

Social and Spiritual Development Strand
Social Science

Unit 1: Natural and Cultural Environments

Themes, Ok Tedi Case Study, Land Issues



Additional Support Material

Acknowledgements

'Theme – The Natural Environment' written and compiled by Lena Rifi (St Benedict's TC).

Ok Tedi material compiled by Sue Lauer (PASTEP).

Layout and diagrams supported by Nick Lauer.

Date: 7 April 2002



Primary and Secondary Teacher Education Project

Australian Agency for International Development (AusAID)
GRM International

Papua New Guinea-Australia Development Cooperation Program

Unit outline

Unit	#	Modules
Unit 1 Natural and Cultural Environments	1.1	Geography Skills (Core)
	1.2	Land Use and Settlement (Core)
	1.3	Environmental Issues (Core)
	1.4	Culture (Core)
	1.5	Resource Management (Optional)

Icons



Read or research



Write or summarise



Activity or discussion

Table of contents

Theme: The Natural Environment.....	1
<i>DEFORESTATION.....</i>	<i>1</i>
Activities	1
Notes	1
<i>DESERTIFICATION.....</i>	<i>2</i>
Activities	2
Notes	2
<i>SOIL EROSION/FARMING.....</i>	<i>3</i>
Activities	3
Notes	4
<i>GREENHOUSE EFFECT</i>	<i>5</i>
Activities	5
Notes	5
References	10
Social Science research assignment	11
<i>Land, Sea or Air</i>	<i>11</i>
<i>Summary.....</i>	<i>11</i>
Ok Tedi.....	12
Land Issues.....	41

Theme: The Natural Environment

Prepared by Ms Lena Rifi

TOPICS: Deforestation
Desertification
Soil erosion/farming
The green house effect.

AIM: to guide the students to discover as much as possible by completing tasks which suit their own abilities.

OBJECTIVES: The students, in small groups, should be able to:

- 1) sketch diagrams, write explanations and descriptions, draw maps and graphs illustrating the growing human effects on the Earth's environment,
- 2) Present their research findings on a chart
- 3) Present their chart and give a brief talk on the topics.

MATERIALS: blank paper for each student, books on each topic, cartridge paper, glue, scissors, pencils, rubbers, etc...

DEFORESTATION

Activities

1. Sketch a diagram illustrating deforestation and soil erosion.
2. Explain what deforestation and soil erosion are
3. Explain what monoculture is and its effects on the land
4. Explain the effects of mining and dams on forests
5. Draw a diagram showing how chemical fertilizers affect the food chain...

Books to use:

- 1) Social Science - Unit 10 CODE, 2) Earth In Danger - LAND

Notes

Deforestation is the clearing of forests to make way for farming, industry and housing. Deforestation can cause many problems.

1 . DEFORESTATION AND SOIL EROSION.

Water trapped in the soil of forests. It is drawn up by trees and released from the leaves into the air as water vapour. Later, the water vapour cools, forms clouds and falls again as rain. When forests are cut down, less rain falls in the area and droughts can occur.

When rain does fall the water runs quickly over the cleared land and can result in flooding. Without tree roots to hold the soil together, it is eroded by the wind and rain. When rainforests are cut down to make way for farming, the soil is no longer enriched

by rotting leaves and branches and soon becomes infertile. The land is abandoned and more forest area is cleared. The soil of the cleared land is so poor that the rain forest may never grow again. Many temperate forests have been cleared for their timber. These forests can be replanted to protect the soil and to ensure a continuing supply of timber.

2. DEFORESTATION AND THE GREENHOUSE EFFECT.

People and animals breathe in oxygen and breathe out carbon dioxide. Trees and plants absorb and use carbon dioxide from the air and give off oxygen and water vapour. When forests are cleared there are less trees to take carbon dioxide, out of the atmosphere. The earth's atmosphere is made up of gases. The carbon dioxide in the atmosphere traps some of the sun's rays and warms the earth. If too much of this gas builds up, then too much heat is trapped. Scientists predict that this will cause the temperature of the earth to rise. This is called the "Greenhouse Effect".

DESERTIFICATION

Activities

1. Draw a diagram and explain what good and bad soil is
2. Explain how we can improve the quality of soil and how we can prevent desertification.
3. Draw a world map and colour the desert areas.
4. Explain what deserts are and what causes them
5. Draw a diagram showing causes of soil salinity

Books to use:

- 1) Social Science - Unit 10 CODE, 2) Changing our World - PRESERVING THE SOIL

Notes

1. WHAT ARE DESERTS?

Deserts are areas of land with low rainfall. They cover almost 1/7th of the world's land. For example, a belt of deserts stretches from the west coast of Africa, across the Middle East to the Gobi Desert in Asia. Deserts are either very hot or very cold. Deserts in Africa and Australia are very hot during the day but can be cold at night. Cold areas near the North and South Poles are also deserts.

Some plants and animals have adjusted to the desert's harsh climate. Cactus, grasses, certain trees and flowers, lizards, frogs, birds, insects and animals such as camels and oxen can survive in the desert. Some people live there too. These are mostly nomads who travel to find water and food.

2. THE SPREAD OF DESERTS

The land that surrounds deserts is called semi-arid land. This land has more rainfall than a desert and more plants grow there. Many people, who can't survive in the inhospitable desert area, live in this semi - arid land and quickly use up its natural resources. They clear the land of wood which they use for heating and cooking. As the trees disappear, nothing is left to hold the soil together. The soil is blown by the wind or washed away by the sudden and fierce rainstorms that occur in these regions. The desert then takes over this barren land.

The spread of deserts is called Desertification. As populations increase, more land is cleared for farming. Overgrazing by cattle and other farm animals destroys the plants that hold the topsoil together. Their hooves trample the soil and grind it to dust. Desertification is caused by wind and water.

Planting the same crops too often, using badly designed irrigation systems and clearing too much land, are all examples of poorly managed farms. These acts have a damaging effect on the land - they destroy the fertility of the soil, causing desertification.

3. THE EFFECTS OF DESERTIFICATION.

The roots of trees and other plants absorb water from the soil. It is released from their leaves as water vapour. This puts moisture into the air. The water vapour forms the clouds and when the clouds of vapour cool, rain falls. In places where desertification has happened there are no plants to release the moisture into the air. Rain clouds don't form, and droughts last longer. Without vegetation, the sun dries the soil to a fine dust. The wind lifts the soil off the land. Dust storms are common in these areas. When the rain does fall, it washes away the soil which clogs and pollutes streams and rivers.

4. LEARNING TO CONTROL DESERTIFICATION.

One way to stop the spread of the desert is to plant trees that provide food, fuel and building timber and which enrich the soil at the same time. The acacia tree does all of these things. Planting trees as windbreaks protects the soil by holding it together. The windbreaks protect livestock by providing shelter from the harsh weather. Some of the trees from wind breaks can be used for fuel and building and new trees planted to replace those that have been harvested.

Planting new forests in arid and semi-arid areas will halt the spread of desert. These forests will have to be carefully managed and replanting done to replace the harvested trees. Using renewable resources such as wind and solar power, means fewer trees need to be cut down for energy-producing purposes.

Irrigation can make land in semi-arid and desert regions productive. Irrigation is used mainly where rivers flow near or through desert land. Water is taken from waterways or from underground water supplies. It is pumped into channels which runs between plants or is sprayed onto the crops.

SOIL EROSION/FARMING

Activities

1. Describe the different types of farming and their effects. Tabulate the information.
2. Explain what biocides are and their effects.
3. Draw organochlorine pesticide in a food chain.
4. List and describe how farming is affecting the various species of wildlife.
5. Draw the rainforest water cycle, and explain its importance.
6. Explain what the green *revolution* is
7. What does 'organic' mean?

Books to use:

- 1) Conserving our World – Farming and the Environment, 2) Social Science - Unit 10
CODE

Notes

1. WHAT IS SOIL EROSION?

Soil erosion is the loss of soil from the land. The soil may be washed away by water or blown away by wind. It is a serious problem. When land has been badly damaged by soil erosion it may never be able to grow crops or pastures again. Even where the land can be repaired, the cost would be enormous. Soil erosion concerns the whole community. Land lost by erosion cannot grow food either for our use or for export.

There are three types of soil erosion:

- SHEET EROSION - when rain washes the soil down a slope.
- GULLY & TUNNEL EROSION - when rain falls on the soil and makes small valleys or gullies which get larger as the water washes away the soil.
- WIND EROSION - usually happens when it is dry and the wind blows away all the fine soil.

2. WHAT CAUSES SOIL EROSION?

Soil erosion is partly a result of the climate. Heavy rainfall causes gully and sheet erosion. Dry weather and strong winds cause wind erosion. However, the worst erosion is caused by man. This can happen in many ways: -

- If man removes the natural vegetation by cutting down trees or ploughing up grassland, he leaves the soil unprotected and it can be easily washed away,
- poor farming methods which cause the soil to lose fertility also can cause erosion.

3. HOW CAN SOIL EROSION BE PREVENTED?

One way is to make sure we do not farm on unsuitable land on a steep slope or where the climate is too dry. There is only one way that hillsides can be farmed and that is by making terraces. These stop the flow of soil and water down the slope. In the same way if you plough around the side of the hill, the furrows will stop the erosion better than if you plough straight up and down. This method is called contour ploughing. Strip farming is another method that can help soil erosion. The farmer plants a row of one type of crop and then next to it a different crop which may help to protect the soil and hold it together. Drainage ditches can also be dug to take the water away from the farmland. An important way to stop erosion is to plant trees. They protect the soil and their roots help to bind the soil together and control the flow of water through the soil.

4. FARMING AND POLLUTION.

Pollution is now a serious problem in many parts of the world. Much of it is caused by the industrial processes used to generate energy and produce the materials we use. However, modern farming practises are also polluting the environment. Many of the materials that we call pollutants already exist in nature. However, such materials can easily become pollutants when present in unnaturally large amounts. The chemicals known as nitrates, for example, occur naturally in the ground, and are naturally in the ground, and are actually essential for plant growth. For this reason the farmers add large amounts nitrate-containing fertilizers to the soil in order to make their crops grow. The plants rapidly take up the chemicals in the fertilizer and develop into stronger plants that produce better yields than those left untreated.

5. IS SOIL EROSION A PROBLEM IN PAPUA NEW GUINEA?

The heavy rainfall in most parts of Papua New Guinea means that whenever the natural vegetation is removed there is a danger of erosion. Most of you will have seen examples of erosion on the bare earth at the side of roads. Timber schemes and big mining projects, such as Panguna also cause erosion. Soil erosion is often a problem in the Highlands, where there are often too many people and not enough land. Steep hillsides are cultivated, and although in some areas the farmers are skilful at making terraces or mounds, much of the soil may be washed away. Like the rest of our environment, the soil is something that has to be looked after carefully. It is important that whatever developments take place, the soil must be conserved.

Differences in the fertility of the soil will also affect land use, so will the relief and drainage. Some areas are too mountainous and rocky for cultivation. Soil erosion is a problem when you try to farm on steep slopes. Other places are too wet and swampy for most types of crops to grow.

GREENHOUSE EFFECT

Activities

1. Draw a diagram to show how the greenhouse effect works
2. Draw a world map and show areas of tropical rain forests...
3. Draw the graph showing global warming.
4. Draw the graph showing radiation.
5. Draw the graph showing life in the atmosphere....
6. What are the alternative energies for us to use in the future?

Books to use.

1) Social Science Grade 10 Unit – Changing World, 2) Save our Earth – The Greenhouse Effect, 3) Social Science - CODE Unit 10.

Notes

1. WHAT IS A GREENHOUSE?

A greenhouse is usually made of glass and becomes very warm and humid inside when the sun shines on it, even though it may be quite cold outside. Light rays from the sun (Infra-red) pass easily through the glass of a greenhouse. Inside the greenhouse, the light heats up the floor, the leaves of the plants and the benches. This heat radiates from the plants and the benches. This means that the heat is trapped inside the greenhouse. Even on dull, cloudy days, the air inside a greenhouse can be much warmer than the air outside. Sometimes the air inside a greenhouse becomes too hot. When this happens, louvers are opened to allow the extra heat to escape until the temperature is back to the correct level.

On the Earth light rays from the sun pass through carbon dioxide in the atmosphere and heat up the surface of the Earth. The air is heated by the warmth coming from the Earth's surface. The carbon dioxide in the air prevents most of the heat from escaping back into outer space. The more carbon dioxide there is in the air, the less heat is lost to outer space and the warmer the Earth's atmosphere becomes. This is why carbon dioxide is called the green house gas.

2. HOW DO PEOPLE'S ACTIVITIES AFFECT THE PLANET EARTH?

The balance between carbon dioxide production and its removal from the atmosphere is a delicate one. Under normal circumstances, the carbon cycle is unable to adjust itself to make sure that the right amount of carbon dioxide is present. Just as a greenhouse worker is able to open and close louvers to control the temperature inside his green house, so the carbon cycle can adjust the amount of carbon dioxide in the atmosphere to make sure that world temperatures remain at a level suitable for life. BUT, unfortunately, over the past thirty years, people's activities have begun to interfere with the carbon cycle. The level of carbon dioxide in the atmosphere today is 7 % higher than it was twenty years ago.

How is this happening?

- Increased Carbon Dioxide Production - Industrial development over the past 200 year's proceeded at an ever-increasing rate. The power for industries comes mainly from the burning of fossil fuels. Vast amounts of carbon dioxide are released into the air from factories, domestic oil, gas and coal heating systems and from exhausts of millions of motor cars
- Decreased Carbon Dioxide Removal – Almost all the deciduous forests in the warmer temperate regions have been cleared to make rich farming land. The tropical rainforests in many parts of the world, especially in the Amazon basin, which absorb enormous amounts of carbon dioxide, are being cleared at a very rapid rate. Many of the forests are being burnt adding even more carbon dioxide, nor does it cause clouds and rain to form. In addition, deforestation increases the rate of soil erosion. Soil particles are carried to the oceans by rivers where the shallow seas around the coast become muddy. In these conditions coral reefs begin to die. Living coral absorbs enormous amounts of carbon from the sea to make calcium carbonate for its skeleton. As the coral dies, less carbon is removed from the sea so the sea is unable to absorb as much carbon dioxide from the atmosphere.
- What is going to happen next? The effect of people's activities is to increase the amount of carbon dioxide in the atmosphere and at the same time to destroy those parts of the environment that can remove it. As carbon dioxide increases in the atmosphere, world temperatures will begin to rise. At the moment it is too soon to predict what effects this will have on the living creatures of the world. Some people think that temperatures will become so hot that most life on the Earth will die. Others say that the ice caps will melt and the sea level will rise by about 1-2 metres.

3. SOME FACTS ABOUT ATMOSPHERIC POLLUTION.

a) Radiation and cloud cover - Radiation from the Sun travels by short wavelengths in the visible part of the spectrum, and is largely not absorbed by the atmosphere. The Earth radiates back heat in longer wavelengths, which bounce off the atmosphere. Much of this heat is absorbed by the atmosphere and reflects back to the Earth. Global warming may cause an increase in cloud cover, which may play a part in both increasing the greenhouse effect (by trapping heat and reflecting it back to the Earth), and in decreasing it (by reflecting solar energy back out to space).

b) Life in the atmosphere - The various greenhouse gases can stay in the atmosphere for a long time before they are eventually broken down into other substances or leave the atmosphere. Many CFCs may remain there for perhaps as a century, and some, CFCs

may last as long as 20,000 years. All this means that we have to stop putting greenhouse gases up there.

c) Energy efficient. Public transport - Look around and see how many cars have just one person riding in them. If there were more buses and trains for us to use, and if we used them instead of taking the car out for everything, we'd really be helping to prevent the greenhouse effect. A bus produces more carbon dioxide pollution than a car, but if you think of their being, 20 passengers on a bus and often only one in a car, the car driver is responsible for up to 4 times as much pollution as each bus passenger. It is especially important that vehicles are kept well-tuned. Every day we see vehicles releasing thick black exhaust fumes because they are not tuned properly or regularly.

d) The carbon cycle - Carbon dioxide plays a vital role in life on Earth. It is one form of carbon, which is an important part of many of the substances that animals and plants use for food and energy. Plants use carbon dioxide from the atmosphere to obtain carbon. Animals obtain their carbon by eating plants and other animals. Carbon is released again to return to the atmosphere as carbon dioxide when plants and animals die and rot, when plants are burned and when animals breathe. Some carbon dioxide is absorbed by the oceans, which altogether hold a huge quantity of it. Not counting the carbon held in the sediments at the oceans, the oceans still hold about 50 times as much carbon as the atmosphere. It may be that the oceans could help slow down global warming by absorbing the extra CO₂ we are producing.

e) Carbon dioxide producers' - About 80% of carbon dioxide pollution comes from the burning of fossil fuels. In the United Kingdom they produce 3% of the world's carbon dioxide from fossil fuels - though they have only 1% of the world's population. North America produces 25%, Western Europe 15%, Eastern Europe 23%, China 11% and other developing countries 16%. In the United Kingdom, the main sources of carbon dioxide are electricity generators, industry, buildings and transport.

f) Proof that energy can be saved - In Denmark the amount of energy needed to heat buildings has been reduced by 35 % over the last 15 years. The Danes use combined heat and power stations (known as cogeneration stations) which are more than twice as efficient as power stations used in the United Kingdom. In the USA, the law is being used against global warming; the 1987 Appliances Efficiency Act is calculated to save 55 million tonnes of CO₂ per year by the year 2000.

h) The effect isn't new - We have been putting carbon dioxide into the atmosphere for centuries, but the amounts have gotten bigger and bigger since the birth of the Industrial Age. In fact, scientists say that the world has already warmed by about 0.5 degrees Centigrade in the last century and is continuing to warm up.

GLOSSARY

Alternative energy sources	Energy sources which produce energy without burning fossil fuels. They include solar energy, wind energy and hydro-electric energy
CFCz	Chlorofluorocarbon; chemicals which are used for a variety of applications, including aerosols, fridges and the manufacture of some types of foam packaging.
Energy	Energy is the ability to do work. It comes in many different forms. We have to generate it in order to use many of the objects which we consider to be vital in the modern world ~ from light bulbs to motorcars. For a very long time we have produced energy by burning wood, coal, oil and gas. But in recent years people have looked at the possibility of using alternative energy sources.
Energy -efficient products	Products which use the minimum amount of energy to do their jobs, therefore saving energy and money. By saving energy they can also help to prevent an increase in the greenhouse effect, because they reduce the amount of energy which has to be generated in the first place, and therefore potentially cut down the amount of fossil fuel burned at power stations.
Fossil fuels	Coal, oil and natural gas: these substances have been buried or trapped beneath the ground for millions of years; they originate from the remains of living creatures, both plant and animal. When they are burned they release energy.
Global Warming	Atmospheric pollution has increased the greenhouse effect by putting more gases that trap heat into the atmosphere. This is causing the Earth's temperature to rise; an effect known as global warming.
Greenhouse effect	The warming effect of the Earth's atmosphere. Some gases in the atmosphere allow energy from the sun to pass through to warm the Earth's surface, then trap the heat coming back. This keeps the atmosphere -and the planet - warm. It is known as the greenhouse effect and helps make life on Earth possible.
Greenhouse gases	The gases which cause the greenhouse effect. Many of them occur naturally in the atmosphere -for example carbon dioxide, ozone and methane - but others, such as CMg, are only there because of human activities.

PRESENTATION AND DISCUSSION

- Each student completes his or her own task neatly. Each task should have a frame resembling anything from the environment.
- Cut and paste the finished tasks onto cartridge paper.
- One person from each group tells the class about the topic their group has researched.

-
1. What is the main concern projected from all the work you have displayed
 2. What are some things we can do to help preserve the Earth?
 3. In Papua New Guinea, what are some things we can do to help prevent pollution caused by

- CFC's
- Greenhouse Gases
- Use of Fossil Fuels
- Radiation and cloud cover
- The Carbon Cycle

-
4. What can you do in your own home to help prevent the pollution of the Earth's environment?

References

CODE: *Social Science* Unit 10

Department of Education PNG (1991). *Changing World*, (Grade 10 Unit) The Jacaranda Press, ISBN 0 7016 2920 7.

Hare, T. (1990). *Save Our Earth – The Greenhouse Effect*, Franklin Watt, Great Britain, ISBN 0 7496 0089 6 ISBN 0 7502 0693 4

Lambert, M. (1990). *Conserving our World - Farming and the Environment*, Wayland Publishing: East Sussex, ISBN 1 85210 828 2

Morrissey, D. (1993). *Changing Our World - preserving the soil*, Macmillan Education Australia, ISBN 0 7329 1475 2.

Smith, D. (1993). *The Water Cycle*, Wayland Publishing: East Sussex

Thomas, R. and Hipgrave, J: (1993). *Earth in Danger-Land*, Macmillan Education Australia, ISBN 0 732 7 1362 4.

Social Science research assignment

Imagine that you are an Environmental Conservationist. You have been asked by the town planner to conduct a survey on the environmental impact of the transport systems; AIR, ROAD and SEA in your area. Your report will help plans for the development of the area for the next 20 years.

You are to do a survey on **one** of the following forms of transport.

Land, Sea or Air

Here are some guidelines to help you ...

Land transport

1. Observe the amount of land transport used at busy areas in town for five days, but spend no more than one hour
2. Tabulate the information collected; eg, foot, bicycles, motor bikes, vehicles, cars, trucks, buses
3. Identify existing environmental problems and make practical suggestions to guide the town planner to avoid those problems.

Sea transport

1. Count the number of sea vessels passing a particular point for five days but spend no more than an hour,
2. Tabulate the information collected; eg canoes, canoes with motors, dinghies, small coastal vessels, large ships
3. Identify possible environmental problems caused by sea transport, and suggest ways of preventing them and preserving the marine life.

Air transport

1. Find out the number of times aeroplanes land at the closest airport for five days
2. Tabulate the information collected. For example, third level airplanes, Air Niugini planes, private planes
3. Use the information to identify the possible environmental problems caused by the air transport and suggest ways of preventing these problems from occurring in the future.

Summary

You are to record the results of your survey, analyse the results, draw some conclusions and make practical suggestions to help guide the town planners to avoid environmental problems caused by transport systems.

The table and the report should be about 3 pages (A 4)

Ok Tedi

An Introduction to the Geography of Papua New Guinea

This section outlines some of the geographical features of Papua New Guinea which are relevant to understanding the Ok Tedi issue. The biophysical environment of the country is varied, despite its equatorial location and is subject to regular and quite rapid changes. This is a difficult environment for people to live and work in. The recent transition of the people from isolated subsistence communities to more literate and commercially-minded communities has created great strains both on the society and in the personal lives of many people.

The leaders of the nation are seeking to shift Papua New Guinea to a modern, export-orientated industrial economy using income from resource exploitation and development. The rapid pace of this shift, the development of skilled human resources and the difficulties imposed by the biophysical environment stretch the talents of a nation which has been politically independent for just over twenty years.

The geography of Papua New Guinea is still dominated by its colonial past and its hundreds of different tribes. There is a shortage of human capital and skills. Its economy is dependent on mineral and timber exports which do not generate sufficient income and employment to benefit all citizens.

This is a classic dilemma for Less Developed Countries: how to preserve the sovereignty of the nation in the ownership and use of resources which provide jobs and incomes, and how to share the wealth from these resources among the people.

Economic activity

The economy of Papua New Guinea is dominated by the primary sector as the following table shows.

Sector	%
Agriculture, Forestry and Fisheries	28.74
Mining & Petroleum	24.88
Services	
• Community & Social Services	14.71
• Commerce	8.15
• Transport	4.90
• Electricity & Other Services Finance, Real Estate & Property	1.36 0.96
Manufacturing	7.91
Construction	4.08
Import Duties	4.31

Table 1: PNG: Contribution to GDP - 1994 **Data source: Australian Agency for International Development, International Development Issues No. 39, 'Papua New Guinea: Improving the Investment Climate', November 1995.**

The mining sector is a major contributor to the national economy. In 1994, copper and gold constituted about 40% of exports valued at K(kina) 1 070 million. This sector is enjoying a boom at the moment because of world commodity prices and the discovery of many new deposits. Papua New Guinea has recently emerged as the sixth largest gold producer in the world.

The Ok Tedi mining project is Papua New Guinea's largest industrial and commercial enterprise. In 1995, export sales from the mine were worth K930 million and represented 28.6% of Papua New Guinea's foreign exchange earnings. The operation has stimulated economic activity and provided employment, infrastructure, health and education services in a region where in the late 1970s there were virtually none of these.

Resource	Location	Owner	Date and Nature of Production
Copper and gold	Panguna,	CRA	Mining commenced in 1969.
	Bougainville Is.	PNG Government	Operation closed in 1989 as a result of a rebellion by local people. At its peak in 1986, 16 000 kg of gold and 179 000 tonnes of copper was produced.
Copper, gold and silver	Ok Tedi, Western province	BHP INMET PNG Government	Mining commenced in 1984. In 1995, 212 737 tonnes of copper, 14 996 kg of gold and 28 432 kg of silver was produced.
Gold	Misima Island near Milne Bay	Placer Pacific PNG Government	Mining commenced in 1989. Low-grade ore. Expected to run out by late 1990s.
Gold	Porgera in the Highlands	Placer Pacific RGC Limited MIM Holdings Limited PNG Government	Mining commenced in 1990. In 1995, 26 403 kg of gold and 2 752 kg of silver was produced. Mine is viable for another 20 years.
Gold	Mt Kare in the Highlands near Porgera	Local landowners together with Ramsgate Resources Menzies Gold	Mining commenced in 1988 with 10 000 local people involved in a gold rush. Small-scale alluvial mining continues.
Gold	Lihir island off the northeast coast of New Ireland	Lihir Gold RTZ PNG Government	Mine development began in 1996 after many years of planning as ore body is inside a dormant volcanic crater.

Oil	Kutubu in the Southern Highlands.	Kutubu Joint Venture - includes local landowners, PNG	Oil first discovered here in 1919. Not actively exploited until 1990s. In 1995 an average of 100 000 barrels was flowing per day
	A pipeline and off-shore loading platform in the Gulf Province	Government, Chevron, BP, Ampol, BHP and Mitsubishi	
Gas	Hides in the Southern Highlands	Exxon, BP	Gas is used to fuel the nearby Porgera mine.

Political and administrative structure

Papua New Guinea has a federal parliamentary system with three tiers of government. The National Parliament sits in Port Moresby, the national capital, and consists of one house with 109 members. At the middle level are 19 provincial governments which are responsible for schools, housing, village courts and cultural and sporting matters. Provincial governments are being restructured so that they are under greater control of politicians both at the centre and in village councils. At the district and village level, there are 167 elected councils which are responsible for roads, bridges, markets, water supplies and other community services.

This decentralised federal system has given local landowners, clans and district councils strong negotiated agreements with timber and mining companies. These agreements allow resource development companies to register companies in which local clans and landowners are significant shareholders. These companies then explore, mine or log local resources while paying the local people significant sums of money as compensation, royalties and shares of profits. Some local clans and landowners who possess valuable resources have thereby become quite wealthy in local terms.

The Geography of the Western Province of Papua New Guinea

The Western Province is the largest in Papua New Guinea and covers an area of 99 300 square kilometres or just over 20% of the nation's total area. Daru is the provincial capital and lies on an island off the far southern coast not far from the international border with Australia. The western boundary of the province is the international border with Indonesia.

The province can be divided into two regions, the smaller mountainous north and the much more extensive area of low altitude plains in the south. The mountainous north where peaks rise to nearly 3 500 metres on the northern border with the Sepik province covers about 10% of the province. The second and much larger region consists of extensive, undulating and swampy lowlands below 100 metres which stretch from the mountain barriers in the north to the southern coastline.

The population of the Western Province is only a little over 110 000 people according to the 1990 census. The population density averages about one per square kilometre. Tabubil, the Ok Tedi mining town, is the largest urban centre with 10 000 people. The centre of Kiunga was established in the 1950s as a government station and then further developed by Ok Tedi Mining Limited (OTML). Today it has a population of about 3 000 people.

Geology and geomorphology of the Ok Tedi area

The mountains of the Western Province consist of Mesozoic and Cainozoic marine sediments. The older sediments at the base of the mountains are mudstones and sandstones, strongly bedded, structurally weak and easily eroded. These are often visible in the lower levels of the deep gorges cut by the upper reaches of the Ok Tedi and other rivers. Overlying these strata are various limestones and other calcareous rocks. The combination of very steep slopes, high rainfall, high temperatures and soft calcareous rocks is a perfect environment for rapid chemical and physical weathering and erosion. Rock faces on cliffs weather quickly and collapse in spectacular rock falls. Some of these falls and slides contain millions of tonnes of rock and can be seen from 20 kilometres away as white gashes along mountainsides. Slumping, sliding and falling rock and soil occur daily. The whole landscape is slowly shifting down-hill.

Two forces, besides gravity generate this high energy, erosional landscape. The first is the daily, torrential rainfall which exceeds 6 000 mm annually in the mountain region of the Province. The high rates of erosion and stream load from landslides explain why the streams are extremely turbid and filled with sand, pebbles, rocks and even boulders bouncing their way down steep river profiles. Rivers are still actively cutting gorges 100 to 300 metres deep into the limestone ridges.

The second active force is the high frequency of earth tremors and earthquakes. Compared with the northern part of Papua New Guinea, the Western Province has a lower frequency of earth tremors and quakes. But in global terms, the frequency of earthquakes measuring greater than 7 on the Richter Scale is similar to the San Andreas Fault zone in California. Earthquakes and tremors regularly trigger massive rockfalls and landslides and are a major cause of erosion and consequent river turbidity.

Gold and copper deposits in the Ok Tedi area

During the Miocene period, volcanic intrusions injected a variety of molten igneous and other materials into these young, soft limestones.

Mt Fubilan, (2 084 metres) contains two intrusions which occurred about 2.5 million years ago. The larger intrusion is the ore deposit being mined by OTML and is known as the Fubilan Monzonite Porphyry. This dome structure is rounded with a diameter of about 850 metres at the top and tapers to about 600 metres diameter at the bottom. The monzonite porphyry of the intrusion consists of quartz, orthoclase, oligoclase and biotite. Subsequent intrusions injected further materials and enriched the mineral forming processes which formed chalcopyrite, bornite and gold. Beneath this concentrated gold cap, rich ores of copper (now being mined) are contained in the form of chalcopyrite and digenite minerals. This ore body, which is less than a square kilometre in area and about 800 metres deep, is the source of the wealth which is driving Ok Tedi Mining Limited.

Rainfall, drainage and stream flow

The Fly River catchment covers about 76 000 square kilometres and is the second largest river basin in Papua New Guinea. The largest river in the Fly catchment is actually the Strickland River. Both rivers rise in the central mountains of Papua New Guinea at altitudes exceeding 2 500 metres and flow southwards through precipitous valleys and gorges. Once on the plains the gradient is reduced and the streams adopt a meandering course through extensive floodplains before flowing into the Gulf of Papua through an extensive delta.

These are large rivers both in volume and length. The streams are also deep and fast flowing. The depth of the Fly at Obo averages about 12 metres which allows the passage of quite large ships. The velocity is about 2.5 kilometres per hour.

Below Obo, the Fly River sweeps across the flood plain and into an extensive delta system. This delta, covering over 7 000 square kilometres and more than 80 kilometres across the mouth, consists of three major channels and more than 15 major islands, the largest of which is Kiwai Island. The water in the channels averages about seven metres and the strongest flow at present is through the most northerly channel.

Since the Fly, the Strickland and their major tributaries rise in the central mountains where landslides and other active mass movements frequently occur, the rivers carry enormous sediment loads. The Strickland, carrying 600-700 parts per million of sediment, is visibly 'muddier' than the Fly, as it flows through areas with different soil types that are supporting more intensive agriculture. Before the Ok Tedi mine began, the Fly River carried only about 100 parts per million of sediment. Since mining began, the suspended sediment load of the Fly has risen to between 450 and 500 parts per million.

Lake Murray which lies between the Fly and Strickland Rivers is a vast off-river storage. It is an extensive lake covering an area of 647 square kilometres but with an average depth of only seven metres. Lake Murray has its own separate catchment area. For 90% of the time, water from Lake Murray discharges southwards into the Strickland River via the Herbert River. At other times, because of varying water levels, the flow is reversed and water from the Strickland flows northward into the Lake.

Despite the naturally turbid quality of both these rivers, their tributaries and adjacent floodplains usually contain very clear water. The turbid waters of the major rivers enter the floodplains and tributaries during the wet season but drain again when the river levels drop in the dry season. The floodplains, numerous ox-bow lakes, tributary streams and lakes such as Lake Murray are an important habitat for crocodiles, fish and birds.

Human geography of the Western Province

The first human settlement of the island of New Guinea occurred about 50 000 years ago during low sea levels in the Pleistocene Ice Age. As people spread east and south into the Star Mountains and the headwaters of the Ok Tedi they discovered the Fly and the Strickland Rivers and picked their way through the deeply dissected limestone and sedimentary terrain.

The soil was rocky, poorly developed and infertile. As a result, agriculture was not as important as hunting and gathering. Population densities therefore remained very low at one person per square kilometre (much less than in the more fertile highland valleys) until the last two decades, when mining stimulated immigration.

The inhospitable biophysical environment has always made life difficult for the Min people who are indigenous to the mountains of the Ok Tedi area. Traditionally, the life expectancy of the Min people was only about 28 years. Not only was the health of the people poor and their stature stunted, but also their isolation and restricted movement limited their technological development. The Min people were semi-nomadic and did not carry large numbers of objects. They did not make pottery, baskets, mats or bark cloth clothing like some other indigenous peoples. By the standards of most people on the island of New Guinea, they were less developed technologically.

There was almost no contact between the Min people and outsiders until the 1940s. During the Second World War, there was increased movement in the area as Australian soldiers and traders escaped over the mountains from the Japanese invasion along the north coast of New Guinea. Soon after the war ended, the first colonial government administration centres were established when Australian officials (Australia administered Papua and New Guinea until its independence in 1975) moved into the Telefomin area about 50 kilometres to the northeast of the Ok Tedi mining area. In 1950, a government station or office was built at Kiunga. As recently as the early 1960s, the Star Mountains were still largely unknown. The first government patrols in the area discovered copper-bearing rocks by observing minerals in the river sediments.

These finds stimulated the interest of Kennecott, a United States copper mining company. Between 1968 and 1972, geologists using helicopters explored and discovered the great copper and gold deposit at Mt Fubilan. The subsequent building of the Ok Tedi mine and the associated settlement of 10 000 people at Tabubil have completely re-organised and re-focussed the human geography of the Western Province. Tabubil is now the largest settlement in the Western Province and has become a focus for mining and other economic activities in the region.

The Western Province was until recently, a geographically peripheral area in the national life of Papua New Guinea. The Ok Tedi mine alone has changed the geography of the province and the nation because it contributes so much to the national income. The Western Province is now an essential component of the nation's economic life and Ok Tedi Mining Limited is the single most important factor in the development of that province.

The Ok Tedi Mine Operation

Exploration and discovery

The Mt Fubilan copper deposit was discovered in 1968 by geologists from the Kennecott Copper Corporation, an American company. The exploration was stimulated at the time by optimistic forecasts for world copper prices and by similar discoveries on the island of Bougainville in 1964. The Mt Fubilan ore contained from 0.2% to 4% per cent copper and 0.5 to 1.0 gram of gold per tonne. This copper and gold content was high enough for commercial development despite the very high capital cost of building the mine.

Kennecott withdrew from the project in 1975 leaving an investment gap. BHP formed an international consortium and opened negotiations with the Papua New Guinea Government. Together, they formed Ok Tedi Mining Ltd (OTML). Today there is a third shareholder, the Canadian company Inmet which became a shareholder in 1993.

Construction of the mine and support facilities

The structure of the orebody determined how the mine was built and the ore extracted. Mining began at the top of the orebody where the gold grades were highest, then progressed down into the lower gold grades and the rich copper ore. Over time, the deeper and lower grade copper ore will be mined.

In 1981, construction of the mine site began at Mt Fubilan together with the development of the towns of Tabubil and Kiunga. Roads and a slurry pipeline from the mine to Kiunga were also started. A small hydro-electric power station was constructed on the nearby Ok Menga in 1985-6, utilising the high velocity stream flow. The construction of these facilities was very expensive because of the great engineering obstacles. Mt Fubilan was a difficult and precipitous site 2,200 metres a.s.l. and 20 kilometres from the only flat site where the mining town of Tabubil could be established.

A port was constructed at Kiunga and all the mining equipment was barged 840 kilometres up from the mouth of the Fly River. A road was then built from Kiunga to Tabubil and on to Mt Fubilan - a distance of 156 kilometres and 1,500 metres higher up the mountains. During a drought in 1982 when the Fly River was too low to allow barges to carry construction materials up the river, Hercules aircraft flew in materials from Madang on the north coast of Papua New Guinea.

In 1983, prior to the commencement of gold production, a major tailings dam was designed and construction began on the Ok Ma about 15 kilometres to the south of the mine. It was planned that the tailings would be piped through a tunnel into this dam and that after the solid particles had settled, the clean water would flow down the Ok Ma and into the Ok Tedi and Fly River.

During the early stages of construction in December 1983 and again in January 1984, the area was subjected to heavy rain. Landslide activity totally destroyed the dam site and the project was subsequently abandoned. \$A65 million of investment in the construction of the dam was lost. This event indicated that any tailings dam constructed in the area would run the risk of being destroyed by a further landslide or earthquake. This would send a wave of concentrated tailings surging down the river system.

The search began for an alternative site while OTML negotiated with the Government for permission to commence mining and to deposit the tailings directly into the Ok Tedi and its tributaries.

Between 1984 and 1988 the rich upper deposits of the ore body were mined exclusively for gold. A gold extraction and treatment plant used cyanide to extract the gold and hydrogen peroxide was used to neutralise the cyanide in the tailings. The coarse tailings were stored in a small dam beside the mine, while the fine tailings were discharged into the river. It was expected that the large volumes of water in the rivers would quickly dilute the tailings and minimise any significant adverse effects.

Mine tailings are the remains of crushed and ground ore which remain after most of the metal bearing mineral has been removed. Tailings usually contain some un-extracted metals such as gold and copper (in the case of the Mt Fubilan ores) and some of the chemicals used to extract the metal. Tailings consist of fine rock-powder, silt and a lot of water. Liquid mine tailings are usually stored in a tailings dam so that the sediments can settle. Once the solids settle, the water becomes clearer and cleaner. Where mining is conducted in wetter parts of Australia, such as Tasmania, this process can be assisted by circulating the water through artificial wetland areas to encourage the further absorption of any soluble metals by the wetland vegetation. Surplus water is tested to ensure its compliance with regulatory standards and then can be released into the natural drainage system.

In the drier climates of Australia, the water in a tailings dam can be recycled and can also evaporate, leaving the tailings as a solid sediment on the dam floor. When the operation finishes, this sediment is covered with topsoil and revegetated. While usual practice in Australia, this is impossible at Ok Tedi, because of the very high rainfall and low evaporation.

In 1988, as the gold cap was exhausted and gold extraction was phased out, the use of cyanide ceased. Copper mining and processing began and the volume of rock and ore passing through the plant increased greatly. The open cut pit was enlarged and deepened. The processing plant on the ridge top was expanded to include three stages of copper processing; a rock crusher, a copper extractor and a slurry plant.

Since the mine and its processing facilities are perched on a precipitous spur of Mt Fubilan, engineers had to decide what to do with the overburden and the rock waste from the pit. The solutions to these engineering problems can be seen in the way in which the mine operates today. Under normal mining practice, these materials would be stored in an adjacent rock dump, stabilised and then revegetated. In some cases they are used later to fill in parts of an open cut pit. However, the rock mined at Ok Tedi is extremely weathered and weak and stable rock dumps cannot be constructed. Also, since the Ok Tedi mine occupies almost the entire summit of Mt Fublian there is no storage space and the waste rock is pushed over the edge of the mountain. This rock erodes and finds its way into the Ok Tedi, as does rock from other natural landslides in the area.

Operation of the mine

The mining, treatment and transportation of the copper ore passes through the following stages.

1. The ore body is drilled and blasted to loosen the ore for mining.
2. The ore is mined in an open cut process with giant electric shovels each of which has a 50 tonne ore capacity.
3. Trucks carry loads of 150 to 190 tonnes of ore to a crusher in the pit.
4. A conveyor carries ore from the primary crusher to the concentrator crushing treatment plant where the ore is further crushed by steel balls rolling around in rotating drums.
5. The flotation plant separates the copper and gold minerals from the ore. Each day, 80 000 tonnes of mined and crushed rock is processed into 1 600 tonnes of dry copper concentrate using the flotation technique. 85% of all the copper mineral in the ore is extracted while 70% of all the gold is extracted.

The flotation process was invented in Australia last century and is similar to the way in which suds operate to extract 'dirt' in domestic clothes washing machines. A chemical frother is added to the water and bubbles are created. They float to the surface carrying the fine grains of mineral and leaving behind the crushed rock. The ore concentrate is collected from the bubbles at the top.

6. The concentrate is mixed with water and thickened into a slurry which is 40% water and 60% solids or fine particles (a fine particle is less than 150 microns).
7. The slurry flows by gravity in a 156-kilometre 900mm pipeline from the top of Mt Fubilan to Kiunga. This is a drop of about 1 600 metres. A pump speeds up the slurry flow where it reaches gentle gradients on the plain.
8. At Kiunga, the water is removed from the slurry and settled for re-cycling. The moist concentrate is then dried in filters and in an oil-fired rotary drier until the moisture content is reduced to about 9%. The concentrate at this stage is a very fine, dark-grey powder which is stockpiled under cover beside the river wharf at Kiunga before being barged down the Fly.
9. Copper concentrate is transported 800 kilometres down the Fly River to Umuda in 2 500 tonne capacity, flat-bottomed vessels. This trip takes two days. The barges travel day and night using radar and spotlights to navigate the wide, meandering river.
10. The concentrate is transferred into the Karabi Floating Silo Vessel Terminal off Umuda Island in the Fly River delta. This is a floating storage container which can hold 50 000 tonnes of concentrate.

From here the concentrate is loaded onto ocean vessels for shipment overseas. About 50 000 tonnes is shipped to overseas markets each month. Concentrate is exported to Japan, Germany, Korea, Finland, the Philippines and other places where copper refineries are located. From the 1 600 tonnes of concentrate processed each day at Ok Tedi, comes 560 tonnes of copper and 20 kilograms of gold.

The principal value of the mine comes from copper. The first copper was mined in 1987 and totalled only 39 488 tonnes. By 1995, this had risen to 212 737 tonnes. Between 1987 and 1994, more than 1.2 million tonnes of copper was produced from the Ok Tedi mine. It is estimated that there are still more than 400 million tonnes of ore which is enough for the mine to operate until about the year 2010.

Development costs

The building of the support facilities for the mine - such as roads, airports, community services and shops - has been a major expense, of approximately \$250m as indicated in the table below.

Facility Cost	
Township of Tabubil	\$80m
Electricity generation plants	\$110m
Port of Kiunga	\$9m
Houses and offices for government officials	\$8m
Kiunga to Tabubil road	\$43m

Table 3: Development Costs - Ok Tedi. Data source: Ok Tedi Mining Limited

Employment

The OTML operations in the Western Province employ 1 900 people together with a similar number of people in contract and other support functions. Most of these people live in Tabubil, while some employees live and work in Kiunga. 90% of the employees are from PNG.

The heart of the mining operations is on Mt Fubilan where the open pit and all the processing plants operate three shifts every day. Buses transport workers between Tabubil and the mine. There is a canteen on site providing a variety of free meals. Since the rainfall on Mt Fubilan averages approximately 1 000 millimetres annually and it rains nearly every day, the work site is awash with mud and clouded in for days at a time. It is a dangerous working environment. The plant at Kiunga on the other hand, sits on a hot, undulating plain surrounded by rainforest beside the sluggish, brown Fly River. Tabubil

The town of Tabubil is located on one of the few areas of level land in the mountain area of the Western province. Tabubil has a resident population of about 10 000 people. The town is a company-designed and operated enterprise although residence is not restricted to company employees. Some local Min people, together with migrants from other areas in Papua New Guinea, have moved into squatter settlements along the eastern edge of the town.

The main functions of Tabubil serve the mine workers and the operation of the mine. A large area is occupied by workshops, store yards, truck and vehicle depots. Company offices dot the central part of the town. A commercial centre includes two banks, two supermarkets, a hardware store, travel agent and fast food outlets. Locally owned companies have been established with the assistance and advice of OTML. Min people own and operate some of these businesses, such as a fast food shop 'Gobble and Go' and the only hotel, which is appropriately named 'Cloudlands'.

The people who live and work in Tabubil enjoy a high standard of living. All the roads in the town are sealed. A 56-megawatt hydroelectric power station generates 80% of the electricity both for the town and the mining and processing operations on Mt Fubilan. Additional power at Tabubil is provided by a diesel powered station and another small hydroelectric station.

The company provides houses for all employees and rental accommodation for public servants and other workers not employed by OTML. It also provides community services such as schools, meeting halls, sports facilities and a cable network television service which cables Australian, American, Malaysian, French, Hong Kong, Indonesian and Philippines television programs into all houses.

The main problem faced by residents in Tabubil is the isolation. Apart from the road up to the mine, there is only one road into the township and that is from Kiunga. Transport to the town is by air for most people and by river for cargo. It takes seven days by river upstream from the mouth of the Fly River to Kiunga and a further three hours by road to Tabubil. The town is serviced by small to moderate sized aircraft. OTML owns a 36 passenger Dash 8 and a smaller seven seater King Air. There are daily flights to Port Moresby which is 800 kilometres to the southeast. The flight takes two hours. Nearly all goods such as food, clothing, vehicles, petrol and building materials are shipped to Kiunga by barge from Port Moresby and Townsville in northern Australia. The town feels isolated.

Nevertheless, many people and their families find it an attractive, peaceful and safe place in which to live. High wages and good living conditions reduce the turnover of workers. Papua New Guinean citizens prefer to bring up children in this safe oasis than return to the housing shortages and public crime and disorder of Port Moresby, Lae or Mt Hagen. There are strongly felt benefits about living in Tabubil.

The Ok Tedi mining operation is an enclave. The mine and its support functions in Tabubil and Kiunga are high cost, high technology activities. While 90% of the workforce are Papua New Guineans, the operation attracts workers from all over the world. The town and mine are surrounded by rainforest and soaring mountains. Despite the enterprise of some local people who grow fresh vegetables for sale in Tabubil, the townspeople have little or no connection with the surrounding subsistence economy. They rely instead on far-away places for food, for clothes, for entertainment, for everything. Tabubil is a cultural, economic and social island. When the ore runs out and the mine shuts down, Tabubil too will probably shut down and the forest will grow back and conceal everything which has been built during the last thirty years. That is the nature of mines and mining settlements

The Environmental Consequences of the Ok Tedi Mine Operation

The mining and processing of copper and gold at the Ok Tedi mine have affected specific elements of the natural environment especially the lithosphere, the hydrosphere and the biosphere. The mining and processing of ores at Mt Fubilan have, in one sense, hastened the natural processes of weathering and erosion on the mountain and the consequent sedimentation of streams. However, the increased volumes of sediments and metals have environmental consequences which vary in impact along the profile of the Ok Tedi and the Fly River.

Since these rivers now carry the tailings and rock waste from the Ok Tedi mine, the nature and behaviour of the rivers determine the main environmental consequences of the mining operation. The greatest impacts of the mine are in the rivers closest to Mt Fubilan and the impacts diminish with distance from the mine.

Mining and the environment

The very nature of mining leads to an intensive and concentrated modification of the lithosphere, especially of those rocks and minerals which are useful to humans. The overburden or surface soil and natural vegetation covering the ore body are usually removed in order to expose the valuable resources, especially in open-cut mining.

Excavating quantities of soil, rock and minerals also affects the hydrosphere. Mining processes often require large volumes of water. Rivers may be diverted to supply enough water for processing the ore.

The atmosphere is sometimes affected when dust from the mine site, or gas fumes and steam from the processing plant, are released into the air. The processing of rock and ore removes the valuable elements and leaves behind large quantities of broken and crushed rock.

This residue has to be stored, deposited or recycled in ways which cause as little damage as possible to the biophysical and human environment.

In short, mining can have severe consequences not only at the mine site but also wherever air and water carry pollutants from the mine site.

Mining engineers and managers at Ok Tedi face some significant and complex challenges. The major ones are the disposal of the waste rock material (no commercial value) and the tailings, in such a difficult climate and environment. Chemical residues used to extract the mineral from the ore are by comparison, a minor concern.

Outputs of the Ok Tedi mine

The Ok Tedi mine produces an average of 600 000 tonnes of mineral concentrate per year. This contains 207 000 tonnes of copper, over 486 000 ounces of gold and 970 000 ounces of silver.

The mine also produces two by-products, tailings and waste rock. The 80 000 tonnes of tailings produced daily also contain quantities of valuable metals because the flotation process is able to extract only about 85% of the copper minerals and 70% of the gold.

The mining process has sped up the process of feeding rock into the river system in volumes large enough to significantly increase the sediment content of the rivers close to the mine.

Each day, about 125 000 tonnes of waste rock are dumped and slide into the river system. The increased quantities of metals and sediments have consequences for the downstream rivers and the life which they support.

Ok Tedi and the environment

The Ok Tedi mine operates in an extremely difficult natural environment. This has limited the options for the management and disposal of waste rock and mill tailings from the operation. Since a tailings dam has not been constructed, the major environmental consequence of the mining operation is that the Ok Tedi downstream from the mine is now a mixing zone in which mine output joins directly with the existing water and sediment of the rivers. The Government and OTML agreed that significant consequences for the environment were inevitable because there could be no tailings dam. Some form of compensation and assistance had to be provided for the people who lived along this stretch of the river.

Fortunately, few people live in the upper reaches of this section of the Ok Tedi which flows in a deep valley. Most villages in the Ok Tedi area are sited on ridge tops far from rivers. This is the customary site for traditional settlements in upland Papua New Guinea. As the river emerges into a wider valley at Ningerum, the number of riverside villages increases and the people in such villages as Iogi and Ieran justifiably claim to have been affected by changes in water quality and stream flow. The conflicts about water quality and environmental consequences are thus geographically focussed on the stretch of the Ok Tedi between Ningerum and the Fly confluence.

While the environmental damage in the Ok Tedi is observable, changes further downstream are not so obvious.

Consequences of the Ok Tedi mine for the hydrosphere.

The two main effects on the water quality of the river system are the increased sediment and copper levels. Before mining commenced, the Ok Tedi at Tabubil carried less than 0.5 million tonnes of sediment each year. The river now carries up to 100 times more material. Not all of this can be supported in suspension and a substantial amount is deposited on the riverbed upstream from the confluence with the Fly River as the slope of the river decreases. Very little copper is dissolved from the solid particles because the river water is alkaline from the limestone terrain.

In the delta, the Fly River carries about 88 million tonnes of natural sediments and approximately 25 million tonnes of sediments which originate from the mine. The small proportion of copper which dissolves from the sediments is potentially biologically available to fish and other organisms. However, to date there is no evidence that these levels are toxic. Dissolved copper levels throughout the Ok Tedi and Fly River system rarely exceed 0.02 mg/L. While greater than earlier predictions on which the Government environmental criteria are based, they are well within international standards. The copper content of the suspended sediments throughout the river system down to the Strickland confluence averages 0.12% in line with their origin from mine tailings. The background level of copper in sediments is 0.006%. There is no evidence of copper levels higher than this in sediments collected in the middle of the Fly River delta, the Gulf of Papua or Torres Strait.

Consequences of mining for the lithosphere

The sediment load in the river system has been increased because of the Ok Tedi mine output. The rivers act as a sorting process. Coarse particles such as boulders, rocks, stones and gravel are deposited in the upper reaches of the Ok Tedi. Finer particles are transported downstream as suspended sand, silt and clay as far as the Fly River delta and the Gulf of Papua.

There are four specific changes to the lithosphere along the river. The most spectacular changes in the river system have occurred in the Ok Mani and the upper Ok Tedi. The great quantities of rock waste have filled the valley by up to 60-70 metres in places and widened the valley floors. The base levels of the valleys are now higher than previously. The forest floor along the banks has been buried by the rising level of rock, gravel and sand.

Near the village of Iogi in the lower Ok Tedi, the reduced river gradient slows the velocity of the stream and sedimentation rates increase. The heavier gravel sediments are deposited, leaving the smaller particles in suspension. The increased sediments in the river channel cause more frequent flooding and longer periods of inundation of the adjoining forest. Floods carry the sediments over the banks depositing them through the riverside rainforest to a depth of up to one metre. As a result, forest dieback has affected an area of approximately 30 square kilometres beside the river near this village. Most of the area affected is on the inside of meanders.

In a few places, sandbanks have formed across the entrance of tributaries of the Ok Tedi. This has caused tributaries and their clear waters to dam up and to be contaminated periodically when sediments from the Ok Tedi flood over the sandbank into the tributary during floods.

The process of overbank flow and sediment deposition which occurs in the Ok Tedi floodplain also occurs in the Fly River floodplain, but to a much lesser extent. The expected but very small change in the frequency of flooding and the very low rates of deposition overall are not likely to result in a similar spread of forest dieback observed on the Ok Tedi floodplain.

The greatest flux of water and sediment into the Gulf of Papua is through the northern channel of the delta. Mining has had an effect on the delta. About 50% of the finer sediments remain in the tidal delta where there is much mixing of marine and fluvial water. Sediments remain suspended for extended periods (perhaps up to 18 months) within the delta because the rate of flow in the different stream channels varies. A possible concern is that increased sediment and copper concentrations might contaminate the northern end of the Great Barrier Reef. Sampling of edible organisms in the waters around the Torres Strait islands show that while copper levels are not higher than anywhere else along the Great Barrier Reef, cadmium, arsenic and selenium occur at levels close to the maximum allowed in seafood by the Australian National Health and Medical Research Council.

Changes in the water quality of the Fly River have influenced the river ecosystem. The effects on river fauna and vegetation in particular have had consequences for the people who depend on these natural resources.

Although the aquatic fauna of the Fly River system are very tolerant of high sediment loads, the additional levels in the Ok Tedi have now filled in important habitats. Fish hatches in the Ok Tedi have been greatly reduced and some species previously recorded are no longer found there. It is possible that some fish species avoid the smell of copper in the Ok Tedi by remaining in the floodplain swamps and tributary streams.

In the middle Fly River, downstream from the Ok Tedi, fish numbers have declined but the diversity remains. There are many reasons that could be contributing to this:

- The effects of the mine.
- The increase in commercial fishing.
- The increased use of nets by village people living along the river.
- The increase in netting of juvenile barramundi along the coastline west of Daru as they migrate towards the Fly River delta after spawning.

The main area of vegetation die back on the lower Ok Tedi is found between Komokpin and D'Albertis Junction. Plant stress and possible eventual death occur where the surface sediments are water logged and there is reduced oxygen concentrations in the root zone. This results from more frequent flooding, prolonged inundation caused by the higher bed of the main river channel and the deposition of sediments around the base of the plants.

The visible extent of stress varies from early yellowing of the leaves to leaf loss. After leaf loss, some plants can generate roots in the new deposits and then regenerate their leaves. Those trees that cannot regrow their leaves eventually die.

Seeds can germinate on newly deposited sediments, from seeds and vegetative parts carried downstream and deposited by the river and floods. However the rate and progress of the colonisation of the affected areas is slowed by:

- The low nutrient level of deposited mine sediments.
- The damage caused by erosion and scouring during flooding.
- Continued sedimentation which buries new seedlings and older plants.

Areas where the new soil surface is high enough to avoid frequent flooding can re-establish typical forest gap plant cover in two to three years.

Environmental management and monitoring

Since there was almost no scientific data about the ecology and environment of the Fly River catchment until OTML began operations, the company has been required to establish a data collecting and environmental monitoring system under the Mining (Ok Tedi Agreement) Act 1976. As a result, the company monitors:

- Levels of suspended sediments in the Fly River.
- Fish resources.
- Off-river water resources in tributaries, floodplains and lakes.
- Biological resources and copper levels in the delta and Gulf to ensure that copper levels do not exceed predicted levels.
- Aggradation in the Fly River so that it remains deep enough for navigation.

OTML spends more than \$5 million annually on these and other monitoring programs. This work is done regularly, with weekly and annual reports prepared. The annual report provides information on the aspects of the environment required by the Government under the Act of Parliament and is reviewed by consultants working for the Department and by independent consultants engaged by the Government. The annual report is a public document obtainable from the Department of Mines and Petroleum in Port Moresby.

Participants in the Ok Tedi Operation

The operation of the mine is a complex matter and involves many groups of people - namely the mining company, the Papua New Guinea Government and mine employees. In turn, the mine has influenced the traditional landowners, the banks and shareholders and provincial and local governments.

Major interest groups connected with the Ok Tedi mining operation

Ok Tedi Mining Limited (OTML)
International business community
Ok Tedi employees
Non Government organisations especially environment groups
Indigenous people downstream from the mine
Indigenous people in mine area
Papua New Guinea Governments
OTML shareholders

Ok Tedi Mining Limited and the shareholders

The main shareholders in OTML are:

- The Broken Hill Proprietary Company Limited which owns 52%.
- The Government of Papua New Guinea which owns 30%.
- Inmet Mining Corporation of Canada which owns 18%.

Shareholders expect profits on the investments they make in an enterprise and a mine is primarily a profit-making enterprise. So far \$1 400 billion has been invested in OTML, but until 1991 there were no dividends on that investment. OTML's profitability has not been easily achieved and it cannot be said that OTML is a highly profitable enterprise.

While all shareholders expect a financial benefit more than anything else, the Government of Papua New Guinea is also interested in how OTML can assist in the development of the country.

Minerals and petroleum which lie underground are owned by the state, whereas forest and other resources above-ground are owned by the clan. This difference between location of the resource leads to great legal complexities and disputes. Often clan leaders incorrectly believe that because they own the land, they also own the underground resource.

There are numerous and frequent public disputes about land ownership and resource use in Papua New Guinea. Most disputes are between clans, between clans and the government or clans and companies. Clans frequently blockade a road or blow up a bridge on a major highway in order to publicise their grievances, causing inconvenience to citizens and government authorities.

There are two groups of landowners interested in the Ok Tedi mine. The first group are the landowners in the Ok Tedi mine area and the second are the landowners living further downstream from the mine along the banks of the Ok Tedi and the Fly River.

Upstream landowners

These are the Min clans and landowners on whose land the Ok Tedi mine, the town of Tabubil and the adjacent services have been constructed. There are about 2 500 people in this group. These people have a great interest in OTML because their traditional amenities of water, soil, forest and wildlife have been altered and even destroyed. Where formerly there was rainforest and the small village of Wangbin, there are now 10 000 people living in the town of Tabubil, with a mine nearby on the top of Mt Fubilan.

These people receive lease and royalty payments under the Conditions of a Special Mining Lease. Royalties are paid at the rate of 2% of gross revenue of OTML. 70% of the royalty is paid to the Papua New Guinea and Western Province Government and 30% is paid directly to the landowners. The payments to the landowners are allocated according to their proximity to the mine. The two villages on Mt Fubilan receive 25% and the villages more distant from the mine receive the remaining 5% between them. In 1994, about \$4.5 million was paid to the Papua New Guinea Government and \$1.8 million was paid directly to the landowners.

In addition to royalties, there are compensation payments made for specific purposes such as roads, access to sites and use of local resources. In 1994, these payments totalled nearly \$1 million. Min people also take up offers made by OTML for employment, education and training.

Downstream landowners

The Awin, Ningerum, Yonggom people and some other linguistic groups live further downstream along the Ok Tedi and Fly River. As the Western Province is the poorest and one of the least developed of the provinces in Papua New Guinea, the Government sees the presence of the mine and the wealth it generates, as an opportunity to develop these communities who live along the river. However, a critical issue has arisen as to whether only those people who live alongside the river should be paid compensation or whether those who live further away from the river should also be compensated.

The Lower Ok Tedi-Fly River Development Trust

This was established in 1990, after OTML realised that not all the royalties paid to governments were reaching village people. Downstream residents living along the course of the river were not benefiting from the wealth being generated up-stream and were not receiving adequate compensation for changes and damage to their habitat. The Trust funds began with a grant from OTML of nearly \$2.5 million and in 1995 had increased to just over \$3 million annually. The Trust area now covers 107 villages extending from Ningerum on the lower Ok Tedi to the islands in the delta. The Trust Board includes representatives of the Papua New Guinea and Western Province Governments as well as OTML and villagers.

The aim of the Trust is to make direct payments to villages for infrastructure and business developments. Until now there has been no money for compensation. The Trust's emphasis has been on family and community development to assist all river people to improve their standards of living. In the period 1990-94, the Trust paid for and supplied many things to communities including:

- 363 water tanks (holding 6 000 gallons)
- 314 small halls and meeting centres
- 15 first aid posts

- 25 classrooms
- 21 shower blocks
- 70 solar pumps
- 19 solar street lights
- 6 tractors (often needed to mow airstrips).

The Trust is also engaged in more sophisticated community projects to develop income earning businesses for local people. One of the most successful investments is the construction of a rubber processing plant at Kiunga and the encouragement given to local farmers to grow rubber as a cash crop. Another community development enterprise and long term investment is commercial fishing. The Trust has constructed and installed freezer storage plants in the villages of Obo and Bosset. As the local people catch river fish (mainly barramundi and black bass), they are frozen, stored and sold mainly to catering and food outlets in Tabubil.

OTML recognises that downstream villagers also suffer specific losses as a result of company activities. Company river boats and barges create waves and washes in the Fly River and traditional hollow-log canoes are easily swamped and sunk. Canoe owners who suffer a loss are entitled to compensation. Many villages are located along the Tabubil-Kiunga road and despite the fact that trucks are limited to speeds of 60kph, wandering domestic pigs and dogs are often killed along the road. While these losses are often difficult to substantiate, each village has a compensation committee to evaluate claims. Where a loss is proven, a villager receives an average compensation of \$200 for the loss of a pig (pigs are major forms of capital accumulation in the culture) and \$20 for a dog. The total cost of these specific compensation payments in 1994 was \$1.7 million.

The whole issue of payments to downstream dwellers is complicated because the arrangements which prevailed between 1990 and 1995 have been re-negotiated and re-written into legislation passed in late 1995 as the Mining (Ok Tedi Restated Eighth Supplemental Agreement) Act 1995. This legislation is an attempt to regulate the compensation claims and to define the liability of the Company. It is also designed to protect the rights of villagers to take the Company to court.

Essentially the Act offers individual clans a choice. They can automatically participate in the compensation system established under the Act or, if they prefer, negotiate with OTML for compensation. If those negotiations are unsuccessful either party can go to the Mining Warden - an independent person who acts in a judicial capacity to resolve disputes arising under PNG's mining legislation. If necessary, the negotiations can go further to the National Court for a determination.

Regardless of the decision the clans make, it will not affect people's continuing rights to claim specific compensation for garden, livestock and other damage as outlined above, and to receive benefits from the Lower Ok Tedi-Fly River Development Trust.

The system under the Act is funded by an initial payment of K14 million from OTML to the Western Province General Compensation Trust, and annual payments thereafter of not less than K4 million. The allocation of these funds to clans will be made by the board of directors of the trustee, which will comprise representatives of the National Government, OTML and the local landowners. National, Provincial and Local Government

The National Government is a 30% shareholder in OTML and has responsibility for making laws about taxes, investment, the environment, mining and local government. The National Government has to balance its need to earn income from its investment against its constitutional and sovereign responsibility to serve its citizens through passing, implementing and enforcing laws.

The Government has responsibilities to all its citizens as well as those in the Western Province connected with OTML operations. Some of the legislation through which the government manages mining and other companies includes:

- The Mining (Ok Tedi) Act 1976.
- Environmental Planning Act 1978.
- Environmental Contaminants Act 1978.
- Water Resources Act 1982.
- Mining Act 1992.

There are arguments for and against this type of government involvement. There are four main arguments against the Government owning shares in a mining company:

- Government funds are tied up in a business operation which could be used for other more beneficial purposes such as building schools.
- The government exposes itself to a commercial risk and may in fact lose its investment as in the Bougainville copper mine in which the government owned 20%.
- Public servants should spend their time and ability running the country not supervising private companies.
- The Government's role of regulating company activities and its effects on the environment could be compromised.

However, there are three arguments in favour of the Government owning shares in a mining company:

1. Being a member of the Board of Directors is a useful way for the Government to know about the inner workings of mining companies operating in the country so that it can influence the decisions on matters affecting Papua New Guinea citizens and the Government.
2. If the company is profitable, the Government earns income on its investment on behalf of its citizens.

The Government is seen to be involved in mining and resource development on behalf of its citizens and is not leaving investment only to foreign interests.

The National Government also benefits significantly by receiving the following incomes from the operations of OTML.

These are 1994 figures:

- Mine equipment import charges of \$5.4m.
- Dividends from its shares in the company of \$6.5m.
- Employee income tax of \$7.2m.
- Royalties of \$6.6m (of which \$4.7m went to the Western Province Government and \$1.9m went to landowners).
- Export income of \$536m which is 20% of Papua New Guinea's total exports.
- User fees for the Kiunga-Tabubil road of \$10.3m.

However the benefits are not just financial. The National Government sees OTML as a mining company and also as a major agent of development in the widest sense. The Government welcomes the contribution of OTML to employment, education and training, infrastructure development and community development in an area where all these are practically absent. For this reason, the Government allows companies in Papua New Guinea to deduct from their tax bill the cost of building facilities such as roads, which benefit the wider community. The Government expects companies to assist development efforts and rewards them financially for doing so.

Since OTML builds roads, operates transport systems, generates electricity and administers many things which governments normally do, the company in effect is a de facto administration in the Province. While this may cause some misgivings by public servants who work in the Province, they nevertheless depend on the Company to assist their work by providing offices, transport, communications and health and educational facilities.

Employees

One of the best ways in which a company can assist the development of an under-developed region is to provide employment. OTML employs the largest number of people in the Western Province. The table shows the numbers of OTML employees at Ok Tedi and Kiunga according to their geographical origins.

Employee by origin	Number	%
Local people from the Ok Tedi area in the Western Province	191	10
People from the Ok Tedi area but who have been living outside the Western Province	366	19
People from outside the Ok Tedi area in the Western Province	46	2
Papua New Guineans from outside the Western Province	1 133	59
Expatriates	192	10
Total	1 928	100

Table 4: The OTML workforce, 1994. Data source: Ok Tedi Mining Limited

The table shows that 90% of OTML employees are Papua New Guineans with 29% of all employees coming from the immediate area of the mine. In short, a very significant number of workers are local Min people. The employment of Papua New Guineans has been steadily increasing as training programs bring more local people into the workforce.

In 1985, there were 1 111 Papua New Guineans in the workforce. In 1994, the number had risen to 1 736 or 90%. As more are trained, more are employed. In 1994, nearly \$1.1 million were spent on education and training.

Non-Government Organisations

Non Government Organisations (NGOs) include a wide range of groups both in Papua New Guinea and overseas who take an interest in OTML and attempt to influence certain aspects of its operation. NGOs include environmental groups, churches, trade unions and development agencies.

The Melanesian Environment Foundation for Pastoral and Socio-Economic Service is a Christian organisation in Goroka which researches contemporary issues about Papua New Guinea. It maintains a close link with the New Guinea Council of Churches. In 1991, the Institute published a study called Development and Environment about environmental issues in Papua New Guinea. This study led to an international conference in Starnberg, Germany, under the sponsorship of the Evangelical Lutheran Church and Catholic Church of Bavaria. The Starnberg Report examined a range of issues including operation of the Ok Tedi mine. The German interest in Ok Tedi was a direct one since, at that time, three German companies owned 20% of the OTML shares.

In a Foreword to the collection of papers presented at the Starnberg Conference, the Institute report stated:

Since the end of the Second World War industrial economic activity has been sought and generated on an unparalleled scale. Ever greater output and productivity have been the dominant policy objectives of all industrial and newly industrialised countries for the past 50 years. The cost of this kind of development has been and is being paid in widespread social and cultural disruption and potentially catastrophic effects on the global environment; not least also in countries with a raw material export economy, like Papua New Guinea but also other countries in the Asia-Pacific region.

The Institute questions the value of some types of development occurring in Papua New Guinea and the social and environmental consequences of large scale and rapid development especially by mining companies.

The second NGO is the Australian Conservation Foundation (ACF) which is based in Melbourne. The ACF is a prominent Australian environmental research and publicity group. Its interest in, and concern about, the Ok Tedi mine is based on four broad policies:

- Supporting indigenous people to maintain their cultural identity and determine their own development paths within the framework of ecologically sustainable development (ESD). The ACF publicises how resource developments such as mining threatens traditional lifestyles in the Pacific, Southeast Asia and on the island of New Guinea.
- Promoting ecologically sustainable development for Australian companies operating overseas. The ACF wants Australian standards to apply to Australian companies in their overseas operations and advocates legally enforceable standards which should apply to these companies.
- Supporting the United Nations and its Committee for Environment and Development.
- Promoting a global agenda for countries to recognise international environment impacts and the role of non-government organisations in working for sustainable development.

The ACF has criticised the environmental and social impacts of the Ok Tedi mine operation because OTML is a part-owned Australian mining company developing natural resources and because the mine has an impact on indigenous people.

Building and operating a mine may seem a straightforward thing to do. However, this outline of interest groups shows that many different people are drawn into mining operations and issues. There are many other groups not discussed above who have displayed a public interest in the operations of the Ok Tedi mine. These include AusAID (the Australian Government organisation for distributing aid overseas), the Australian Government, the Papua New Guinea Parliament and the Australian media.

Glossary

ACF: Australian Conservation Foundation.

Aggradation: The process in which water, ice and wind deposit materials such as sand and rocks and build up the level of the earth's surface.

Alluvial gold: Gold which has been weathered and eroded from solid rock and washed down a stream and deposited by water in sediments.

Anaemia: Medical condition in which the blood has a reduced level of red cells and the body is less immune to disease.

A.s.l.: Above sea level.

Biosphere: The component of the earth consisting of living things especially, plants, animals and humans.

Bornite: A copper ore mineral found in hydrothermal formations often called peacock ore because of its iridescent colours when tarnished.

Cainozoic: The geological era which lasted from 65 million to 18,000 years ago.

Calcareous: A rock type which is high in calcium carbonate. Limestone rocks are calcareous.

Chalcopyrite: The main type of copper ore. It occurs in hydrothermal veins.

Clan: A group of people who share the same language, religious, ancestral, locational and other characteristics. Usually a numerically small group of people.

Commodity price: The price of major raw materials such as copper, oil, wheat, wool, iron ore, rubber and other goods used in manufacturing.

Concentrate: A liquid or a powder which has a very high content of the metal or mineral and in which most of the impurities have been removed.

Cumec: Cubic metres (of water) per second.

De facto: The actual rather than the legal owner or operator.

Die-back: The slow withering and dying of foliage on a plant. The plant may not die completely but most of the foliage disappears.

Digenite: Copper sulphide mineral.

Enclave economy: An economic activity such as a mine which is isolated from the adjacent area and linked directly with an overseas economy.

Expatriate: A person who lives and works in a country for a limited time but is not a citizen of that country.

Flotation: A process for extracting a mineral from an ore by attaching the crushed mineral to bubbles which float to the surface of the solution.

Fly-in, Fly-out: A system whereby workers do not live permanently at an isolated mine site. Instead they fly in to work usually for two weeks before returning home for a week's leave.

Hydrosphere: The water component of the earth. It includes ice, snow, rain, rivers and the seas.

Hydrothermal: A process in which water is heated to very high temperatures by an igneous intrusion. The water changes the rocks and may dissolve and dilute the minerals changing their form and location around the igneous intrusion.

Joint venture: A business activity by two or more partners, one of whom is local and one of whom comes from overseas.

Karst: Limestone landforms in which water percolates through the soluble limestone to form underground rivers and caves.

Kina: Currency unit in Papua New Guinea valued at approximately \$A1.00.

Lithosphere: The outermost rock layer of the earth including the soil.

Mesozoic: The geological era which extends from 251 to 65 million years ago. This is the era in which the dinosaurs lived.

Molybdenum: A silver-grey mineral found in quartz and other igneous veins which

have cooled from high temperatures. Since it has a very high melting point, it is used to harden steel alloys.

Monzonite: A coarse-grained igneous rock.

NGO: Non-Government Organisation.

Ok: The word for river in the Min dialect.

Oligoclase: A type of feldspar which is an important rock-forming silicate mineral and often associated with igneous and metamorphic rocks.

Open cut: A surface excavation in the earth from the which ore is mined.

Orthoclase: A type of feldspar which is an important rock-forming silicate mineral and often associated with igneous and metamorphic rocks.

OTML: Ok Tedi Mining Limited.

Ounce: Imperial measurement of the weight of precious metals. One ounce (oz) equals 28.3 grams.

Overburden: Soil and rock on the surface of the earth which covers valuable minerals and rocks. In an open cut operation, the overburden is removed before mining the ore in the rock underneath.

Ox-bow lake: A lake which forms in a bend of a river. The lake silts up at both ends when the river changes course.

Particulates Matter in tiny solid forms suspended in a liquid.

Peripheral: On the edge of, away from the centre. The opposite is core.

Pit: A large hole or open cut from which rock and ore are dug for processing.

Porphyry: A description applied to igneous rocks which have large crystals set into a fine groundmass. These rocks are often mineralised.

Quartz: One of the major rock forming minerals. It is often found as veins associated with intrusions or metamorphic rocks and can contain valuable minerals such as gold.

Reagent: A chemical mixture like washing powder which separates and extracts the metals and minerals from the unwanted elements in the ore.

Royalty: A payment of money to an owner for the use of a product, service, information or idea.

Sago: A palm tree which grows in tropical swamps. The pith is extracted from the trunk and processed into a staple, carbohydrate food.

Slurry: A liquid mixed with concentrate so that it can be pumped long distances in a pipeline. This is a faster, cheaper and safer method of moving concentrate than using trucks.

Subsistence An economy in which people produce all their own food, clothing, housing and economy: other daily needs rather than buy them with cash.

Tailings: The remains of the ore after most of the valuable metal has been extracted.

Tailings dam: A pond or lake where tailings mixed with water are stored until the solids are deposited out of the solution leaving the water clear. In dry climates, the water evaporates leaving the tailings as sediment.

Turbid: Water which is cloudy and high in sediments.

Update of the Ok Tedi Mining and Environment Issue

As a result of the mining, large quantities of mine-derived material have been deposited in the river system. This non-toxic rock waste has filled in the valley of the Harvey Creek and the Ok Mani downstream from the mine. The finer sediments have been carried by the Ok Tedi and the Fly Rivers hundreds of kilometres downstream as far as the Gulf of Papua. The social and environmental consequences of this sedimentation caused a major legal and environmental problem for Ok Tedi Mining Limited

The environmental issue which caused the legal dispute

Mining operations at Ok Tedi have caused changes throughout the river system. In Harvey Creek, just below the mine, the stream has deposited large volumes of coarse rock and gravel while further downstream in the lower Ok Tedi, the deposits are sandy. Towards the river mouth, deposits consist of very fine particles only a few centimetres thick.

Residents along the river were affected by the mine in different ways. In the upper tracts, near the mine, people were less affected by the sediments because in the upper tracts, there is little flat land beside the river and most people live along the ridge tops. In addition, they were already benefiting from the mine's presence through employment in the mine, land rent, royalties and the provision of education facilities.

But along the Lower Ok Tedi, 100 kilometres south of the mine, about 2500 residents were most affected by the increased river aggradation. People live along this stretch of the lower Ok Tedi and the deposition of large quantities of mine sediments has impacted their lives. It was these people who made a legal claim against OTML.

OVERVIEW & COMMENTARY by EE

There has been some major news regarding Ok Tedi mine's impact upon the environment of Papua New Guinea. A damning environmental report on the Ok Tedi copper and gold mine has raised the possibility that the mine, accounting for 10 percent of PNG's annual gross domestic product, will have to shut down. The primary developer, Broken Hill Proprietary (BHP) of Australia, after years of denial, now admits that dumping wastes into the Fly River has tremendously degraded it. The independent reports confirmed waste rock and tailings were building up in rivers near the mine, causing flooding that was killing trees, damaging gardens and possibly harming algae and fish. What is done now, knowing what is known, will have grave consequences for both the environment and economy of PNG. BHP must be made to take responsibility for damage that has occurred, and is likely to continue to occur. The government, which is hard pressed financially, must not be forced into a decision of bankruptcy from closing the mine or allowing mining to continue as it has. There are other choices, such as building the tailing dam that has been considered for years, or outright compensation from BHP to the government for the damaged

Mine Wastes PNG Rivers, Global Ban Urged

Source: Environment News Service, <http://ens.lycos.com/>

Date: August 11, 1999 Byline: Bob Burton

PORT MORESBY, Papua New Guinea, August 11, 1999 (ENS) - The release by Australian mining company Broken Hill Proprietary of reports confirming severe environmental impacts of mine wastes dumped in Papua New Guinea's Ok Tedi River has sparked calls for a global ban of river and sea dumping of mine tailings. The Ok Tedi open-pit mine produces copper and gold. The president of the Washington D.C. based Mineral Policy Center, Stephen D'Esposito, describes BHP's Ok Tedi mine as an "an environmental catastrophe where an entire river system has been destroyed by mine waste." "We need a worldwide ban on dumping mine waste in rivers, a practice which is effectively prohibited in developed countries, like the U.S, Canada and Australia," D'Esposito says. Four years after Broken Hill Proprietary (BHP) ran an advertising campaign proclaiming that mine wastes it dumped in the Ok Tedi River in Papua New Guinea were "virtually identical" to natural sediment, it conceded today it "should never have become involved" in the project. The BHP environmental reports released today confirm that fisheries in the Fly River have been damaged and mine wastes have spread down 1,000 kilometres (620 miles) of the Ok Tedi and Fly Rivers. The wastes have also spread across more than 100 square kilometres (39 square miles) of land adjoining the river, killed large areas of tropical forests and smothered village vegetable gardens. "A further 200 square kilometres (78 square miles) of vegetation in the upper Middle Fly is under stress," the BHP reports warn. The reports indicate that up to 900 square kilometres (360 square miles) could be damaged if the mine ran until 2009 when the copper-gold orebody is expected to be exhausted. Environmental and development groups fear that BHP is pushing to be allowed to continue polluting the Ok Tedi River. "River systems should not be used to dispose of mine waste," said Brian Brunton, a spokesperson for a coalition of Papua New Guinea community groups. The coalition, including the Environmental Law Centre, NANGO, NGO Environmental Working Group, the Pacific Heritage Foundation and Greenpeace Pacific, said if

mining continued, "BHP should cease pushing overburden from the ore into the river and a new safe way should be found to deal with tailings, even if this means the mine should be smaller, and new technology found to extract greater metal content." Releasing the reports to a meeting of local government officials and community groups from Papua New Guinea, BHP's managing director and CEO, Paul Anderson, said, "With the benefit of these reports and 20/20 hindsight the mine is not compatible with our environmental values and the company should never have become involved." The Port Moresby based manager of Ok Tedi Mining Limited, Vincent Bull, told ENS that BHP "don't have a preferred option" on how to deal with the damage from mine wastes. Community groups fear that BHP is considering adding its shareholding in the Ok Tedi Mine to the list of copper projects it is closing or selling. "BHP shareholders should bear the environmental cost of mine closure, and should not be allowed to offload their environmental responsibilities onto the PNG taxpayer and the government of PNG," Brunton said. Dredging feasibility experiment. The Papua New Guinea Government has approved an 18-month A\$60 million trial of dredging to fix mine waste impairment on the Lower Ok Tedi River. A separate feasibility study for construction of a 110 kilometre, 800 mm tailings pipeline continues. In 1996 BHP was forced to commission the reports into the environmental and social impacts of the mine as a result of a landmark legal settlement to a class action taken by 30,000 Papua New Guinean villagers. The landowners launched a \$4 billion damages claims against BHP in the Victorian Supreme Court in Australia for economic loss and environmental damage and argued that BHP should be forced to build a tailings dam. BHP responded by secretly drafting legislation for the Papua New Guinea Government, a 30 percent shareholder in the Ok Tedi mine, making it a criminal offence for those found to have taken legal action against BHP in courts outside PNG. The legislation included provision for those found guilty to be imprisoned for up to five years. BHP was found guilty of contempt of court, causing its share price to plummet. The contempt finding was later overturned on appeal on a technicality. Tarnished by the controversy, BHP agreed to an out of court settlement with the landowners. The settlement includes the investigation of alternatives for disposing of the mine waste and a compensation package for the landowners adversely affected by the wastes. Many groups involved in the Ok Tedi issue are not persuaded that BHP has learned any lessons from the Ok Tedi debacle. Bull, asked what he would do if he was starting Ok Tedi from scratch, paused before cautiously responding, "Well that's a good question."

Mine closure threatens Papua economy rescue plans

Source: Reuters

Date: August 13, 1999 Byline: James Regan

SYDNEY - One of the first acts of Papua New Guinea's reformist government, installed a month ago to fix an economy teetering on bankruptcy, may be to oversee the dismantling of one of the nation's biggest export earners. A damning environmental report on the Ok Tedi copper and gold mine in the Pacific nation's rugged Star Mountains has raised the possibility that the mine, accounting for 10 percent of PNG's annual gross domestic product, will have to shut down. Closing of Ok Tedi would devastate the local economy of PNG's remote Western Province, where efforts to diversify into agriculture had made little economic impact, and jeopardise the new government's national economic rescue plans. The

mine's operator and majority shareholder, The Broken Hill Pty Co Ltd of Australia, has assured the government it will hold talks before making any decision on the mine's future. But BHP's managing director Paul Anderson has made no secret of his company's desire to rid itself of Ok Tedi. "From BHP's perspective as a shareholder, the easy conclusion to reach, with the benefit of these reports and 20-20 hindsight, is that the mine is not compatible with our environmental values and the company should never have become involved," Anderson said. The independent reports confirmed waste rock and tailings were building up in rivers near the mine, causing flooding that was killing trees and possibly harming algae and fish. The mine has already paid out A\$500 million (US\$325 million) to local landowners in 1996 for environmental damage and more claims are pending. "The future of the Ok Tedi mine is a matter of great significance to the government, to the people of the Western Province, and the nation as a whole," said Department of Minerals Resources Secretary Kuma Aua. The report has also triggered concern in the capital Port Moresby that efforts by the administration of new Prime Minister Sir Mekere Morauta to pay off a crippling 2.2 billion kina (US\$792 million) in public debt and attract low-interest loans would run into trouble. The prospect of the mine closing increases the urgency of an IMF mission expected to arrive in PNG next week and a visit from World Bank officials. The International Monetary Fund and PNG talks on a standby aid agreement ended in October and negotiations for a US\$120 million World Bank loan also stalled. Most of PNG's debt was run up under former Prime Minister Bill Skate, ousted on July 14 by Morauta's People's Democratic Movement amid allegations of mismanagement and corruption. Under Skate, foreign exchange reserves were depleted to a record low and inflation more than tripled to around 20 percent. This week Morauta launched an emergency mini-budget that relies on an injection of 266 million kina in external financing. The aim of the mini-budget is to reduce the 1999 budget deficit by 119 million kina to 157 million kina. Morauta spent part of Thursday in a ceremonial signing of new supply contracts with Australian energy companies hoping to tap PNG's plentiful but largely undeveloped gas reserves. PNG is hopeful enough customers will agree to buy the gas to enable Chevron Corp to proceed with a 2,655 kilometre (1,650 miles) gas pipeline under the Coral Sea to Australia. The pipeline could generate up to 14.5 percent of GDP and create thousands of new jobs, Morauta said. However, Chevron has yet to commit to developing it.

Papua New Guinea: Beyond Admission, No Solution to Mine Damage

Source: Inter-Press Service

Date: August 12, 1999

CANBERRA, (Aug. 12) IPS - One of Australia's biggest mining companies has just admitted major environmental damage by a project it runs in Papua New Guinea, but this does not necessarily bring a happy ending to the controversy. The pressure has now shifted to the near-bankrupt government of Papua New Guinea and whether it can, and will, insist that Australia's Broken Hill Proprietary (BHP) clean up the damage wrought by the Ok Tedi mine. "The mine simply can't continue to operate as it is. There have to be changes made in the regulatory regime," the Port Moresby-based manager of Ok Tedi Mining, Vincent Bull, told IPS. "Obviously it is up to the state to make those judgments having taken into account the social, economic and environmental interests that have to be accommodated," he added. BHP,

which hopes the gold and copper mine's future will be resolved at its November board meeting, yesterday released reports showing damage from mine waste that for well over a decade has flowed down the Ok Tedi river and destroyed food gardens, fishing grounds and villagers. Four years after it ran an advertising campaign proclaiming that the 90 million tonnes of mine waste it dumped each year into the Ok Tedi river were "virtually identical" to natural sediment, BHP admitted its error. "With the benefit of these reports and 20/20 hindsight, the mine is not compatible with our environmental values and the Company should never have become involved," said BHP managing director and chief executive officer Paul Anderson. The environmental reports were released at a meeting of local government, community and church leaders in Port Moresby on Aug 11. But despite BHP's admission, community groups in PNG are not optimistic that new Prime Minister Makere Marauta, who was a founding director of Ok Tedi Mining, will insist that BHP clean up the damage. After all, the PNG government -- which has a 30 percent stake on the Ok Tedi mine -- is in dire straits. Having taken office only in mid-July, the Marauta government is struggling to negotiate a financial rescue package with the International Monetary Fund and find enough revenue to cover social services. With the Ok Tedi mine accounting for one-fifth of PNG exports, Marauta is under intense pressure that the mine continues. On Aug 10, he launched an emergency mini-budget including tax changes designed to encourage mining and oil development to bring more hard currency in. Activists say BHP's responsibility does not end with the release of the environmental reports, which the firm was forced to commission in 1996 after a legal settlement to a class action suit taken by 7,000 Papua New Guinean villagers. Some environmental and development groups fear that BHP is pushing to be allowed to continue polluting the Ok Tedi river. "River systems should not be used to dispose of mine waste," said Brian Brunton, a spokesperson for a coalition of PNG community groups. "BHP should cease pushing overburden from the ore into the river and a new safe way should be found to deal with tailings, even if this means the mine should be smaller, and new technology found to extract greater metal content," Brunton said. The coalition includes the Environmental Law Center, PNG Alliance of NGOs, the NGO Environmental Working Group, the Pacific Heritage Foundation and Greenpeace Pacific. The BHP reports confirm that fisheries in the Fly River have been damaged and mine wastes have spread down 1,000 kms of the Ok Tedi and Fly Rivers and across more than 100 sq km of land adjoining the river, killed large areas of forests and smothered village vegetable gardens. BHP's Bull insists the firm does not have a "preferred option" on how to deal with the damage from mine wastes. Activists fear that BHP is considering adding its shareholdings in the Ok Tedi mine to the list of copper projects it is closing or selling. "BHP shareholders should bear the environmental cost of (any) mine closure, and should not be allowed to offload their environmental responsibilities onto the PNG taxpayer and the government of PNG," Brunton argued. "If mining finishes early, BHP shareholders should carry any cost of social dislocation to the affected people of the Fly River, by developing alternatives to ensure that those people have sustainable livelihoods in future," he added. Already, critics suspect that BHP is passing on tough decisions to other parties -- in this case the cash-strapped PNG government caught between the need for revenues and the ill effects of a flawed mine project. They say BHP's actions echo the approach of one of the world's leading public-relations crisis managers, US-based Peter Sandman, who has advised BHP and other Australian mining firms to defuse local opposition by "outsourcing" hard decisions. "Offer communities the choice of either insisting on environmental clean-up or trade possible benefits from the company for other social services," Sandman has said. "This is a way of getting external groups to face hard choices, and of outsourcing controversial decisions that would have little credibility if made within the company." Bull denies BHP is outsourcing the problem, but is unapologetic for not inviting the landowners who sued BHP to Wednesday's briefing. "The people who are plaintiffs in the

court case are represented by those elected representatives on their local government council," he said. The disclosure of the environmental reports are the latest twist in the Ok Tedi controversy. In 1995, the PNG landowners filed a 4 billion damage claim against BHP in the Victorian Supreme Court in Australia for economic loss and environmental damage, and argued that BHP be forced to build a tailings dam instead of letting mine waste flow down the river systems. BHP responded by secretly drafting legislation for the PNG government that would make it a criminal offence to take legal action against BHP in courts outside Papua New Guinea. BHP was found guilty of contempt of court, causing its share prices to plummet. (The contempt finding was later overturned on appeal on a technicality). Stunned, BHP agreed to an out-of-court settlement with the plaintiffs, one that included investigation of alternatives for proper disposal of mine waste and a compensation package for affected landowners. Even with this week's admission, groups involved in the Ok Tedi issue are not persuaded that BHP has learnt its lesson. Asked what he would do if he was starting Ok Tedi from scratch, BHP's Bull paused before cautiously saying: "Well, that's a good question."

Land Issues

DON'T TAKE OUR LAND

Another holy war is looming in the jungles of the Purari delta, home of virgin forests untouched since creation. The jungle is a supermarket with milk and honey as well as mineral wealth which is mostly undiscovered.

The nine clan groupings that are on a bloodbath are the people that make up Baimuru. They are consolidating themselves to fight off strangers from their land. But this is not just another of those stories. The holy war is over sacred ancestral sites where the Baimuru people trace their beginnings. They feel offended that Rimbunan Hijau, a Malaysian logging company has moved in and taken over their land without consultation. "How would you feel if I went and pleased myself to a large chunk of your backyard?" was the way Andy Emex put it.

Andy has just returned to the city from the hotspot; he was invited to witness the serious concerns of the people by a council of elders. His particular assignment was to verify if the Baimuru people's land at the Purari Delta had been sold to foreigners. Andy said he went down in the nick of time because the people were ready for bloodbath. The foreign company had cleared a huge section of the sacred site that the Baimuru people are careful not to set foot on. Said Andy: "The local people do not visit this area because it is respected as the birthplace of our ancestors, but the foreigners have very little regard for our customs. "Not only do they intrude on our property, but they have the audacity to be humbugs in our midst," said Andy who is working round the clock to stop the people taking the law into their own hands, while at the same time group all the clans to set up an umbrella organisation.

He says the people are bitter and feel betrayed that their political leaders have stabbed them in their back. Despite the talk of a fight back, deep down, the people are scared. But when nine clans are involved, it is a very big issue which is the source of Andy Emex's strength. "I am coming out openly because as the leader of my people, have to take their land back, land which is crawling with resources and money-making opportunities.

"Sure we need development, but we are waiting for the right time and the opportunity to take charge of things ourselves. The land lying idle does not mean it is no man's land or, that the owners do not want to work it; that is where these greedy, self-centred leaders have made the mistake to bring suffering to my people," said Andy who was once a bad boy on the streets of Port Moresby.

The Baimuru people sell plastic in the city. The city cemetery is full of their young people while many more are in the prison," he said. Andy wants to encourage them to return to their land where they have everything.

The culture of the Baimuru people is one where trouble is shaken by the roots until it is devoid of life. Their ancestors are believed to have gone up a tower similar to one built by Nimrod - the tower of Babel, to escape the great flood, and they got struck by God, changed their language and chucked them out of the skies.

They have their own version of every great story recorded in the Bible including the story of creation.

There are 230,000 of them, they are starved of opportunities to better themselves, and real light is yet to reach the delta. In response to the threat to their homeland, the Lai Hiare, the main tree from which the nine tribes are descended, have set up an integrated land group - the Baimuru Development Corporation.

Close to their heart is the subject of genealogy which establishes the basis of their land rights and ownership before and after the Eremoni (Noah's flood). Andy says there has been a dreadful awakening and the village council of chiefs, many of whom are holding on to their last breath, are ready to die with their people. There is already talk that there is going to be bloodbath.

The Rimbunan Hijau Frontier Holdings has settled in Kaumaea point on the Purari River because of a phantom consultant who never sat with the people for discussions. Andy Amex, who is also called Akia Kairi, has returned to Port Moresby after having sat with village people and elders. The plea of the people is that they want development, but the intruders must first stop what they are doing and talk. If the plea is ignored, then they promised another Bougainville in the Purari Delta.

A spokesman from the Rimbunan Hijau head office in Port Moresby denied the allegation that the company had helped itself to the people's land, or that they had been overlooked. The spokesman was unhappy that here was a case of people, who seemed to be chasing their own agenda, and such threats were of no help to anybody. He said the company had done everything right. "Before anyone can move in, there are procedures to be followed," he said.

"Before moving in, you have to sit down with landowners and a land rental agreement is drawn up," he said. Only when an agreement is reached that an application is made to the PNG Forestry Authority who, upon receipt of an application, sends an inspector to the site for inspection", he said. When satisfied, certified approval is granted. The company only moves in after this approval by PNGFA is granted, said the spokesman. He said that as far as RH headquarters was concerned, the procedure had been carefully followed, adding that he found the talk of disruption very distressing indeed, especially when he did not know the people making the accusations against his company.

Post-Courier, 4 February 2000