OK TEDI MINING LIMITED

ENVIRONMENT DEPARTMENT

FUTURE VEGETATION DIEBACK EXTENT IN THE LOWER OK TEDI AND FLY RIVER FLOODPLAINS

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EXECUTIVE SUMMARY

Introduction

This report details the results of the study into future vegetation dieback extent in the Ok Tedi and Fly River floodplains. Initial estimates of future extent were reported as part of the 1999 HERA studies and this report aims to update those estimates with respect to pessimistic, likely (dredging to mine closure) and likely (no dredging) scenarios.

Climate

Variations in climatic patterns, particularly periods of extreme events such as the El Nino and La Nina events, are seen as a major influence on the ultimate extent of dieback in the Ok Tedi and Fly catchments. Although much of the dieback in the upper catchment has been induced by mine induced bed aggradation, it is hypothesised that some, if not all, of the dieback in the lower catchment is the result of extreme climatic conditions.

Vegetation dieback in the Middle Fly region of the Western Province is a naturally occurring phenomenon that was evident prior to mining. Although not citing vegetation dieback directly Gillison (1983) alludes to a dynamic vegetation environment in the Middle Fly pre-mine. *"A prominent feature of the savannas of south-western Papua (including the Fly-Digul river systems) is the extensive area subject to seasonal inundation. This has a dramatic effect on the distribution pattern of savannas.* ***The complex scale of fire and flood maintains a changing vegetation ... much of Papua New Guinea is in a state of flux controlled as it is by changing water tables in extensive lowlands and modified extensively by man made fire."***

In the estimation of future dieback extent, particularly with respect to the likely scenarios, the effects of an average cycle of drought and flooding has been incorporated. It is expected that at least one severe El Nino and La Nina will occur through to mine closure and this has been built in to the estimation process. It has been assumed that the most detrimental events, extended El Nino / La Nina events or the El Nino that is followed immediately by a La Nina, will not result through to mine closure.

Dieback Extent - Pessimistic

An estimate of the extent of vegetation dieback in the Lower Ok Tedi and Middle Fly has been undertaken with respect to a pessimistic outcome. **The pessimistic estimate does not constitute a prediction of future dieback but rather the maximum extent in the case of extreme mine and climatic effects. The analysis does not discriminate between causes of vegetation dieback.**

This definition is based on the entire catchment floodplain excluding the topographically higher zones on the margins of the catchment, the grassed areas and the rivers and lakes. For the purposes of this definition it is assumed that all tree species within the catchment boundary will be impacted, irrespective of flood tolerance, topography and hydrological constraints. The extent defined is a worst case estimate. The pessimistic estimated dieback extent in the Lower Ok Tedi and Middle Fly floodplains is 4,112 square kilometres.

Dieback Extent - Likely

The likely estimate of the extent of vegetation dieback in the Lower Ok Tedi and Middle Fly comprises a modification of the pessimistic extent to reflect an expected outcome under average climatic conditions and with respect to "dredging to mine closure" and "no dredging" scenarios.

The definition of likely extent is *"the topographically depressed zones of the catchment including the sub-floodplain of all lakes and tributaries. Isolated zones of elevated land are excluded, even if not at the margins of the catchment. Grassed areas and rivers/lakes are excluded."* This definition has been incorporated with modification by the revised pessimistic estimates, the improved understanding of system processes and the dieback monitoring results of 2001 and 2002.

The likely estimated dieback extent in the Lower Ok Tedi and Middle Fly floodplains is 2,395 square kilometres if dredging to mine closure is maintained and 2,842 square kilometres if dredging ceases.

Although it was assumed that the predominant differentiation between the dredging and no dredging scenarios would be in the upper catchment this has not been the case with the Lower Ok Tedi zones showing a similar difference to the rest of the catchment zones. This is primarily because dieback in the upper zones is already near the maximum expected level with only limited scope to vary between scenarios. In addition one of the primary differentiation factors between scenarios is the impact at the catchment edges and in backwater zones. Backwater zones predominate in the lower reaches of the catchment. **The primary difference between scenarios in the upper reaches of the catchment will be with respect to dieback severity rather than extent.** It is estimated that vegetation recovery will continue through the Lower Ok Tedi, Upper Fly and into the Wygerin zone with the continuation of dredging. With no dredging it is expected that the majority of recovered vegetation to date will revert to dieback status and that the majority of impacted zones will contain severe dieback. Dieback severity is an issue that needs to be considered when assessing the relative merits of the dredging program.

Dieback Extent Downstream of Ogwa

While this report does not include a study into the extent of dieback downstream of Ogwa on the Fly River a preliminary assessment has been made of the potential for extensive dieback in the region. Dieback in the reach is expected to be transitional and concentrated in the zone immediately downstream of Ogwa. Factors such as insignificant bed aggradation, tidal effects, flood tolerance of vegetation and the perched nature of the floodplain have been evaluated in assessing the risk of vegetation dieback. This assessment is, however, made with little supporting data and a study based on accurate and reliable data is recommended.

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Version 1.0 31st March 2003 (Draft)
Version 1.1 1st April 2003

1.0 INTRODUCTION

This report comprises the results of the work undertaken to estimate the future spatial extent of vegetation dieback in the Lower Ok Tedi and Middle Fly River floodplains. The work builds on the estimates derived for the 1999 OTML HERA process and considers changes based on dieback monitoring since 1999 and the improved understanding of dieback spread characteristics. The report is to assess future dieback extent with respect to pessimistic, likely (dredging to mine closure) and likely (no dredging) scenarios. Climatic conditions are expected to have a large influence on ultimate extent; however the findings of this report (likely scenarios) are with respect to average conditions without compounding or extended extreme events. It should be noted that vegetation dieback will be evident with a wide range of severity. This will include vegetation that is undergoing some form of recovery, vegetation that is stressed (up to 30% defoliation but where the tree is still alive) or vegetation that is highly stressed (greater than 30% defoliation and where the tree may be dead). The dieback extents defined in this report do not address the issue of severity.

2.0 STUDY AREA

The Ok Tedi and Fly River lie in the Western Province of Papua New Guinea, rising in the Star Mountains at an altitude of approximately 3500 meters above sea level and at a distance of approximately 1000 kilometres from the sea. Annual rainfall in the catchment headwaters is 10 meters, decreasing to approximately 4 meters at Kiunga and 2 meters at Obo (Halse *et al*, 1996).

The study area is the floodplain of the Lower Ok Tedi and the Middle Fly River. The Lower Ok Tedi zone commences at Iogi and ends at the junction with the Fly River, D'Albertis Junction, approximately 30 kilometres to the south. The lateral floodplain extent in this zone is defined by a topographic rise to both the east and west, resulting in a relatively flat floodplain of approximately 10 kilometre width, although it also includes the catchment of several tributary rivers extending up to 15 kilometres from the main Ok Tedi channel. In this zone the Ok Tedi is a meandering river, with channel width of 150 to 200 meters. The elevation drop over the 30 kilometres is approximately 15 meters.

The Middle Fly floodplain extends from Kiunga, on the Fly River, down to the junction with the Strickland River, Everill Junction, approximately 160 kilometres to the south. The river traverses approximately 450 kilometres through the floodplain. The channel width varies from approximately 200m in the upper reaches to 350 meters in the lower reaches. In this zone the Fly River has very little gradient, with an elevation drop of only 20 meters between Kiunga and Everill Junction. This has resulted in an extensive floodplain, particularly in the middle and lower reaches of the river. Floodplain width is variable, ranging from 15 to 20 kilometres in the upper reaches to 30 to 40 kilometres in the lower Middle Fly. Due to the flat topography in the region the floodplain boundary is not fixed and varies with rainfall in the catchment and floodplain inundation level and frequency. The Fly River downstream of Bosset is tidal, with bed elevations at some locations 10m below sea level.

Figure 1 shows the Ok Tedi and Fly River along with definition of the dieback monitoring zones. Marshall and Rau (1999) define the physical extents of each zone.

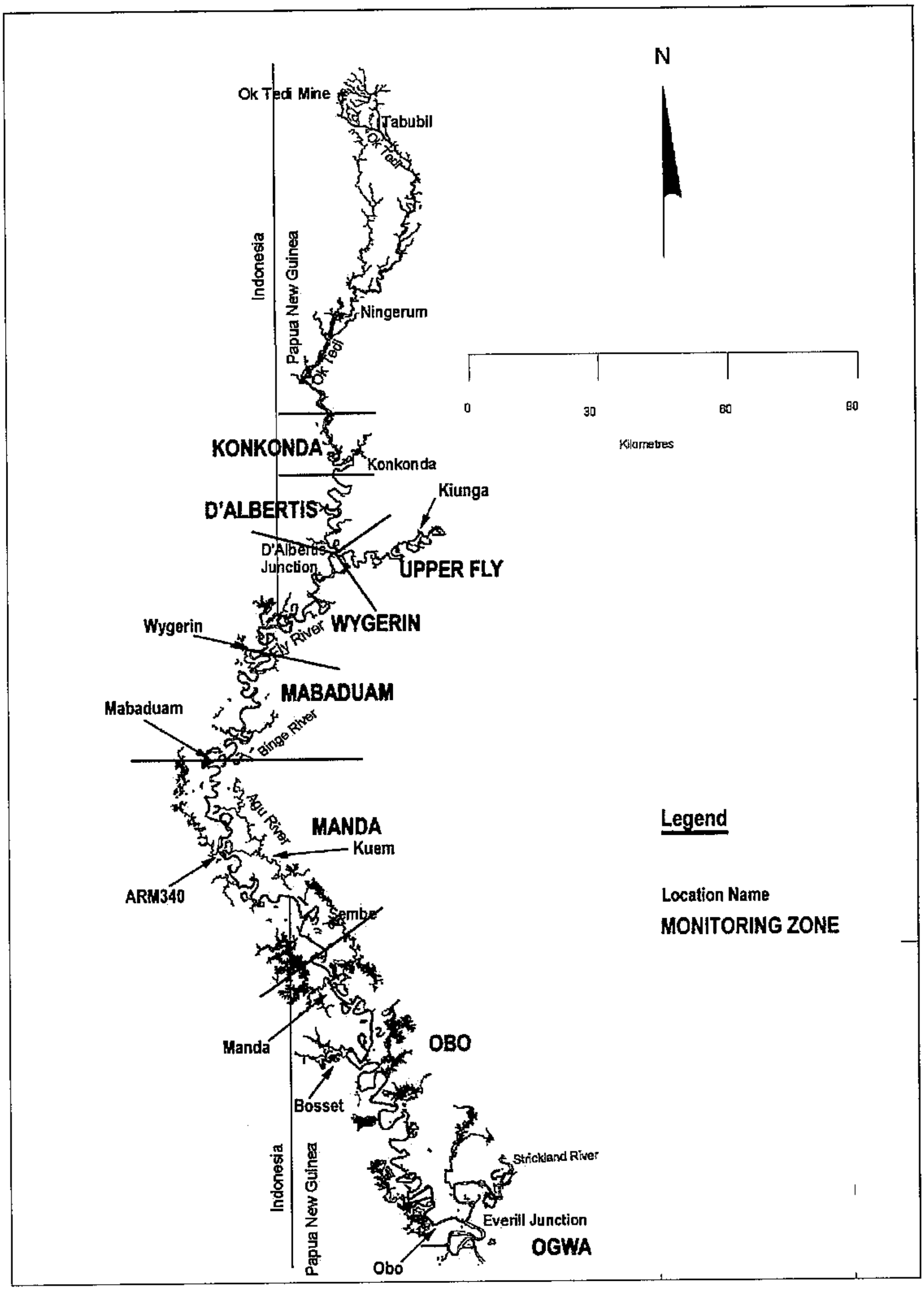

Figure 1 Index Map – Ok Tedi and Fly River, Western Province, PNG

3.0 CLIMATE

While much of the current dieback in the Lower Ok Tedi and Middle Fly is the result of mine induced bed aggradation and consequential increases in overbank flooding duration, it is hypothesised that some, if not all, of the dieback in the lower catchment is the result of extreme climatic conditions. Although this report does not attempt to discriminate cause of dieback it does assess the input factors that contribute to vegetation dieback. The determined extents of likely impact rely heavily on average climatic conditions. While extreme conditions are expected, and in fact are normal and typical for the region, the estimates assume the historical cycle of drought and flood will continue.

Vegetation dieback in the Middle Fly region of the Western Province is a naturally occurring phenomenon that was evident prior to mining. Although not citing vegetation dieback directly Gillison (1983) alludes to a dynamic vegetation environment in the Middle Fly pre-mine. *"A prominent feature of the savannas of south-western Papua including the Fly-Digul river systems) is the extensive area subject to seasonal inundation. This has a dramatic effect on the distribution pattern of savannas ...* ***The complex scale of fire and flood maintains a changing vegetation*** *which is difficult to map and creates savannas of variable structure and floristics which intergrade with permanent open swamps at one extreme to dense mesophyll forests on extensive levee systems at the other." "Whereas the environment of the Australian continent has produced relatively stable vegetation,* ***much of Papua New Guinea is in a state of flux controlled as it is by changing water tables in extensive lowlands and modified extensively by man made fire."***

The progression of dieback through the Lower Ok Tedi catchment has been fundamentally sequential, starting at Iogi, in the Lower Ok Tedi in 1992, and progressing downstream. Dieback then progressed rapidly into the Middle Fly, again progressively downstream, between 1996 and 1998. The rapid increase in area impacted is most likely due to the benign nature of the Fly River floodplain, in comparison to that of the Ok Tedi, but it is also possible that climatic factors had more of an impact than previously assessed. A relatively dry period between 1991 and 1994 (1992 El Nino) would have retarded the rate of vegetation dieback through the system, however with the onset of the wet period between 1995 and 1996 the rate of dieback growth would have increased significantly.

Although it could be hypothesised that an extended dry period would retard dieback growth this would be incorrect. One of the consequences of extended drought is that man-made fires may not be contained and could burn out large areas of forest within the catchment. This occurred during the El Nino of 1997 – 1998. Much of the fire impacted vegetation in the catchment was severely stressed, but recovering when the 1998 – 2001 La Nina immediately followed the drought. Fire stressed vegetation was again stressed, this time by extended flooding, and these areas quickly became subject to extensive and severe dieback. An example of this was the forest between Binge River and Ioke Creek along the eastern bank of the Fly River. An area of 67 square kilometres was transformed from a dense and healthy floodplain forest to a vast swamp system in a short period of time, with initial fire during drought followed immediately by extensive flooding. Although this was recognised, and reported as such in Marshall and Rau (1999), the difficulty in determining cause of dieback has resulted in no further cause assessments over subsequent monitoring periods.

During 1999 a dieback reconnaissance was undertaken in the lower Middle Fly to assess dieback extent. The results of the reconnaissance, and of subsequent dieback monitoring epochs, have shown the rapid progression of dieback throughout the whole of the Middle Fly catchment. This progression was most significant during the 1999 – 2001 La Nina period, with floodplain flooding frequencies approaching 100%. Very few tree species can survive prolonged periods of flooding and much of this vegetation over the floodplain has been impacted. It has been argued that this dieback is predominantly a function of the climate, as opposed to any mine induced impact. Although probable, this hypothesis is difficult to substantiate. One data set that gives a basis to this, however, is the extent of dieback as a percentage of likely extent (figure 2).

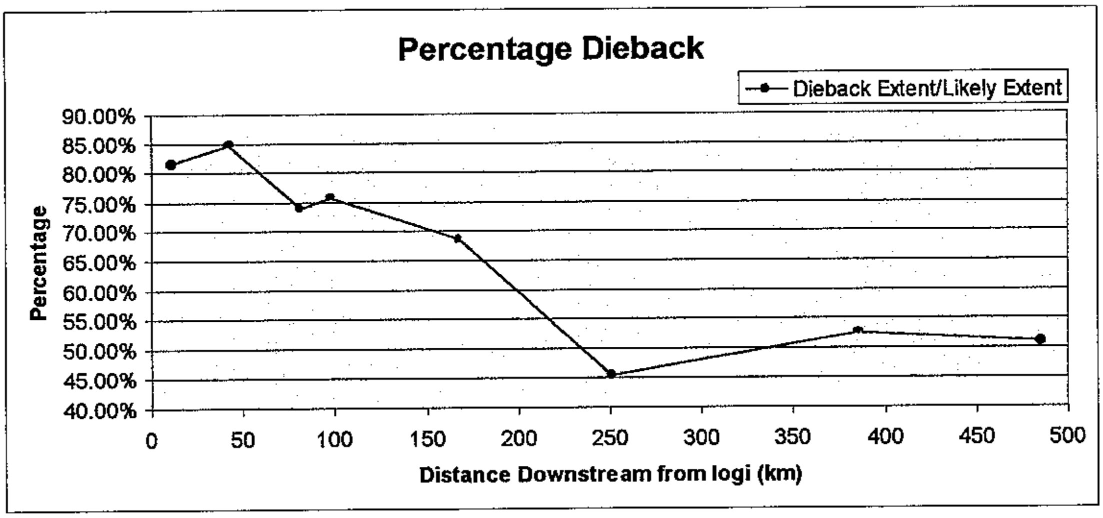

Figure 2 Vegetation Dieback (Aug '02) as a Percentage of Likely Extent

Based on the historical observations in the Lower Ok Tedi and upper Middle fly that dieback growth increases progressively in both a downstream direction and normal to the channel, it can be argued that the dieback downstream of kilometre 250 (ARM340) is not following the same cause process as that upstream. In fact dieback percentage downstream of ARM340 increases slightly. Although there is some bed aggradation between Manda and Obo it is not significant as a percentage of total channel volume and is not expected to have been the trigger for such extensive lower catchment dieback. Although it is possible that the bed aggradation increase has pushed the flooding frequency over a critical threshold it is more probable that the extensive and extended flooding of the La Nina climatic cycle between 1999 and 2001 is the cause of the dieback in the lower reaches of the catchment. Based on the sequential trend of the upper reach it would have been expected that vegetation dieback would have tapered out by kilometre 400 (Bosset), with no dieback in the very lower reaches of the catchment. Figure 1 shows the relative locations along the Fly River of the places cited in this section.

The above examples have been included to highlight the importance of climate in the determination of ultimate dieback extent rather than trying to discriminate between types of dieback with different causes. In the estimation of future dieback extent, particularly with respect to the likely scenarios, the effects of an average cycle of drought and flooding has been incorporated. Figure 3 shows the Southern Oscillation Index (SOI) from 1876 through to the present time. Based on the assumption that high SOI will give a wet period with higher than average flooding and that a low SOI will give a dry period with possible drought, the historical data has been analysed to assess what might be expected into the future. Since 1876 an El Nino has resulted every 6 to 7 years and a La Nina every 7 to 8 years. It is expected that at least one severe El Nino and La Nina will occur through to mine closure and this has been built in to the estimation process. The cycles that are most detrimental to the vegetation are the extended El Nino / La Nina events or the El Nino that is followed immediately by a La Nina. It has been assumed that these conditions will not result through to mine closure and their impact has not been included in the analysis.

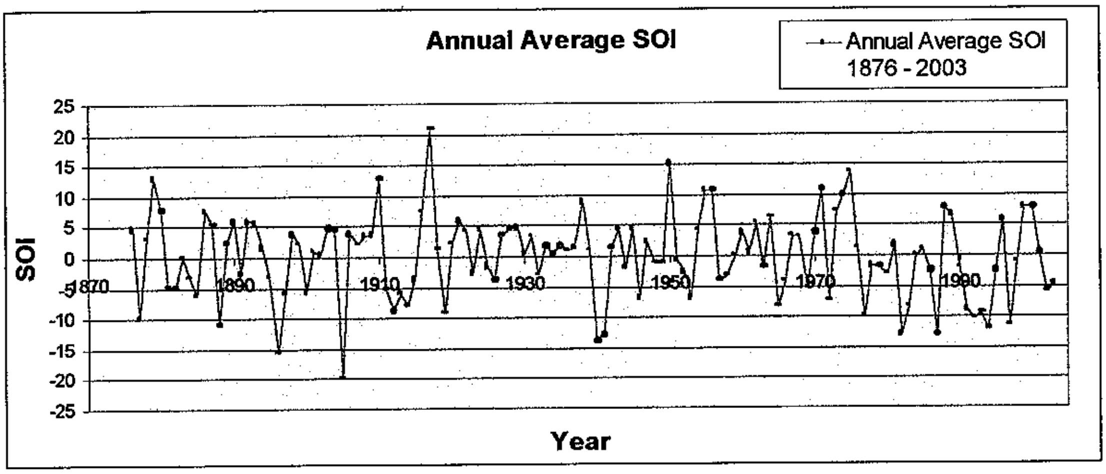

Figure 3 Annual Average SOI 1876 to 2003

4.0 METHODOLOGY OF ESTIMATION

A detailed description of the methodology of estimation of dieback extents is beyond the scope of this report; however a general coverage of the process has been included below.

Data sets comprising historical extents of vegetation dieback, past definitions of future dieback, definitions of vegetation regimes with the catchment, satellite and aerial imagery (showing the changes in floodplain vegetation regimes over time), bed aggradation trends, technical journals (detailing vegetation behaviour to prolonged inundation) and floodplain topography have been utilised in the analysis. In zones where accurate and complete floodplain topography is available a robust, quantitative approach has been adopted to estimate future dieback extent.

An elevation constraint at a level to reflect flood elevation across the floodplain has been applied to the topographic model. A bound is established at the junction of the constraint elevation and the topographic model within which the forest vegetation will be subject to inundation. Vegetation within the bound will be subject to root anoxia and dieback if the duration is greater than the tolerance threshold of the species. The extent is verified against vegetation regimes (to assess the response of vegetation to inundation as a function of flooding tolerance) and historical dieback progression. The extent is then updated and modified accordingly. Discrimination between the various scenarios was achieved by varying the elevation constraint to reflect different levels of flooding and by varying inundation duration, particularly the backwater zones. Accurate floodplain topography is only available in the Ok Tedi floodplain.

Within the Middle Fly and Upper Fly catchments the estimation of future dieback extent has been primarily subjective, but based on a set of consistent, quantitative rules. Although floodplain topography would improve the estimation process within the Fly floodplain it would need to be of a very high accuracy, particularly normal to the main stem. Estimation of dieback extent has been based primarily on historical trends, approximate floodplain topography and isolated accurate elevation nodes and vegetation regime definitions. Observation and experience gained from monitoring the system for the past 10 years has been extensively utilised to define ultimate extent and to assist with discrimination between scenarios. A significant proportion of the Middle Fly floodplain is within Indonesia and inaccessible. Verification of observed vegetation behaviour to flooding has not been possible within this zone. Interpretation of satellite and airborne imagery has been critical to the determination of current dieback extent and estimation of future dieback boundaries within the catchment.

5.0 DIEBACK EXTENT - PESSIMISTIC

An estimate of the extent of vegetation dieback in the Lower Ok Tedi and Middle Fly has been undertaken with respect to a pessimistic outcome. The estimate follows on from the work undertaken in August 1999 (Carroll et al (1999)) with updates based on a better knowledge of system processes. The revision has been based on the actual dieback monitoring of September 2000 (Marshall (2001)) and August 2002 (Marshall (2002)) as well as improved definition of backwater zones along the edges of the catchment.

The pessimistic estimate does not constitute a prediction of future dieback but rather the maximum extent in the case of extreme mine and climatic effects. The analysis does not discriminate between causes of vegetation dieback.

This definition is based on the entire catchment floodplain excluding the topographically higher zones on the margins of the catchment, the grassed areas and the rivers and lakes. For the purposes of this definition it is assumed that all tree species within the catchment boundary will be impacted, irrespective of flood tolerance, topography and hydrological constraints. The extent defined is a worst case estimate.

The 1999 definitions reported in Carroll et al (1999) were based on the best available estimates of catchment extent and expected dieback behaviour. The significant refinements with the current update include:

- Improved understanding of dieback behaviour at the margins of the catchment and in backwater zones. This has significantly altered estimates in the Upper Fly and the lower zones of the catchment.
- Improved definition of the extent of tree species within the grassed floodplains downstream of Mabaduam.

The dieback monitoring estimates of September 2000 and August 2001 have improved the understanding of dieback behaviour throughout the catchment. Spanning a period of extraordinarily high water levels over an extended period (1999 – 2001 La Nina) the progression of vegetation dieback through the system has given a reliable guide as to the potential extent in the future.

The reliability of current estimates has improved considerably in comparison to the 1999 definitions. The factors contributing to this improved reliability include:

- The Lower Ok Tedi monitored extents are approaching the physical limits of the floodplain. As the floodplain topography in this region is well defined it is possible to define the future limit of dieback with confidence.
- High water level during the recent La Nina period has resulted in considerable dieback in the upper reaches of the Upper Fly. This has resulted in improved knowledge of the future extents of backwater induced vegetation dieback in the Upper Fly. Extrapolation to future extent is more reliable with the benefit of actual extent under adverse climatic conditions.
- As with the Upper Fly, the actual extent of dieback along the catchment margins in the Middle Fly has contributed significantly to revision in future pessimistic extent. With little topographic definition, particularly to the west of the Fly River, the estimates of dieback extent were difficult to determine with any accuracy. Actual dieback, as well as the behaviour of dieback progression through the catchment, as contributed to improved estimate reliability at the margins of the catchment.
- The behaviour of dieback in the backwater zones of inlet tributaries to the Fly River is now better understood. The 1999 definition adopted a conservative extent in backwater zones. This has been refined based on observed trends in the catchment to date.

- The lower Middle Fly zones of Manda and Obo had negligible vegetation dieback prior to the 1999 analysis. Since that time the actual extent has progressed well into both zones. Original estimates of flood tolerance of tree species within the grassed floodplain proved incorrect. These zones have been added to the 2003 definitions.

Table 1 gives the future pessimistic estimates of dieback within the Lower Ok Tedi and Fly River catchments.

Zone	**1999 Pessimistic (km^2)**	**2003 Pessimistic (km^2)**	**Percent Change**
Konkonda	159	118	-25%
D'Albertis	219	207	-5%
Upper Fly	175	227	+30%
Wygerin	426	474	+11%
Mabaduam	661	643	-3%
Manda	1,085 [a]	1,134	+5%
Obo	1,064 [a]	1,148	+8%
Ogwa	-	161	
TOTAL	3,789 [b]	4,112	+8% [b]

Table 1 Vegetation Dieback – Pessimistic Estimates

Notes:

a Total estimated area has increased. This comprised a decrease in total area at the catchment margins, due to better understanding of dieback behaviour, but is offset by significant zones of tree species within the grassed floodplain zones.

b The 1999 estimate does not include an extent estimate for the Ogwa zone. Excluding Ogwa the estimates are 3,951 km^2 and 3,789 km^2 for 2003 and 1999 respectively. This equates to an increase of 4% over the Konkonda to Obo catchment.

Figure 4 shows the pessimistic extent of vegetation dieback within the Lower Ok Tedi and Fly River catchment. The downstream limits at Ogwa, on the Fly River, and Levame, on the Strickland River, do not indicate that this will be the physical limit of dieback but rather reflects the downstream limit of monitoring. The probability of dieback downstream of Ogwa is covered in section 7.

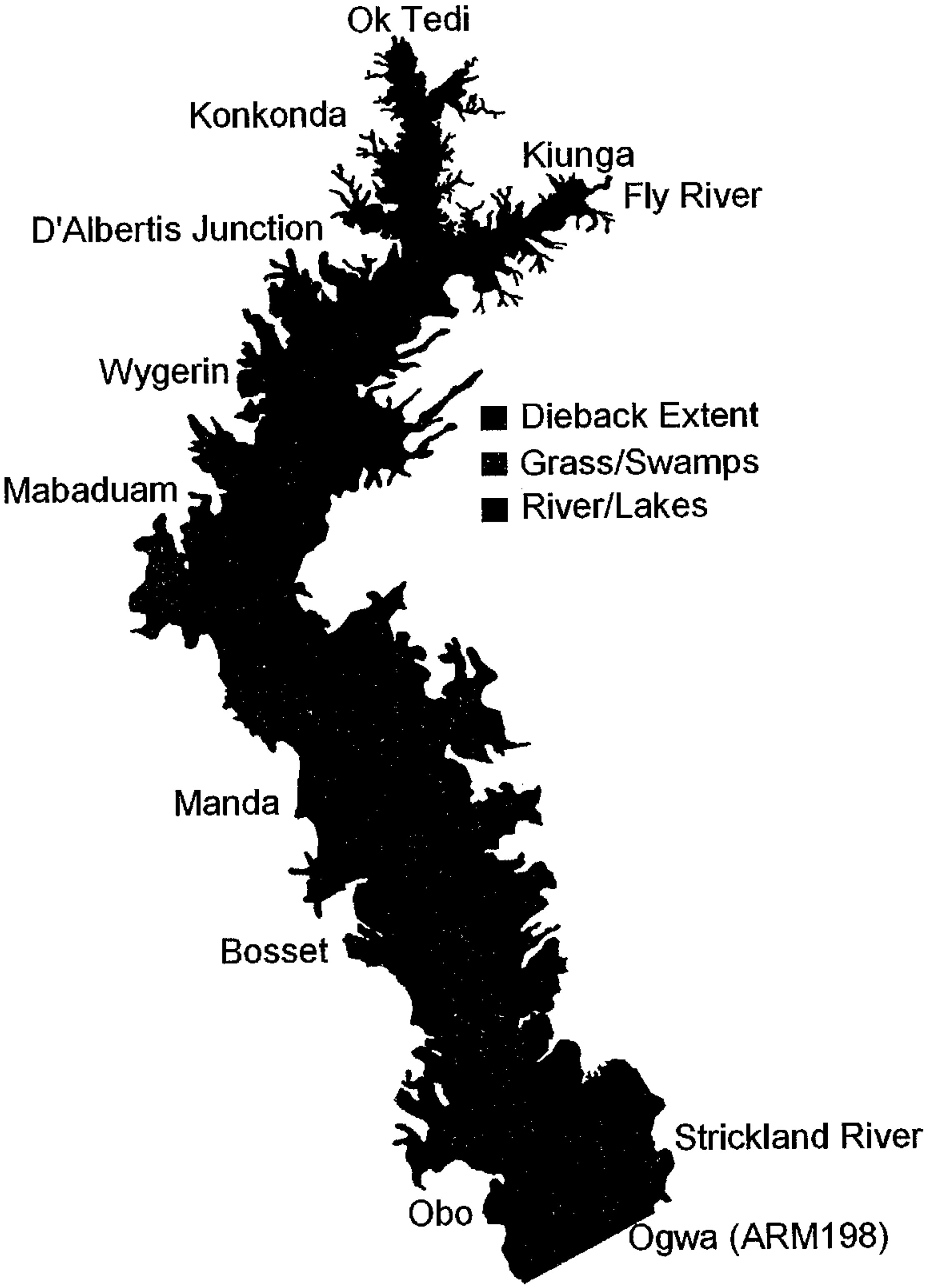

Figure 4 Pessimistic Dieback Extent
Lower Ok Tedi and Middle Fly River

6.0 DIEBACK EXTENT – LIKELY

The likely estimate of the extent of vegetation dieback in the Lower Ok Tedi and Middle Fly comprises a modification of the pessimistic extent to reflect an expected outcome under average climatic conditions and with respect to "dredging to mine closure" and "no dredging" scenarios. The major uncertainty in the definition is the climatic impact on the catchment although an average occurrence of extreme events through to mine closure has been incorporated.

The refinements detailed in section 1 have been incorporated into the estimation of likely extent. In particular the improved knowledge of dieback extent and propagation in backwater zones has been incorporated and has been critical to the discrimination between the dredging to mine closure and no dredging scenarios.

In Carroll et al (1999) the definition of likely extent was *"the topographically depressed zones of the catchment including the sub-floodplain of all lakes and tributaries. Isolated zones of elevated land are excluded, even if not at the margins of the catchment. Grassed areas and rivers/lakes are excluded."* This definition has been incorporated with modification by the revised pessimistic estimates, the improved understanding of system processes and the dieback monitoring results of 2001 and 2002.

As with the pessimistic extent, the likely analysis does not discriminate between causes of dieback.

Table 2 gives the future likely estimates of dieback within the Lower Ok Tedi and Fly River catchments with respect to the dredging to mine closure and no dredging scenarios.

Zone	**1999 Likely (km^2)**	**2003 Likely Dredge to Mine Closure (km^2)**	**2003 Likely No Dredge (km^2)**
Konkonda	92	92	113 [a]
D'Albertis	182	156	198 [a]
Upper Fly	118	131	210 [a]
Wygerin	260	330	390
Mabaduam	393	413	472
Manda	735	705	800
Obo	789	479	569
Ogwa	-	90	90
TOTAL	2,569 [b]	2,395	2,842

Table 2 Vegetation Dieback – Likely Estimates

Notes:

a The estimated dieback extents in the Konkonda, D'Albertis and Upper Fly zones approximate the pessimistic estimates. The only difference is the exclusion of several elevated zones within the pessimistic boundary.

b The 1999 estimate does not include an extent estimate for the Ogwa zone. The 1999 estimate was a (dredge to mine closure) estimate and hence there is a 10% reduction in total area compared to the equivalent 2003 coverage.

Figure 5 shows a graph of the dieback areas that are expected to result for the three scenarios; pessimistic, likely (dredging to mine closure) and likely (no dredging). Note that the pessimistic and likely (no dredge) results are identical to D'Albertis Junction and with only minor variance to Wygerin.

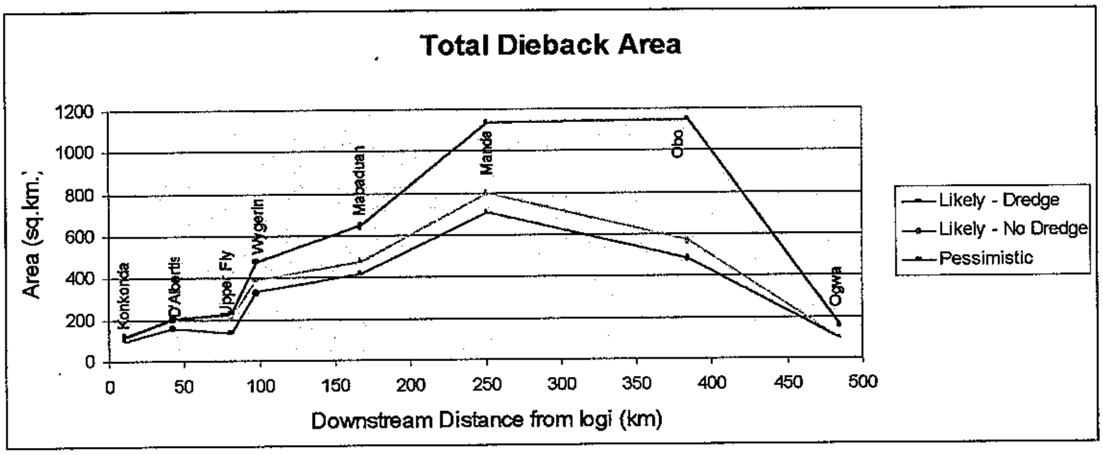

Figure 5 Dieback Estimates – Pessimistic, Likely (Dredge), Likely (No Dredge)

Figure 6 shows the likely extent of vegetation dieback in the Lower Ok Tedi and Middle Fly if dredging continues through to mine closure in 2010 while figure 7 shows the extent if there is no dredging.

The differentiation of likely impact (dredging) and likely impact (no dredging) has, to a certain extent, been subjective. The major area of differentiation has been in the area of extent of backwater impact, the final lateral extent of impact and the internal zones within each reach. The differentiation has been applied consistently across the catchment and has been based on observed behaviour over recent monitoring epochs. The likely (no dredge) scenario has adopted the pessimistic estimates for the Lower Ok Tedi. In this zone the final floodplain boundary is well defined and it is expected that without dredging, the likely extent will equate with the pessimistic estimate.

In the Upper Fly zone the differentiation was based primarily on the upstream extent to which the backwater impact would be evidenced. The current dieback extents in the region are a result of the 1999 – 2001 extended La Nina event. Vegetation in the reach is now recovering with the drop in river level, and backwater impact, since late 2001. Likely dieback extent in the reach has been based on these observations as well as estimated backwater impact during future extreme climatic events.

It had been assumed that the predominant differentiation, in terms of area, between the dredging and no dredging scenarios would occur in the upper reaches of the catchment. This differentiation would be primarily in the Konkonda, D'Albertis, Upper Fly and Wygerin reaches, with minimal difference further downstream where climatic impacts would predominate. This, however, has not been the case with the Lower Ok Tedi zones showing a similar difference to the rest of the catchment zones. This is primarily because dieback in the upper zones is already near the maximum expected level with only limited scope to vary between scenarios. In addition one of the primary differentiation factors between scenarios is the impact at the catchment edges and in backwater zones. Backwater zones predominate in the lower reaches of the catchment. In the vicinity of Obo and in the Ogwa zone there is negligible difference between the scenarios. **The primary difference between scenarios in the upper reaches of the catchment will be with respect to dieback severity rather than extent.** It is estimated that vegetation recovery will continue through the Lower Ok Tedi, Upper Fly and into the Wygerin zone with the continuation of dredging. Despite being vegetation recovery the classification under the scope of this report will be dieback. With no dredging it is expected that the majority of recovered vegetation to date will revert to dieback status and that the majority of impacted zones will contain severe dieback. Dieback severity is an issue that needs to be considered when assessing the relative merits of the dredging program.

Figures 8, 9 and 10 show a comparison between the likely (dredging to mine closure) and likely (no dredging) scenarios. The differentiation is greatest at the edges of the catchment and in the backwater zones of tributaries to the Ok Tedi and Fly River. In each figure the base map is the likely (dredging to mine closure) scenario and the orange outline is the likely (no dredging) scenario.

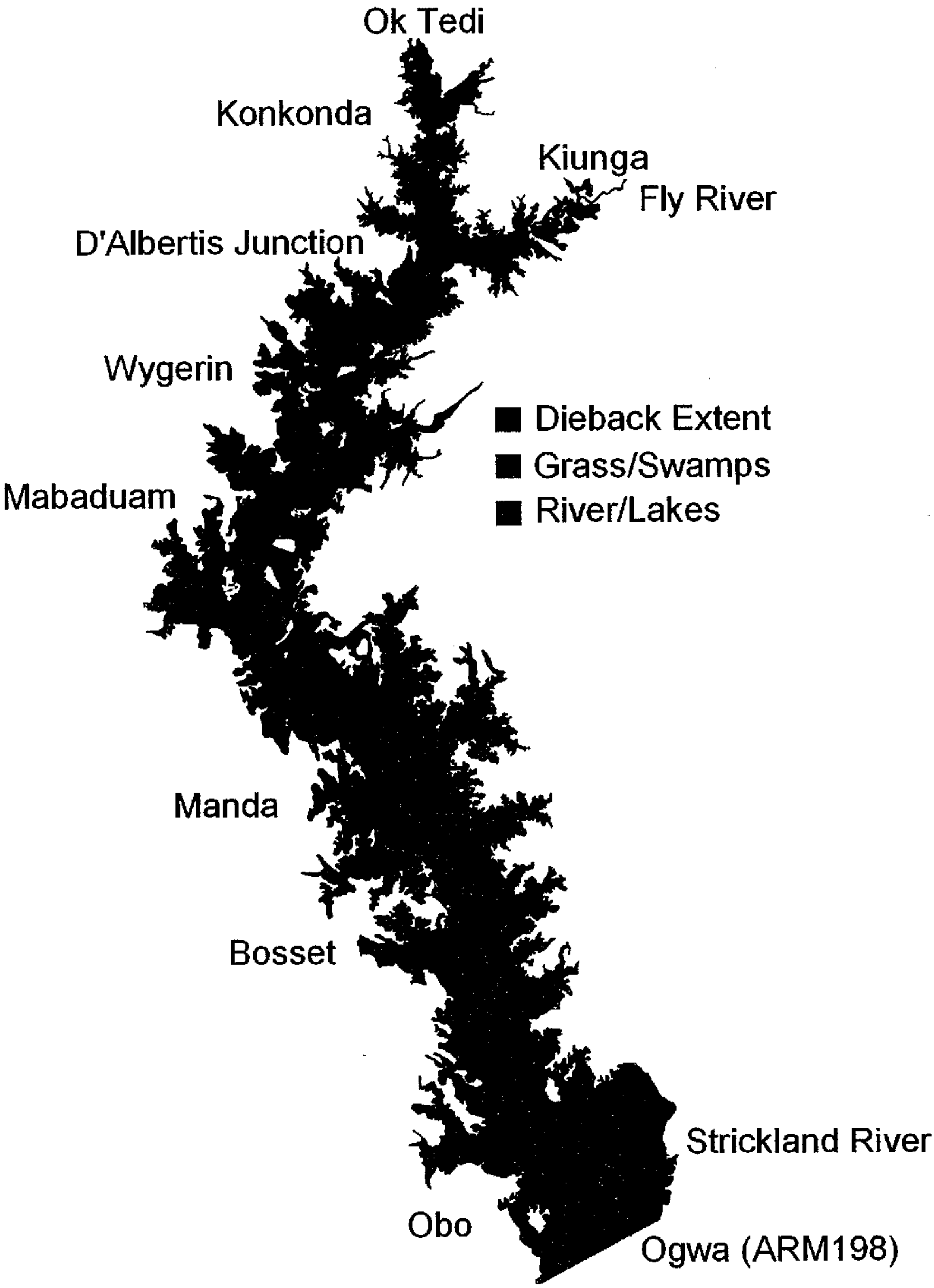

Figure 6 Likely (Dredging to Mine Closure) Dieback Extent
Lower Ok Tedi and Middle Fly River

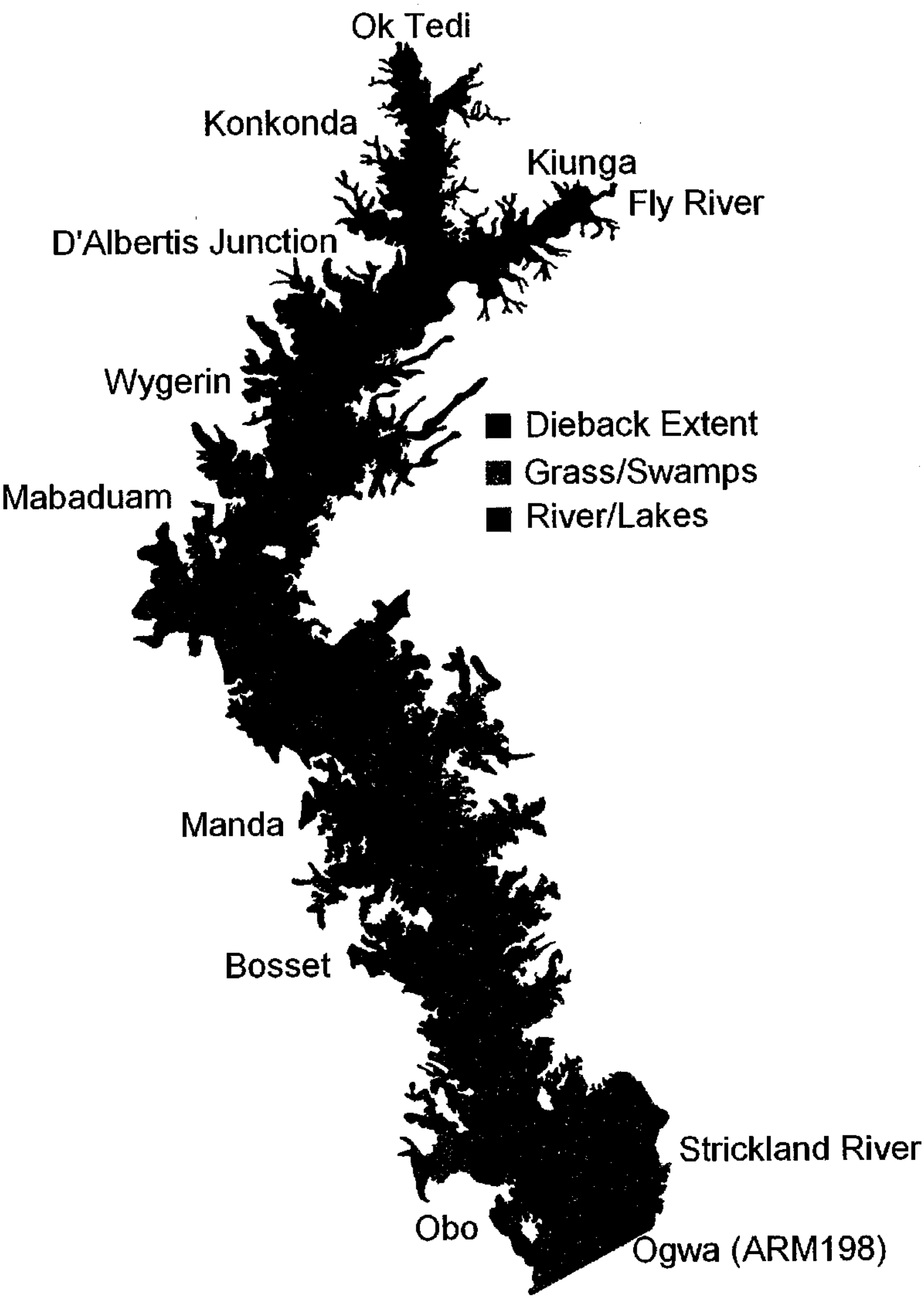

Figure 7 Likely (No Dredging) Dieback Extent
Lower Ok Tedi and Middle Fly River

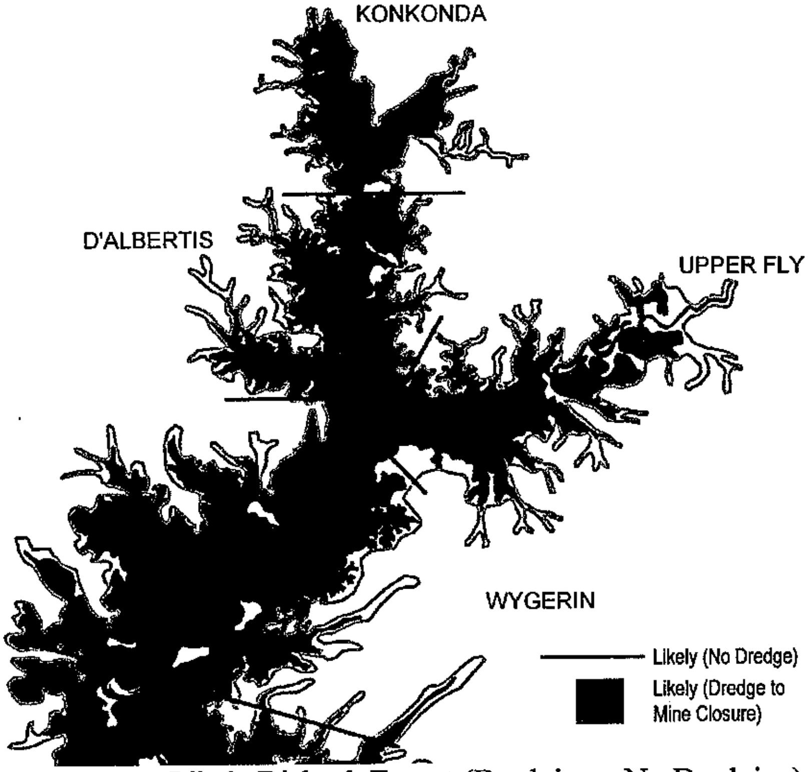

Figure 8 Likely Dieback Extent (Dredging v No Dredging)
Konkonda to Wygerin

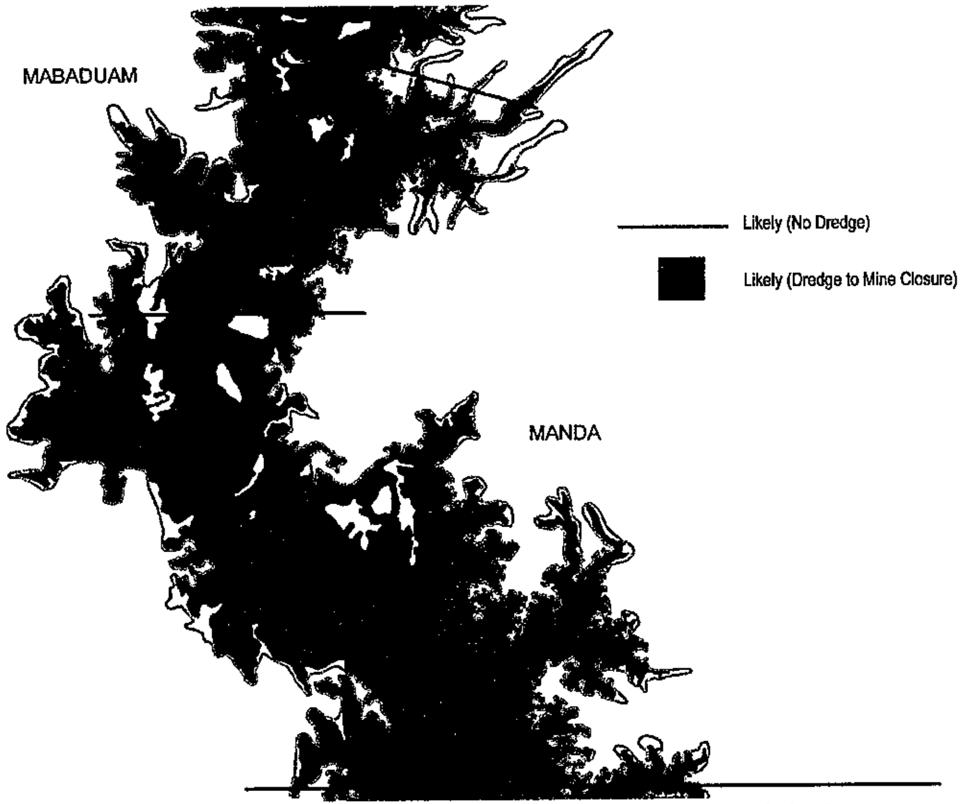

Figure 9 Likely Dieback Extent (Dredging v No Dredging)
Mabaduam to Manda

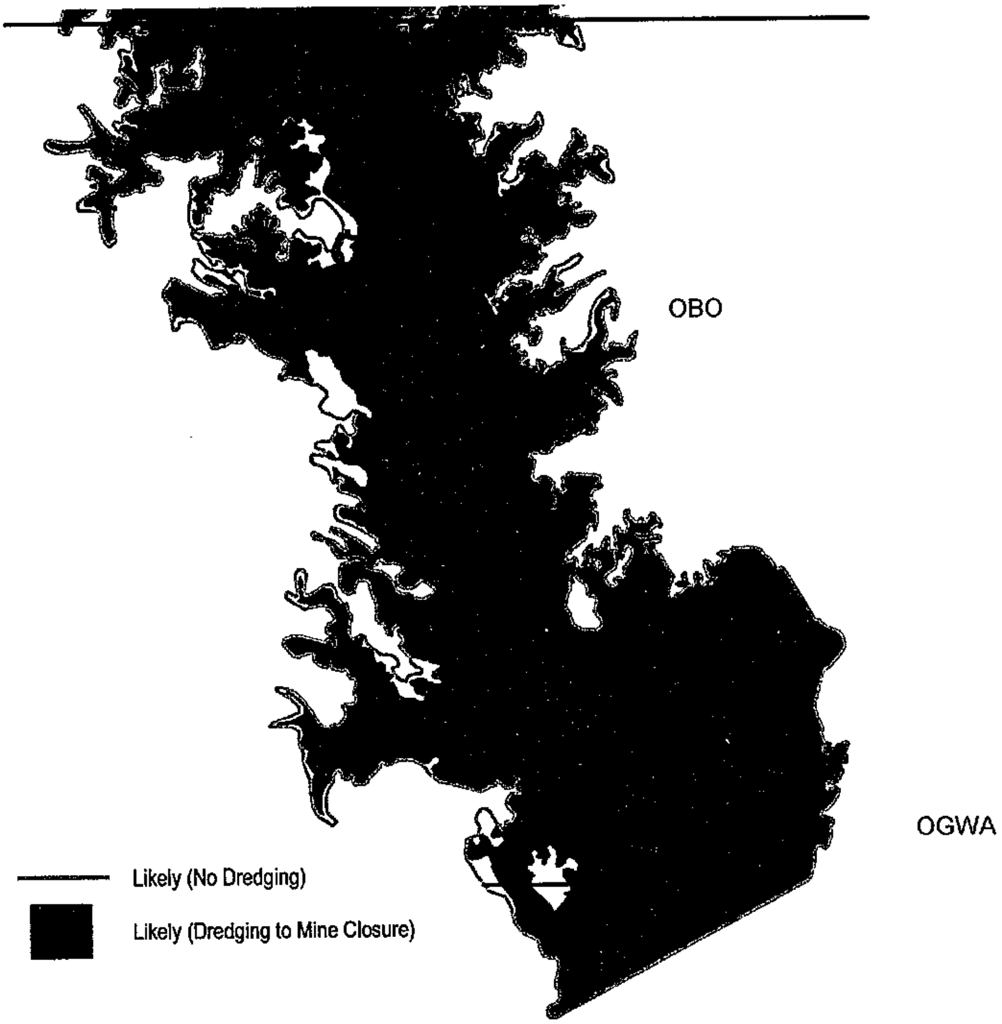

Figure 10 Likely Dieback Extent (Dredging v No Dredging)
Obo to Ogwa

7.0 DIEBACK EXTENT DOWNSTREAM OF OGWA

This report excludes a study into the extent of dieback downstream of Ogwa on the Fly River as dieback is not expected to be a significant issue based on the following:

a) Bed aggradation, whilst evident, is not significant as a percentage of channel volume. Vegetation dieback, as a consequence of mine impacts, is not expected to be extensive, although isolated pockets of tree species in low lying floodplain zones may become stressed. Impacts due to extreme climatic conditions are more probable; however the impacted zones are expected to readily recover once the climatic conditions moderate. Dieback in the reach is expected to be transitional and concentrated in the zone immediately downstream of Ogwa.

b) With increase in downstream distance from the mine the potential for vegetation dieback is expected to decrease. Flood induced dieback results predominantly due to an increase in flooding duration beyond a vegetation tolerance threshold. Much of the vegetation adjacent to the river in the lower reaches is already periodically inundated as a function of tidal impacts. Vegetation species such as mangroves have high flood tolerance and are not adversely impacted by periodic inundation. The tidal cycle in itself ensures periodic draining of the floodplain and aeration of the root system. In cases of extended flooding adventurous root systems provide the necessary oxygenation.

c) Although no measurements have been undertaken to confirm the hypothesis it is probable that the Lower Fly floodplain is topographically higher (in a relative sense) than that of the Middle Fly. It is hypothesised that the Strickland River floodplain is higher due to its higher sediment load (Dietrich (2003)) and this concept can be extended into the Lower Fly. The extensive forests, as opposed to the swamp and aquatic regimes of the Middle Fly, on the Lower Fly floodplain also give weight to the theory of a higher floodplain. Extensive and prolonged flooding of such a perched floodplain, sufficient to induce vegetation dieback, is not expected.

Although vegetation dieback will occur in the Lower Fly reach of the catchment it is not expected to be extensive or severe. This assessment is, however, made with little supporting data and should the potential for vegetation dieback in the Lower Fly be a critical issue then a study based on accurate and reliable data should be undertaken.

8.0 REFERENCES

Carroll D.G, Marshall A.R. & Moi A.S. (1999) The Results of Dieback Modelling on the Ok Tedi and Fly River Floodplains, Ok Tedi Mining Ltd (internal report)

Gillison A.N. (1983) Savannas of Australia and Southwest Pacific, In 'Ecosystems of the World 13 - Tropical Savannas' (Ed Bourliere F.) pp217-227

Halse S.A., Pearson G.B., Jaensch R.P., Kulmoi P., Gregory P., Kay W.R., Storey A.W. (1996) Waterbird Surveys of the Middle Fly River Floodplain, Papua New Guinea, *Wildlife Research*, 1996, 23, 557 – 569

Marshall A.R. & Rau M.T. (1999) Lower Ok Tedi and Middle Fly – Estimate of Current Vegetation Dieback and Classification of Floodplain Vegetation, Ok Tedi Mining Ltd (internal report)

Marshall A.R. (2001) Lower Ok Tedi and Midle Fly Vegetation Impact – September 2000, Ok Tedi Mining Ltd (internal report)

Marshall A.R. (2002) Lower Ok Tedi and Middle Fly Vegetation Dieback Monitoring 2001 – 2002, Ok Tedi Mining Ltd (internal report)

Dietrich W.E. (2003) Personal Communication – Discussion on Strickland River floodplain elevation.