacts on water and soil/sediment quality associated with the mine, waste dumps, and deposited sediments are a particularly critical issue.

In addition, the DLRA must consider and assess the possibility of tie channels being cut off by aggradation, exacerbating present natural low dissolved oxygen (DO) sags and perturbing the life cycle of fish that regularly migrate between the river and the OWRBs.

6.0 Other Comments

The following general comments are provided to assist OTML's Environment Department in fulfilling their role and responsibility of assessing and mitigating any environmental impacts related to the mine. All of these comments have been previously provided by the PRG.

6.1 Knowledge Strategy

There are voluminous reports on various aspects of the environmental programme, but no overall synthesis has been prepared. We have previously (first and second PRG reports) suggested the need, beyond the HERA, for a single document in which the key environmental *issues* were identified in a clear and succinct way and within the context of the Ok Tedi/Fly River ecosystem. We have also suggested how this should be done as part of a knowledge strategy that is updated regularly. Further, we have indicated the need for a mechanism in place to complete, update, and relate such a synthesis and knowledge strategy to the monitoring program so that any necessary changes can be implemented in a timely manner. *OTML needs to develop such an overall mechanism, overall synthesis, and yearly updates.*

6.2 Scientific Credibility

We commend the Environment Department for choosing to undergo periodic peer review and for appointing a PRG. A very large amount of high quality scientific work has been undertaken over the years, but too little of this has been published in the scientific literature

and hence been subject to normal peer review. To further enhance the scientific credibility of their work, we strongly recommend an increased emphasis by the OTML Environment Department on publication of HERA-related and other work in the peer-reviewed literature. We have previously suggested that OTML consider publication of a book on the Ok Tedi/Fly River Ecosystem. We continue to believe this would enhance the scientific credibility of the Environment Department's work as well as assisting in a needed knowledge strategy (cf. Section 6.1, above) and in maintaining corporate memory (see Section 6.3, below).

We continue to emphasize peer-reviewed publication of the OTML Environment Department's scientific work.

6.3 Corporate Memory

It continues to be all too apparent that staff turnover results in a huge loss of information. To some extent this loss could be minimized by proper cataloguing of all reports produced by the Environment Department in the form of a bibliography with brief summaries of what was done and the key findings. To date this has only been partially done for the Biology Section. Ideally a reference library, which is secured against loss, should be established at the mine site to provide staff (and visiting consultants) access to all materials. Further, future reports should be recorded onto CD's such that many copies can be made and easily stored.

Given the reality of staff turnover, the PRG may ultimately provide OTML with the repository for "corporate memory". This may be one reason to continue the PRG beyond the completion of the HERA (other reasons are provided in our second report).

The PRG continues to recommend that OTML use appropriate means to develop and maintain information necessary to their corporate memory.

6.4 Monitoring versus Investigative Studies

Although the PRG appreciates the importance of compliance monitoring, we also continue to note that this work is reactive (i.e., events are observed after they have occurred) rather than predictive (e.g., whether there is a relationship between aggradation and aquatic habitat that would explain fish species/biomass declines remains to be established). Further, we again note that biological monitoring conducted as part of the APL is not designed to determine whether or not any changes are mine related (i.e., monitoring is exposure-based, not effects-based).

We continue to strongly recommend that resources and focus be shifted to more predictive work to allow for proactive rather than reactive decision-making.

At the July 6-8, 1999 Brisbane meeting, the PRG were encouraged to review OTML's environmental monitoring program and submit recommendations for changes / improvements. It was noted that, although there is no assurance that these recommendations will be implemented in whole or in part, they will be very seriously considered by the PNG government. We accept this charge from OTML and will begin same when the HERA is completed such that the recommendations in the DLRA can form part of this review process. It is our understanding that, as part of this review, OTML will prepare and submit to the PRG a white paper which summarizes, briefly, what monitoring is being done and why it is being done.

We anticipate, in accord with discussions during the latter part of the July 6-8, 1999 Brisbane workshop, that our recommendations for revisions to the present OTML monitoring program will be based on optimizing resources and efforts while not compromising the integrity of the existing data base, specifically:

Assuring compliance with the requirements of the PNG government (with permission from OTML we will make some recommendations regarding what we believe are necessary changes to these requirements).

Resolving key uncertainties to optimize mine management and environmentally-friendly decision-making.

Determining the status of key adverse effects (e.g., flooding) to better assess changes including recovery.

Providing any additional information needed to address downstream stakeholder sensitivities and concerns.

As part of this review we anticipate emphasizing a multi-disciplinary rather than discipline-specific approach. We also anticipate emphasizing solid QA/QC programs to assure that the data generated are technically defensible.

For example, in our second report (23/07/98) we recommended that "*the floodplain samples collected as part of the APL monitor in 1994 and 1995 need to be rerun in order to determine copper concentrations* [original emphasis]. Results reported for both these years were anomalously low and it is not apparent that the possibility of laboratory error was ever resolved. These data provide the means by which floodplain deposition rates are estimated. Split samples were kept for these years and should be available to the Chemistry staff." To our knowledge this has yet to be done.

We will also emphasize timely data generation. At the July 6-8, 1999 Brisbane workshop, the problem of lengthy analytical backlogs was noted. For instance, fish samples have not been analyzed for contaminant analyses since 1994. Independent review of the Flew human health report also expressed concern regarding analytical backlogs, specifically for contaminant analyses of human hair samples (Foursight Associates Pty Ltd., 1999). We anticipate that our review and recommendations regarding monitoring programmes will include discussions with appropriate OTML Environment staff to determine what is realistically feasible in terms of timely and credible information generation.