

## Introduction

The Porgera Joint Venture (PJV) commissioned CSIRO<sup>1</sup> in 1996 to manage an independent review of the Porgera gold mine at Porgera in the Highlands of Papua New Guinea.

PJV felt that it was appropriate, as five years had passed since operation to conduct an independent review in accord with its environmental policy. The policy requires an active program of environmental auditing, independent reviews, studies and risk assessments conducted by credible Organisations as in-house initiatives to:

- Fill gaps in scientific knowledge;
- Provide recommendations for improving the environmental management of riverine systems;
- Confirm that compliance with regulatory requirements and corporate policies were achieved.

PJV has to respond to these recommendations. The recommendations were incorporate with the specific site Issue Management Plan (IMP). Priorities were set from the CSIRO's 48 recommendations and because of the many issues to be fully addressed; the urgent and important items were worked on first. There are still a few items to be fully addressed and they will be done by the end 2001.

The responses are in tabular form giving the *Recommendation* number; Current Status (Oct 2001); Proposed Completion Date/Action by PJV and Acknowledgement (Porgera Environmental Advisory Komiti (PEAK) Sub-Committees). PEAK Sub-Committees (Technical/Social) has to acknowledge and be satisfied with PJV's responses on specific task.

Below are, PJV's up-to-date responses to the CSIRO's report 48<sup>2</sup> recommendations. Each specific recommendation is discussed separately.

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<sup>1</sup> Commonwealth Scientific Industrial Research Organisation

<sup>2</sup> The original, CSIRO's Report (CSIRO 1996), Section 7 of the report lists the summary of the report's recommendations. With respect to chemical effects (pp. 7-3), number (20) was allocated to two recommendations. PJV has re-number these recommendations as Recommendation 20A and Recommendation 20B.

The following list summarises the review team's recommendations, made (in italics) in the various sections of the report, *Review of Riverine Impacts*, (CSIRO, 1996). Several recommendations have been combined here; to avoid repetition, but the source of each is given in square brackets [chap-page]. The recommendation progress from human health issues to those for aquatic life, then mine processes chemical effects, sediment and physical effects, and sampling/reporting techniques.

## **With respect to humans**

The CSIRO review team considers it important for the PJV to:

1. *Supply basic drugs and equipment such as chloroquine, antibiotics, dressing material and aspirins to people living along the Strickland and Lagaip rivers. In addition the PJV could arrange for a person from each village to be trained as a Village Aid worker. [3-13]*

*PJV Response*

<i>Recommendation: No. 1</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Social Sub-Committee)</i>
<i>Basic drugs &amp; equipment</i>	<i>PJV is continuing to assist in supplying drugs along the river system both to Aid Post and Health Centres at the major sub-districts H.Q of Lake Kopiago, Oksapmin, Nomad and Lake Murray.</i>	<i>Ongoing</i>	<i>Acknowledged</i>
<i>Village Aid Worker</i>	<i>PJV is working closely with the Government Health Department in each area to assist with training of villages' needs and Medicare. PJV is currently having discussions with Non Government Organisation (NGO) groups such as World Health Organisation (WHO), Religious Missions and Aid Agencies to assist with health training and supplying of Medicare.</i>	<i>Ongoing</i>	<i>Acknowledged</i>

2. *Consider providing solar-operated refrigerators for medical purposes. [3-15]*

*PJV Response*

<i>Recommendation: No. 2</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Social Sub- Committee)</i>
<i>Solar refrigerators</i>	<i>PJV has assisted in replacing refrigerator units at Lake Kopiago and Lake Murray.</i>	<i>Complete for Lake Murray &amp; Lake Kopiago</i>	<i>Acknowledged</i>

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

3. Consider trading with villagers in areas other than Lake Murray, in order to give them some economic independence and improve malaria and filariasis control. The PJV might buy bulk fruit and vegetables from the villagers, for consumption at the mine site, and sell them treated mosquito nets at a subsidised price. [3-14, 3-15]

**PJV Response**

<i>Recommendation: No. 3</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Social Sub-Committee)</i>
<i>Trading with villagers</i>	<i>We don't think it's economically viable to trade with villages on the Strickland River and our vegetables come from other landowners in a more economic and efficient arrangement.</i>	<i>We are trading &amp; doing business with villages around the Porgera minesite. The possibility of reopening the Lake Murray Fish Factory is presently being considered. It is not economically viable to trade with villages on the Strickland River</i>	<i>Acknowledged</i>
<i>Medical visits</i>	<i>PJV medical staff (HEO) visits villages along the river together with Environmental and Community Affairs personnel during routine sampling.</i>	<i>Ongoing</i>	<i>Acknowledged</i>

4. Introduce communication campaigns, advising on the maintenance of drinking water quality, on housing and ventilation to reduce respiratory infections, and on the building and proper use of pit toilets. [3-151]

**PJV Response**

<i>Recommendation: No. 4</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Social Sub-Committee)</i>
<i>Communication campaigns</i>	<i>Education on hygiene is an ongoing commitment and PJV is seeking the cooperation from NGO and government health groups. As part of this recommendation, 400-litre water tanks have been installed at most villages along the river &amp; plan is underway to educate communities on good house keeping practices.</i>	<i>Communication campaigns will be in-cooperated with the current medical &amp; community relations patrols along the riverine system</i>	<i>Acknowledged</i>

5. Undertake clinical examination of the villagers during sampling of their hair and/ or blood for heavy metal analysis, to permit more meaningful correlation between hair analyses with clinical findings, and ensure the results are communicated to the villagers to further improve relations with them. [3-14]

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

*PJV Response*

<i>Recommendation: No. 5</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>Hair/Blood</i>	<i>Sampling of scalp hair samples is part of the current PJV biological sampling program. As for the blood samples, an independent consultant (Dr. Peter Sapak) collected blood samples at Lake Murray in January 2000.</i>	<i>Blood analyses results have been in-cooperated in the Dietary Study report. Report have been accepted by PJV &amp; circulated among PEAK members for comments.</i>	<i>Acknowledged</i>
<i>Communication of results</i>	<i>All results reported to the national government as required &amp; PEAK. Efforts are being made to communicate the results to stakeholders as well.</i>	<i>Presentation of the dietary survey results was communicated to Lake Murray villager's by Dr Sapak during September 2000.</i>	<i>Acknowledged</i>

6. Measure metal residues in villagers' food items that (a) have not been previously defined, (b) are common food items, or (c) may contain significant metal concentrations. Metals should be analysed in all edible parts of the villagers' foods, collected under all sorts of river flow conditions, and the results, particularly for sago, should be compared with those of similar analyses of items from a 'control' system. [3-15, 3-17]

*PJV Response*

<i>Recommendation: No. 6</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>Red-finned catfish/Turtle</i>	<i>Red-finned catfish muscle and liver tissues have been sampled since 1996. Turtle tissue sampling for metal concentration analysis has been done on ad hoc bases.</i>	<i>Red-finned catfish sampling - Ongoing Turtle tissue sampling - ad hoc bases as it can be fished out quickly.</i>	<i>Acknowledged</i>
<i>Sago</i>	<i>Sago 'processed starch' portion have been analysed for metals. Summary of the results was presented to PEAK during the October meeting at Porgera Mine site.</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>Reference system (Recom. 13)</i>	<i>Reference sites have been identified on the Kaiam River</i>	<i>Complete</i>	<i>Acknowledged</i>

7. Determine why residents of lower Strickland villages (e.g. Bebelubi and Tiamsinawam) do not have greater dependence on fish. [3-17]

*PJV Response*

<i>Recommendation: No. 7</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Social Sub-Committee)</i>
<i>Bebelubi/ Tiamsinawam</i>	<i>Previous studies by Dwyers (1995) and Yok (1990) indicated that people from Bebelubi and Tiamsinawam of the lower Strickland are mainly hunters and gatherers. They do catch and eat a fair amount of fish but not as plentiful compared with the inhabitants of lowland Strickland and Lake Murray. PJV is satisfied with the information contained in these two independent reports.</i>	<i>Complete</i>	<i>Acknowledged</i>

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

8. Conduct new surveys of habits and dietary preferences of villagers from Eyaka, Wankipe, Bebelubi, Tiunsinawam, and lower Lake Murray (i.e. Kusikina, Miwa and Lake Murray Station at Boboa), obtaining data on total daily food and water intakes in grams and litres during all seasons, specifying what aquatic species are consumed, and exactly what water sources are used for drinking and bathing, and the extent of swimming. [3-17]

*PJV Response*

Recommendation: No. 8	Current Status (Oct 2001)	Proposed Date/Action by PJV	Completion	Acknowledgement (PEAK Social Sub-Committee)
Wankipe	Dietary & nutritional surveys were carried out by Dr. Peter Sapak, UPNG	Report completed and trip made to Wankipe in April 2001 to report findings to villagers		Acknowledged
Tiunsinawam	Dietary & nutritional surveys were carried out by Dr. Peter Sapak, UPNG	Same as above		Acknowledged
Lake Murray area	Dietary & nutritional surveys were carried out by Dr. Peter Sapak, UPNG	Report was accepted by PJV and made available to PEAK for comments.		Acknowledged

9. (after tasks 6-8), conduct formal quantitative probabilistic human health risk assessments for residents of each village along each reach of the river system (e.g. mine to SG2; SG2 to SG3, etc.), for major exposure pathways: drinking water; food (fish, turtles, crocodiles, terrestrial game, garden produce, sago making, etc.); incidental water ingestion (swimming); gold panning (Porgera River waste dumps only); etc. [3-17]

*PJV Response*

Recommendation: No. 9	Current Status (Oct 2001)	Proposed Date/Action by PJV	Completion	Acknowledgement (PEAK Technical Sub-Committee)
Screening Level Risk Assessment (SLRA)	Study completed by Parametrix and presented to PEAK <sup>3</sup> in August 1998	Complete in 1998		Acknowledged
Response by PJV to the SLRA	PJV yet to make formal responses in relation to its specific recommendations	December 2001		

10. Use internationally recognised sediment toxicity criteria when making a preliminary judgement concerning the potential for risks. If potential risks are found to exist, then it is recommended that the PJV measures metal concentration in sediment pore water and also conduct site-specific sediment bioassays to further assess such risks. [4-11]

*PJV Response*

Recommendation: No. 10	Current Status (Oct 2001)	Proposed Date/Action by PJV	Completion	Acknowledgement (PEAK Technical Sub-Committee)
(i) Sediment criteria	Requested CSIRO to provide information on sediment guidelines and extra sampling if required	June 2001		Acknowledged
(ii) Pore water	Pending results above	December 2001		Acknowledged
(iii) Sediment bioassays	Pending results above	December 2001		Acknowledged

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

11. Accurately define the Hg pathway to humans and quantify its contribution to Hg levels and additional risk. As part of that, (i) consider the use of filter-feeding molluscs as biomonitors for Hg (if possible, at least two sites should be chosen, one close to the Lake Murray outlet into the Herbert River and the other upstream, far removed from the possible influence of mine-derived sediment); (ii) find out why the percentages of methylated Hg (MeHg) relative to total Hg are so much lower than expected; (iii) measure benthic oxygen demand at various points in Lake Murray to determine if littoral areas are sites of greater heterotrophic microbial activity; and (iv) determine the feasibility of using stable isotopes to clarify the flow of carbon in the Lake. [5-7, 5-8, 5-9]

PJV Response

Recommendation: No. 11	Current Status (Oct 2001)	Proposed Completion Date/Action by PJV	Acknowledgement (PEAK Technical Sub-Committee)
(i) Hg pathway	Complete	Awaiting final report from CSIRO	Acknowledged
(ii) Molluscs as biomonitors	Ongoing since 1996	Ongoing	Acknowledged
(iii) % of MeHg relation to total Hg	Complete	Awaiting final report from CSIRO	Acknowledged
(iv) Benthic oxygen demand	Identifying suitable consultants	December 2001	Acknowledged
(v) Stable Isotopes	Complete	Awaiting final report from CSIRO	Acknowledged

**For aquatic life:**

12. Evaluate the bioavailability of particulate metals (in particular As and Pb) at SG2 and SG3. [4-12]

PJV Response

Recommendation: No. 12	Current Status (Oct 2001)	Proposed Completion Date/Action by PJV	Acknowledgement (PEAK Technical Sub-Committee)
Toxicity test	Previous testing work has used end-of-pipe tailings in laboratory water, and has not stimulated the conditions in the Lagaip. The assessment of metal bioavailability will be done via laboratory testing under control conditions using Lagaip River waters and whole effluent, with considerable care taken to closely mimic river water geochemistry, but a range of metal concentrations. Behavioural and avoidance test will also be carried out for fish in freshwaters.	Suitable consultants will be identified to carryout the task. Work should start in the fourth quarter of 2001. CSIRO were approached to provide advice on the bioavailability of particulate metals at SG2 & SG3	Acknowledged

13. Research the ecology and population sizes of aquatic creatures that are part of the human food chain in all parts of the Strickland river system including lakes/ channels adjacent to the Herbert River, so as to understand how their occurrence, reproduction, and feeding are affected by river conditions, turbidity, sedimentation and embeddedness, as well as by variables associated with the mine wastes. Make a phased investigation of the potential risks from such effects. (This includes defining the relative importance to aquatic life of tributaries to the mainstream Lagaip and Strickland rivers, and comparing the results with those from 'control' or reference catchments.) For fish, the review team recommends PJV estimate the 'standing stock' of key species, that is the abundance and biomass per unit area and volume of water sampled. [4-6, 5-8, 6-7]

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

*PJV Response*

<i>Recommendation: No. 13</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) 'control' sites</i>	<i>This is a difficult task because ideally the control catchment should be independent from the Strickland and be close to the Strickland to ensure similar hydrology and species assemblages. Pseudo control sites have been established at Lake Murray, Kiunga and Lagaip and Ok Om.</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>(ii) 'standing stock' estimates</i>	<i>Issue addressed and considered not practical for implementation. Sampling techniques employed at Lake Murray was reviewed in 1995 with recommendations to use purse seine and two sets of gill nets (i.e. <sup>3</sup>5-inch to 7-inch as standard sampling techniques for fish sampling at Lake Murray.</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>(iii) Invertebrates</i>	<i>The biology team has no experience with monitoring benthic invertebrates except for bioaccumulation studies on fish, prawns and mussels. It would be unreasonable to expect the staff to develop expertise in this area.</i>	<i>A pilot study by ERISS<sup>3</sup> or other suitable agencies to collect samples to examine the availability of invertebrates for this approach in different habitats could be useful to clarify this situation. 4<sup>th</sup> quarter 2001</i>	<i>Acknowledged</i>
<i>(iv) Side channels</i>	<i>This will be conducted in conjunction with the invertebrate survey.</i>	<i>4<sup>th</sup> quarter 2001</i>	<i>Acknowledged</i>

14. Define whether there are 'critical periods' in the life cycles of the fish (targeted by villagers for food) with respect to dissolved metals, TSS<sup>4</sup>, sedimentation, flow, etc., and adjust the sampling program to focus on any critical period(s) found. [5-9]

*PJV Response*

<i>Recommendation: No. 14</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Define critical periods</i>	<i>The critical periods of exposure were assumed to be during low flow periods and during flow reversals in the Herbert River.</i>	<i>Complete and Ongoing</i>	<i>Acknowledged</i>

15. Identify appropriate spatial scales and allocate sites and determine an appropriate frequency of sampling for biological monitoring; also employ multiple capture techniques to estimate the abundance and composition of aquatic biota, and incorporate the results of this exercise into a GIS to provide spatially-referenced descriptions of change in populations over time. [5-9]

<sup>3</sup> Environmental Research Institute of the Supervising Scientist

<sup>4</sup> Total suspended solids

**PJV Response**

<i>Recommendation: No. 15</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Multiple capture techniques</i>	<i>Multiple capture studies for Lake Murray would require a major fishing effort and changed sampling methods to ensure the health of target specimens. Purse seining is currently being used to determine fish densities in Lake Murray. Fish densities have been measured at up to 300 g/m<sup>2</sup>. Multiple capture technique is considered not practical for implementation.</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>(ii) GIS</i>	<i>Environmental Lab is already linked to the GIS network</i>	<i>Complete</i>	<i>Acknowledged</i>

**With respect to mine processes:**

*16. Monitor the effects (trends) of reduced neutralisation circuit residence time on the tailings effluent quality associated with increased mill throughput from 10,500 to 16,500 tonnes per day; at the same time continue to monitor pH, TSS and cyanides and conductivity on a daily basis, and (ii) initiate monitoring of such parameters as Fe, Ca and SO<sub>4</sub>, Cl, thiocyanate and process chemicals in the tailings, to improve understanding of the sorption/precipitation processes involved in metal removal, and to help refine the equilibrium speciation calculations performed on the effluent. The composite heavy metal samples should be analysed weekly rather than at the present fortnightly frequency. [2-5]*

*PJV Response*

<i>Recommendation: No. 16</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) WTC audit</i>	<i>Report presented to PEAK in November 1998</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>(ii) Fe, Ca and SO<sub>4</sub>, Cl, thiocyanate &amp; process chemicals</i>	<i>In progress</i>	<i>On going</i>	<i>Acknowledged</i>

*17. Vigorously pursue the possibility of containing all or part of the tailings solids and waste rock on-site. [2-5]*

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

*PJV Response*

<i>Recommendation: No. 17</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Tailing solids</i>	<i>PJV is vigorously pursuing the PPSM process, which stabilizes the CIP tailings in the form of a paste with a view to potentially place, this paste in the stable dumps in preference to discharging to the riverine system.</i>	<i>In-house technical review: Literature reviews of metals removal technologies and co-disposal complete. - Phase 1, co-disposal research complete. - Phase 2, co-disposal research on-going. Progress review to be presented by the 3<sup>rd</sup> quarter 2001</i>	<i>Acknowledged</i>
<i>(ii) Waste rock</i>	<i>Waste rock disposal options are being reviewed along with the life-of-mine plan. This is ongoing process and all parties will be kept informed of the plan when they become available.</i>	<i>New stable dump commenced construction in 2001 – Anawe North</i>	<i>Acknowledged</i>

**With respect to chemical effects:**

18. Fully evaluate the riverine impacts of the [tailings and] waste rock inputs, by (i) measuring the size distribution of particulate material in tailings effluent and eroding from the erodible waste dumps and reaching the river, and the mineralogy/chemical composition of the fine fraction and its reactivity in the receiving waters; and (ii) monitoring dissolved inputs derived from the weathering and leaching of the erodible waste dumps. [4-8]

*PJV Response*

<i>Recommendation: No. 18</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) size distributions of particulate materials (tailings &amp; erodible dumps)</i>	<i>Suitable consultants will be identified to fully evaluate the riverine impacts of the tailings and displace rocks inputs.</i>	<i>3<sup>rd</sup> quarter 2001</i>	<i>Acknowledged</i>
<i>(ii) monitoring dissolved inputs derived from the weathering &amp; leaching of the erodible waste dumps</i>	<i>Routine monitoring of creeks above and below erodible dumps is on-going. Additionally, the PJV is working on prediction modeling of future dissolved inputs resulting from weathering and leaching. Preliminary results on metal leaching (ML) and ARD on the property was presented to PEAK in March 1999.</i>	<i>Monitoring - ongoing. Prediction modeling update report by 1<sup>st</sup> quarter 2002.</i>	<i>Ongoing</i>

19. Undertake research with the aim of determining a tailings 'signature': that is, a unique set of geochemical elements in the tailings that can be used to trace their downstream movement and to quantify mine-derived inputs. [4-8, 5-5]

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

*PJV Response*

<i>Recommendation: No.</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
19			
(i) Tailings 'signature'	Report Completed – May 2001	Complete	Acknowledged

20A. Continue to monitor metals associated with suspended solids at SG3 and at sampling locations below SG4, adjusting the data to take account of particle size, so they can be reliably compared throughout the river system; use the data to (i) test whether or not the 'signature' of mine-derived solids can be detected, notably for tailings inputs, and to follow this signature over time; (ii) serve as an estimate of particulate metals loading delivered to the lower Strickland flood plain; and (iii) allow a comparison of the metal concentrations in this material with internationally accepted sediment quality criteria. [4-12, 5-7]

*PJV Response*

<i>Recommendation: No.</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
20A			
(i) 'signature' metals detected?	Tailings 'signature' have not been established for sampling sites below SG3 as yet.	On hold, depending on the outcome of Recommendation 19.	Acknowledged
(ii) particulate metals loading (lower Strickland flood plain)	Estimates of particulate metals loading delivered to the lower Strickland floodplain are yet to be established.	On hold, depending on the outcome of Recommendation 19.	Acknowledged
(iii) comparison with internationally accepted sediment quality criteria	Proposed ANZECC Sediment Quality Guidelines (2000) is currently being used.	Used in the 1999 annual report and will be ongoing.	Acknowledged

20B. Consider reporting the range of monitoring data for dissolved contaminant concentrations, as well as the mean and variance values. [6-18]

*PJV Response*

<i>Recommendation: No.</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
20B			
Reporting of all monitoring data for dissolved contaminant concentrations	This recommendation is supported and will serve as the bases for the 1998 water quality report write-up.	January 1999 and Ongoing	Acknowledged

21. Analyse the TSS samples collected in the Lagaip and Strickland Rivers not only for the concentrations of various mine-derived metals but also for Fe, Al, Mn and organic matter, after the samples have been separated into ranges of particle sizes. [6-6]

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

*PJV Response*

<i>Recommendation: No. 21</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>Analyses for Fe, Al, Mn plus other trace metals and organic matter</i>	<i>All metals are determined in river and lake water column (total &amp; dissolved) and sediments (total &amp; -63 <math>\mu</math>m size fractions), and is on-going.</i>	<i>Analyses for Fe, Al, and Mn implemented in February 1999 – on-going. Organic matter in water column after particle sizing not practical. In L/Murray TOC/DOC is on-going and at Mamboi planed to start Oct 2001.</i>	<i>Acknowledged</i>

22. Maintain and expand the present water quality and discharge sampling regimes at the compliance point SG3 and at potential compliance point SG2, to be sure of sampling a representative range of river conditions, including very low and very high flows. [6-2, 6-5]

*PJV Response*

<i>Recommendation: No. 22</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date /Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>Sampling a representative range of river conditions including very low and very high flows.</i>	<i>D49 sampler (28kg) is currently being used at SG2 and SG3. The only limitation to this sampler is collecting water samples at very high flows.</i>	<i>Ongoing</i>	<i>Ongoing</i>

23. Lower detection limits for dissolved Ag and Pb, because dissolved concentrations of Ag, Hg and Pb are frequently undetectable; monitor only total Hg at SG3, as the true dissolved Hg values are likely to be in the pico-molar region. Report water hardness separately. [4-1 1, 4-12, 6-4]

*PJV Response*

<i>Recommendation: No. 23</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Detection limits</i>	<i>Analytical detection limits for all metals analysed for sediments and water samples are currently being reviewed with all our contracting external laboratories.</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>(ii) Water hardness</i>	<i>This recommendation was supported and served as the bases for the 1999 water quality report write-up.</i>	<i>Complete</i>	<i>Acknowledged</i>

24. Following appropriate risk assessment, discontinue monitoring dissolved metals in the lower Strickland River (i.e. only monitor total metals) because the true concentrations are likely to be in the nano- to pico-molar range, and ultra clean sampling and handling techniques would be required to minimise sample contamination. [5-6, 5-7]

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

*PJV Response*

<i>Recommendation: No. 24</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Discontinue monitoring dissolved metals?</i>	<i>This recommendation was discussed and rejected.</i>	<i>Both dissolved and total metal fractions will be measured as done in the past.</i>	<i>Acknowledged</i>

25. Compare the current technique for measuring dissolved metals (filtration under a laminar flow hood), against in situ dialysis by the procedure used by Benes (1980), with the intention of adopting the latter approach if it proves feasible. [6-6]

*PJV Response*

<i>Recommendation: No. 25</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Procedure used by Benes (1980)</i>	<i>CSIRO to provide advice on better alternative option</i>	<i>December 2001</i>	<i>Acknowledged</i>

26. Reconsider the location of monitoring sites along the riverine system from Porgera to the Fly Delta, to (i) assess the suitability of each site to contribute to the resolution of spatial and temporal variability in monitored data, and (ii) identify suitable locations for the placement of 'control' sites. [6-5, 6-18]

*PJV Response*

<i>Recommendation: No. 26</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Spatial &amp; temporal variability; power analyses</i>	<i>The changes to the riverine sampling regime to include additional control sites and more frequent sampling were designed to increase the potential power of the sampling program in these regards. Nevertheless, it is intended to undertake power analyses of the existing sampling programs.</i>	<i>Reference sites - Complete</i>  <i>Power analysis - September 2001</i>	<i>Acknowledged</i>
<i>(ii) Placement of 'control' site</i>	<i>See response under Recommendation 13</i>	<i>Complete</i>	<i>Acknowledged</i>

27. Consider measuring the concentrations of metal ions in the pore water of sediment cores to help in the risk assessment; for these measurements, collect and analyse the pore water using pore-water peepers. [5-6]

**PJV Response**

<i>Recommendation: No. 27</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) collect &amp; analyse the pore water using pore-water peepers</i>	<i>CSIRO as approached to provide advice and equipment</i>	<i>December 2001</i>	<i>Acknowledged</i>

## With respect to sediment and physical effects:

28. Initiate a program of systematic coring of the surface sediments on transects extending at least 2 km either side of the Strickland and Herbert river channels at key positions, and in off-channel water bodies, to establish if mine-derived sediment can be detected. [5-5, 6-7]

PJV Response

Recommendation: No. 28	Current Status (Oct 2001)	Proposed Completion Date/Action by PJV	Acknowledgement (PEAK Technical Sub-Committee)
(i) Systematic coring	The systematic coring of the surface sediment of the lower Strickland was implemented in August 1997. ECOWISE Environmental Consultants did the sediment coring with data analyses, interpretation and report preparation by CSIRO. The report was presented to PEAK in August 1998.	Sampling is planned for the Mamboi River – Oct 2001	Acknowledged

29. Develop a better understanding of the sediment balance by combining field data and geomorphic interpretation of flow and sediment processes into a sediment transport model, and calibrate it by measuring aggradation in the river channel below SG4, using cross-sections or GPS survey or remote sensing of sediment plumes. [4-6, 5-5, 6-6, 6-7]

PJV Response

Recommendation: No. 29	Current Status (Oct 2001)	Proposed Completion Date/Action by PJV	Acknowledgement (PEAK Technical Sub-Committee)
(i) Sediment transport model	Partially implemented	December 2001	Acknowledged

30. Obtain information for a sediment balance model by (i) aerial photography or remote sensing, initially of the whole river system, providing a background or baseline, and later focussing on particular aspects once or more per year, revealing changes in the river channels and identifying problem areas; (ii) particle size analysis of the river beds about every six months to determine trends in sedimentation from data on the changing composition of the beds over time; (iii) suspended solids sampling every week at SG3 and SG5, with a campaign effort downstream of SG1, using the depth-integrated method in a representative range of river heights to calibrate the current gulp sampling method, to yield a reliable estimate of annual sediment load. [4-12, 6-7]

PJV Response

Recommendation: No. 30	Current Status (Oct 2001)	Proposed Completion Date/Action by PJV	Acknowledgement (PEAK Technical Sub-Committee)
(i) aerial photography /remote sensing	We are going PACRIM 2 mission run by NASA and CSIRO/University of NSW to the Pacific including PNG early 2 <sup>nd</sup> 2000 – remote data of the lower Strickland River to asses with our current studies of the area.	1 <sup>st</sup> quarter 2002	Acknowledged
(ii) particle size analysis (every 6 months)	This item is part of the current sediment monitoring program	Ongoing	Acknowledged
(iii) TSS sampling every week (SG3 & SG5)	This item has been discussed and not considered for implementation. Current monthly sampling at SG3 is sufficient. SG5 station on the Strickland River is no longer operational.	Complete	Acknowledged

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

31. Evaluate the usefulness of remote sensing for tracking the fate of sediment and the frequency and extent of Lake Murray level fluctuations. [5-5]

*PJV Response*

<i>Recommendation: No. 31</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>Remote sensing</i>	<i>We are going PACRIM 2 mission run by NASA and CSIRO/University of NSW to the Pacific including PNG early 2<sup>nd</sup> 2000 – remote data of the lower Strickland River to asses with our current studies of the area.</i>	<i>1<sup>st</sup> quarter 2002</i>	<i>Acknowledged</i>

32. As part of a reassessment of the water and sediment balance for Lake Murray, and the current hydrological monitoring program near the Lake, during several flow-reversal events (i) check whether or not the waters of the Herbert River are colder than Lake Murray water and whether or not the two waters mix, and (ii) identify whether the Herbert and Mamboi rivers are important pathways for mine-derived sediment entering the Lake. [5-4, 5-5]

*PJV Response*

<i>Recommendation: No. 32</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Water temperature (Lake Murray &amp; Herbert River). Whether or not the waters mix</i>	<i>PJV water quality database shows that water temperature in Herbert River on average is 30°C during normal flow and drops to 24°C on average during flow reversal. Water does not mix.</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>(ii) Herbert &amp; Mamboi are important pathways into the Lake</i>	<i>The Mamboi connects to the lower part of the Herbert River during high flows and not the Strickland River as previously taught. However, during periods of extreme floods (1:10 year event), the Strickland does flow into the lower part of the lake via Mamboi – Dr Andy Markham &amp; D. Yok</i>	<i>Complete</i>	<i>Acknowledged</i>

33. Estimate the annual export of sediment from the Strickland River to the Fly River, based on data from SG3 and SG5. [5-5]

*PJV Response*

<i>Recommendation: No. 33</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>Estimate annual export of sediment</i>	<i>Average load passing through SG5 is approximately 50-70 MT.</i>	<i>Ongoing</i>	<i>Acknowledged</i>

34. Mount a monitoring campaign to (i) examine the behaviour of the erodible waste dumps, particularly their capacity, inputs from the mine and losses to the river (assessed by automatic water sampler and rainfall/runoff model), to better define material inputs and transport in the river system; (ii) determine how much mine-derived sediment is deposited downstream of SGI and upstream of the Lagaip confluence, using river bed particle size analysis, cross-section surveys and imaging from fixed reference points. [6-7]

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

*PJV Response*

<i>Recommendation: No. 34</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Behaviour of erodible dumps</i>	<i>This is done by Geotechnical Section on a quarterly bases.</i>	<i>Ongoing</i>	<i>Acknowledged</i>
<i>(ii) Determination of mine-derived sediment</i>	<i>Mine derived material has been estimated and presented in the 1997 annual report and will be updated annually.</i>	<i>Ongoing</i>	<i>Acknowledged</i>

**With respect to monitoring and reporting techniques:**

35. Reorganise the hydrometeorological station system, ensuring calibration of new stations (on Kogai River for example) against the old, some of which can be closed. Update the HYDSYS database with all historical data that can be obtained from other operators for all stations. The HYDSYS database must also contain basic information such as catchment area, station elevation, latitude and longitude, for each gauging station. Seek specialist advice on how best to extend the rating curves derived from these stations. [6-3, 6-4]

*PJV Response*

<i>Recommendation: No. 35</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Hydrological stations upgrade</i>	<i>All hydrological stations upgraded</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>(ii) HYDSYS database</i>	<i>HYDSYS database upgrade completed with all historic data. GPS points of all monitoring station have been added to the database</i>	<i>Complete</i>	<i>Acknowledged</i>

36. Undertake a comprehensive review of data collected over the past five years with a view to choosing sample sizes suitable for on-going compliance monitoring. [6-16]

*PJV Response*

<i>Recommendation: No. 36</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Comprehensive review</i>	<i>Comprehensive review of the data is planned with the results included in the Annual report</i>	<i>Review annually</i>	<i>Acknowledged</i>
<i>(ii) Sample size</i>	<i>Statistical training is required especially POWER analysis procedures</i>	<i>September 2001</i>	<i>Acknowledged</i>

37. Identify, in consultation with the regulatory authority, appropriate and powerful statistical methods to analyse data gathered as part of the EMMR Computational details and data processing requirements should be prescribed in sufficient detail to ensure (i) the results are reproducible; and (ii) there is no ambiguity in methods to be adopted. [6-16]

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

*PJV Response*

<i>Recommendation: No. 37</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Statistical methods</i>	<i>Training has been given to staff to improve their knowledge and computer skills for analysing and interpretation of environmental data</i>	<i>Review Annually</i>	<i>Acknowledged</i>
<i>(ii) Sampling/analytical methods</i>	<i>The sampling program and analytical methods will be reviewed in a view for continuous improvement to the program</i>	<i>Review Annually</i>	<i>Acknowledged</i>

38. Enhance the statistical capability of the environmental laboratory by providing new and existing staff with (i) leadership in the form of a specialist statistician (this person would be trained to Honours or Master's degree level in mathematics and/or statistics) and (ii) training, as necessary, in contemporary statistical methodology (this should include an element of spatial statistics, time series analysis, statistical design, non-parametric statistics, probability theory and risk assessment). [6-9, 6-16]

*PJV Response*

<i>Recommendation: No. 38</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Leadership (specialist statistician)</i>	<i>This item was discussed and the general feeling was that, item (ii) should be implemented as high priority.</i>	<i>On hold</i>	<i>Acknowledged</i>
<i>(ii) Contemporary statistical methodology</i>	<i>Statistics training in 'Statistical Design and Analysis' was done in 1996 and 'Statistics and Database Quality Control' was done in 1998. These courses were conducted by Dr David Fox of the Biometrics Unit of CSIRO, WA and Dr Ross Smith of the R&amp;D Environmental Consultants respectively.</i>	<i>Review on ad hoc bases</i>	<i>Acknowledged</i>

39. Use appropriate statistical tools and graphical methods whenever possible, for visualising and presenting compliance data. For example (i) use more sophisticated ways of detecting outliers in complex, multivariate data sets, (ii) cease the current practice of logarithmically transforming compliance data prior to the computation of sample statistics (sample means and standard deviations that are routinely reported to the regulatory authority should be based on raw untransformed data). [6-13, 6-18]

*PJV Response*

<i>Recommendation: No. 39</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Detecting outliers</i>	<i>Box-plots are currently used to detect outlier values</i>	<i>Ongoing</i>	<i>Acknowledged</i>
<i>(ii) Graphical presentation of data</i>	<i>Box and LOWES smoother plots are used to show trends for parameters monitored. Scatter plots are used for visualising &amp; presenting compliance data.</i>	<i>Ongoing</i>	<i>Acknowledged</i>
<i>(iii) Cease log transformation</i>	<i>Descriptive statistics are based on untransformed data</i>	<i>Complete</i>	<i>Acknowledged</i>

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

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40. Upgrade computing processing and storage facilities in general, and peripheral hardware; investigate the use of electronic media for data acquisition. [6-9, 6-11]

*PJV Response*

<i>Recommendation: No. 40</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Computers</i>	<i>6 new Pentium computers purchased</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>(ii) Data acquisition</i>	<i>Analytical results are sent via email, with hard copies by post</i>	<i>Complete</i>	<i>Acknowledged</i>

41. Develop a unified database management strategy for the environmental laboratory, that addresses security, storage, maintenance, and back-up issues; consider the establishment of a single database for the storage of all data collected by the laboratory, outsourcing the task of setting it up. [6-13, 6-15]

*PJV Response*

<i>Recommendation: No. 41</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Unified database management</i>	<i>Currently discussing with the Computing Section on the possibility for having Environmental own server or use other alternatives servers that are available on site</i>	<i>June 2001 (Possibility exists for the Lab to the connected to the mill server)</i>	<i>Acknowledged</i>

42. Upgrade the environmental chemistry laboratory area and seek accreditation for the environmental laboratory as soon as possible. [6-10]

*PJV Response*

<i>Recommendation: No.42</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Chemistry Lab upgrade</i>	<i>Renovations done to the laboratory to separate chemistry work area from the rest of the laboratory</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>(ii) Seek accreditation</i>	<i>Currently looking at our chemical methods /calibration procedures for laboratory instrumentation</i>	<i>December 2001</i>	<i>Acknowledged</i>

43. Formulate and adopt a consistent approach to (i) units of measurement for all data collected by the environmental laboratory; and (ii) the recording and treatment of data whose values are below the achievable detection limits (all data should be recorded to as many significant figures as the accuracy of the experimental procedure will permit). The environmental laboratory should establish criteria against which monitoring data, such as the results of analyses, are compared. [6-10, 6-11]

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

*PJV Response*

<i>Recommendation: No. 43</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Units of measurement</i>	<i>Units reported are:- water quality as mg/L; total suspended solids as mg/L; sediment mg/kg (dry weight); fish tissues as mg/kg (wet weight)</i>	<i>Complete</i>	<i>TSS is % in annual report</i>
<i>(ii) Record &amp; treatment of data</i>	<i>Values that are below the analytical detection limit are reported at that value, knowing that actual value lies somewhere between 0 and the detection limit.</i>	<i>Ongoing</i>	<i>Acknowledged</i>

44. Use appropriate QA/QC procedures for all in-house analyses.

*If external laboratories report unacceptable values for QA/QC samples, the matter should be investigated promptly in a well-defined sequence of actions, and the outcomes fully documented. A special investigation should research whether significant changes occur in the concentrations of dissolved metals, free CN and ammonia due to the storage of samples with a range of suspended solids concentrations. [6-11]*

*PJV Response*

<i>Recommendation: No. 44</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>QA/QC samples</i>	<i>Field blanks, in-house reference materials and replicate field samples are always included with samples send to external laboratories for analyses</i>	<i>Ongoing</i>	<i>Acknowledged</i>

45. Upgrade the quality of the annual environment reports, including interpretation of current results in the light of those of previous years; consider the preparation and publication of a series of overview and review reports on the environmental work being undertaken; and report the results of health surveys and analyses to villagers living along the river system. [6-19]

*PJV Response*

<i>Recommendation: No. 45</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>Biology section submission for the Annual Report</i>	<i>Addressed in the Annual Report.</i>	<i>Ongoing</i>	<i>Acknowledged</i>
<i>Hydrology section submission for the Annual Report</i>	<i>Addressed in the Annual Report.</i>	<i>Ongoing</i>	<i>Acknowledged</i>
<i>Chemistry section submission for the Annual Report</i>	<i>Addressed in the Annual Report.</i>	<i>Ongoing</i>	<i>Acknowledged</i>
<i>Result of health surveys</i>	<i>See Recommendation 4</i>	<i>Ongoing</i>	<i>Acknowledged</i>

46. Adopt a monitoring culture that embraces some basic principles and procedures of statistical process control (SPC) to enable management to better observe, understand, and control key components of its production facility. [6-13]

**Comments progress with recommendations of the Review of Riverine impacts of PJV, CSIRO 1996**

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*PJV Response*

<i>Recommendation: No.46</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>Basic principles &amp; procedures (SPC)</i>	<i>Controls in place for daily monitoring of the pH</i>	<i>Ongoing</i>	<i>Acknowledged</i>

*47. Develop a coherent and comprehensive research plan for the operations, which addresses specifically how the results of this research will be transferred to management and stakeholders. [6-19]*

*PJV Response*

<i>Recommendation: No. 47</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>Environmental Operating Plan (EOP) Development</i>	<i>Review of the EOP based on the findings of the 1999 sampling programs and mine plans</i>	<i>New EOP to be issued by Dec 2001</i>	<i>Acknowledged</i>
<i>Riverine Issues Management Plan</i>	<i>Plan completed</i>	<i>Actions to be completed by Dec 2001</i>	<i>Acknowledged</i>

*48. Broaden the objectives of environmental monitoring, placing increased emphasis on interpretation of results, and on investigative studies within a unified framework aimed at identifying and understanding relationships between Porgera activities and downstream environmental effects. [6-19]*

*PJV Response*

<i>Recommendation: No. 48</i>	<i>Current Status (Oct 2001)</i>	<i>Proposed Completion Date/Action by PJV</i>	<i>Acknowledgement (PEAK Technical Sub-Committee)</i>
<i>(i) Monitor (and manage) for impact</i>	<i>Revised Environmental Management Monitoring Plan (EMMP) submitted to Department of Environment and Conservation (DEC) in 1997. No response as yet from DEC.</i>	<i>Complete</i>	<i>Acknowledged</i>
<i>(ii) Monitor (and manage) for impacts</i>	<i>Field sampling</i>	<i>Ongoing</i>	<i>Acknowledged</i>