Environmental Impacts of Terrestrial Mining with Case Studies and Comparison to Potential Impacts of Deep Sea Mining

Pacific ACP States Regional Training Workshop on Geological, Technological, Biological and Environmental Aspects of Deep Sea Minerals

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Akuila Tawake

SOPAC Division

Secretariat of the Pacific Community

Presentation Outline

- Environmental Impacts of Mining,
- Mining Waste,
- Mining Waste Disposal Methods,
- Challenges of On-land Tailings Disposal ,
- Mining Waste Characterisation,
- Impacts of Mining Waste Disposal
- Case Studies:

  - Ok Tedi Copper Mine - Riverine

  - Lihir Gold Mine – Submarine Tailings Disposal

  - Gold Ridge Gold Mine – Tailings Dam
- Deep Sea Mining and Potential Impacts
- Video of the Construction of the Ramu Nickel Mine

“Noumea Convention”

Convention for the protection of the natural resources and environment of the South Pacific Region

Article 13 MINING AND COASTAL EROSION

“The Parties shall take all appropriate measures to prevent, reduce and control environmental damage in the Convention Area, in particular coastal erosion caused by coastal engineering, mining activities, sand removal, land reclamation and dredging”.

Adverse Impacts of Mining

- Significant footprint;
- Significant waste materials (waste rock and tailings) are generated that are generally toxic;
- Unsafe disposal of waste materials can cause long-term environmental impacts;
- Breakdown of traditional structures and values;
- Increase in cash flow and economic activities can contribute to social problems such as increase in drunkenness and family related problems;
- Rapid social change associated with mine development widens the gap between the ‘haves’ and ‘have-nots’.

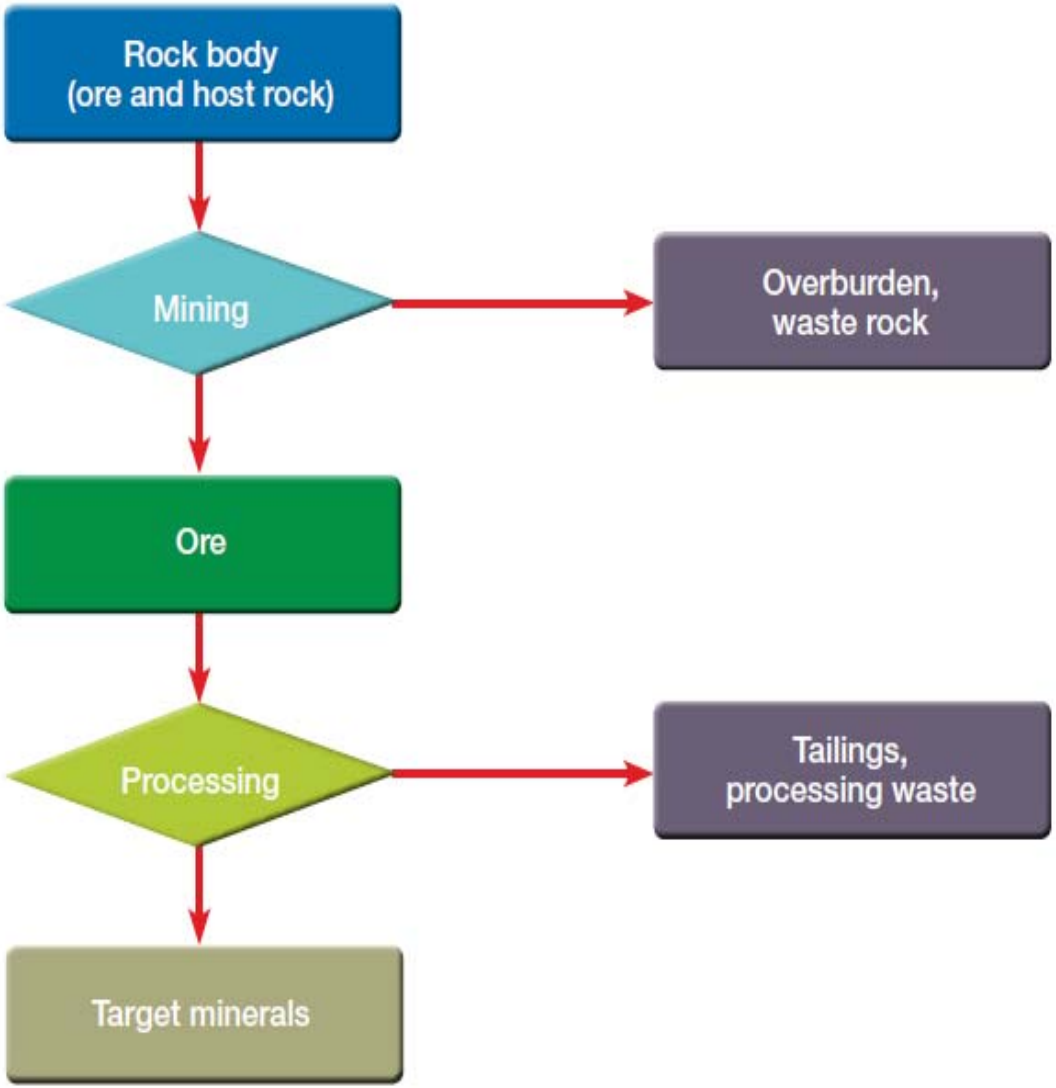
Environmental Impacts of mining…

Mining Waste…

- The management of mine waste is often externalized – passed from the mining operation to other parties or the public.

- This waste if not properly controlled, can result in the smothering of surface waters, contamination of ground waters, and the release of hazardous substances.

Mining Waste…



Mining Waste

- Metal Mining…..

  - has significant volume of waste rock materials that need to be shifted and managed.

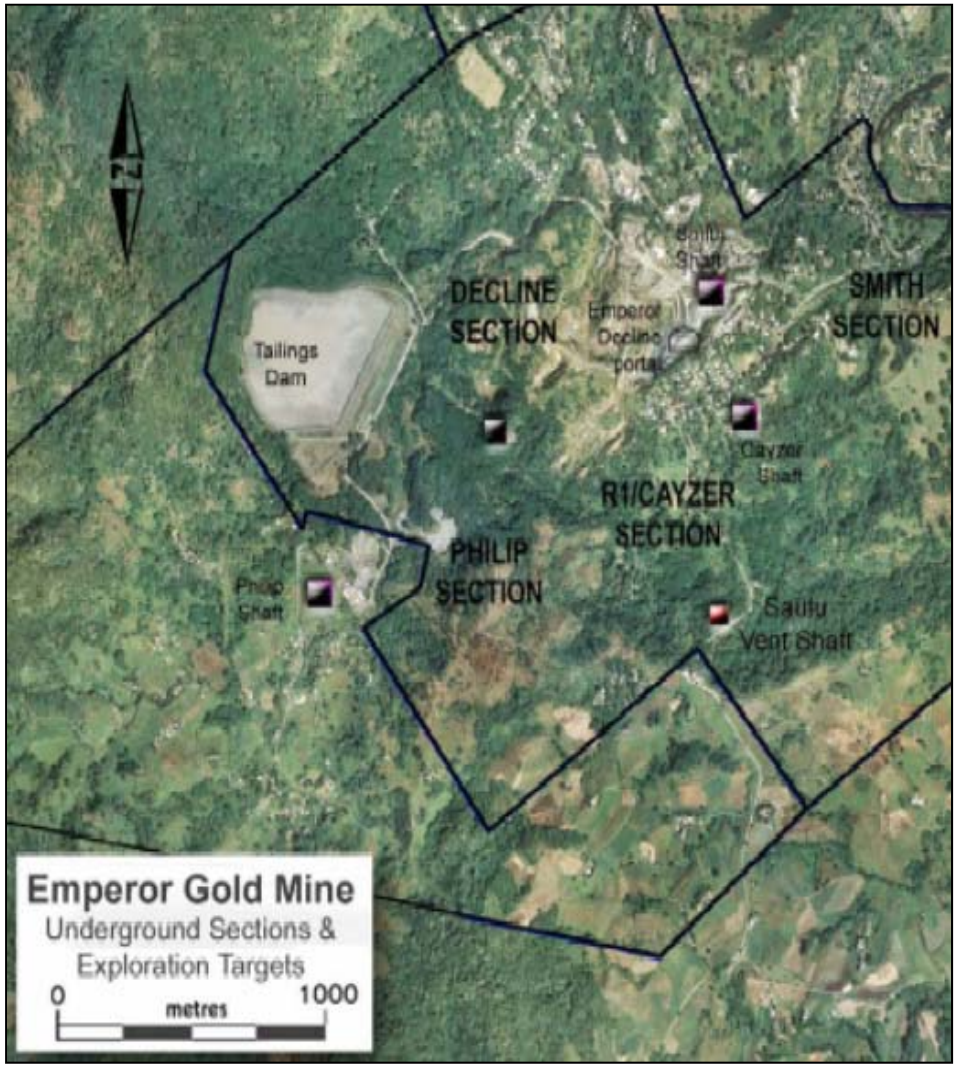
- Major mining waste comprises the following:

  - waste rock,
  - tailings,
  - acid rock drainage,
  - fuel/oil/greases,
  - dust and silt,
  - sewage,
  - sulphur and toxic gases given out from the mill chimney.

Mine Waste Disposal Methods

- A number of waste disposal methods are used globally:

  - Tailings dam,
  - Landfill,
  - Backfill,
  - Riverine,
  - STD/DSTP,
  - Thickened Tailings.



Simberi Gold Mine Waste Disposal…

Challenges of On-land Tailings Disposal…

- *Tectonics:*

  - Earthquake activity in the region (particularly in PNG and SI) is among the highest in the world,

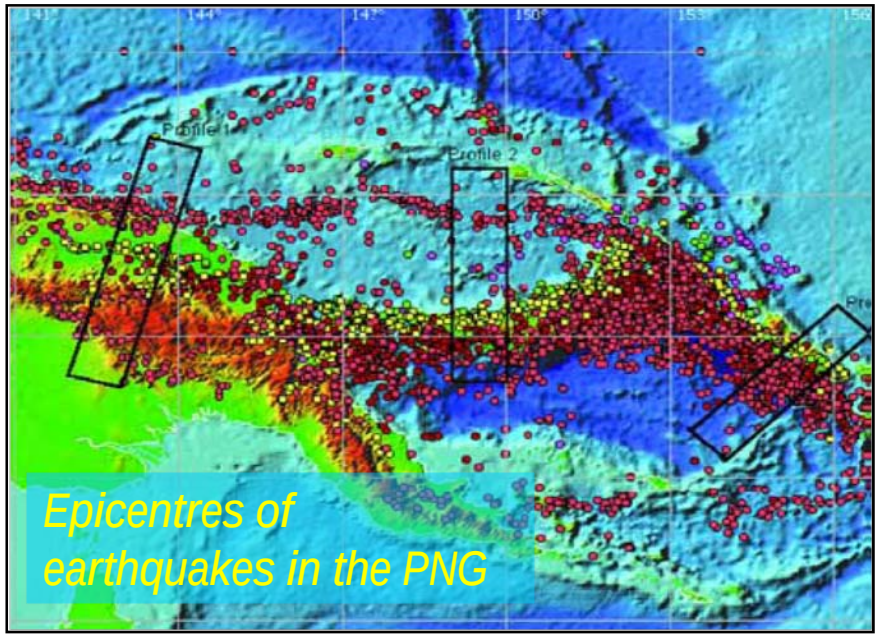
  - Slope stability.

- *Geology and Geotechnique:*

  - Weak sedimentary rocks can be unstable for dam construction,

  - Deep weathering of Volcanic and Intrusive Rocks,

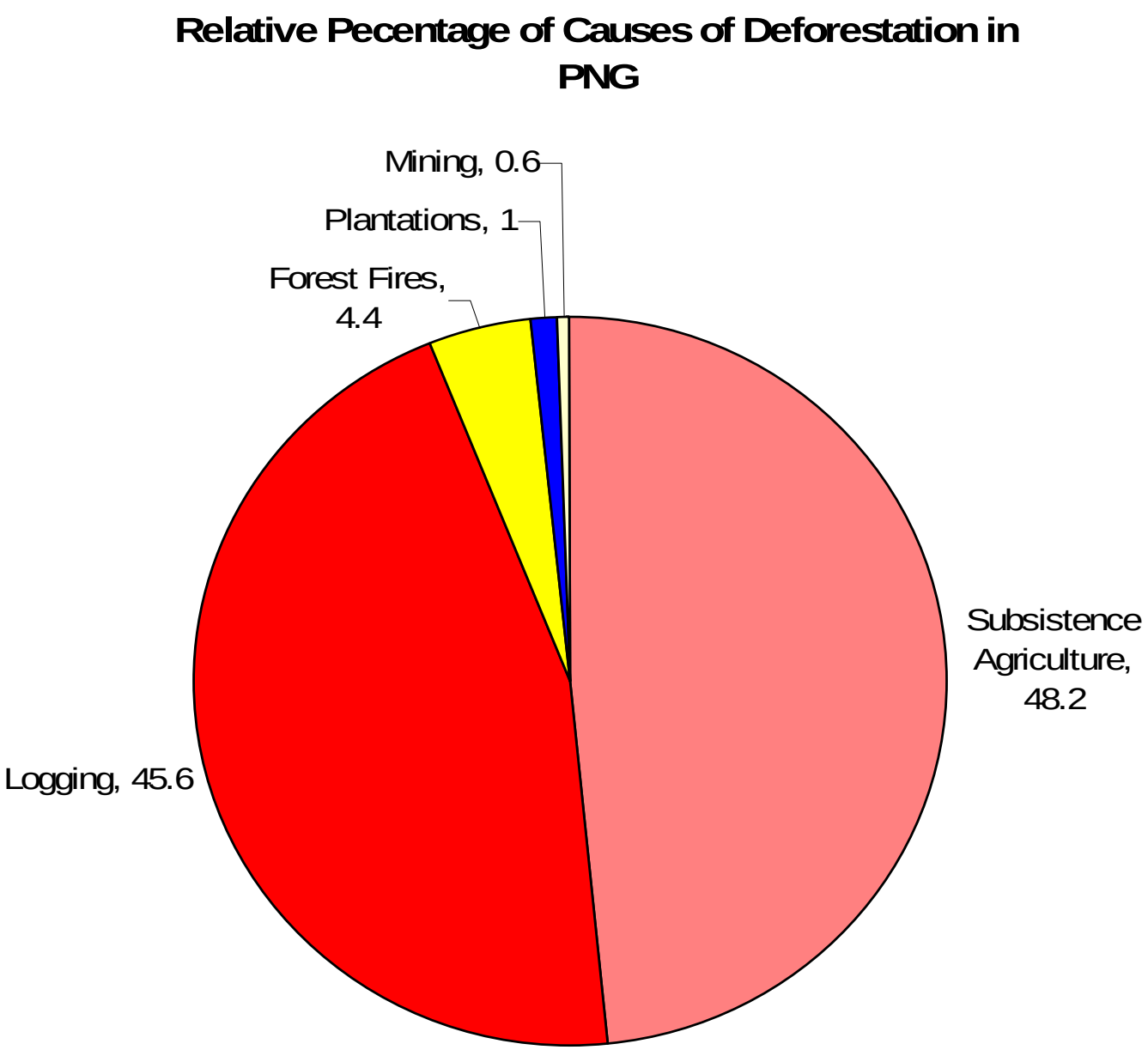
  - Karstic Features – caves and solution sinkholes.



Challenges of On-land Tailings Disposal (con't)…

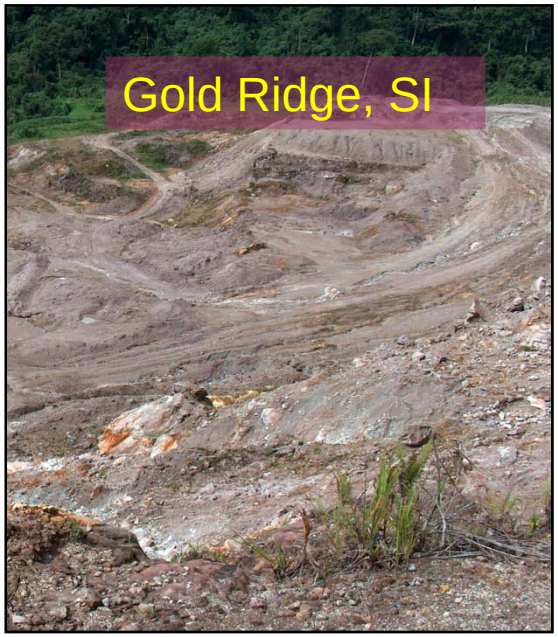
- *Climate:*
  - Rainfall,
  - El Nino.
- *Topography:*
  - Steep and rugged mountainous terrain,
  - Near-vertical karstic limestone cliff,
  - steep, deeply incised river valleys.
- *Geomorphology:*
  - Landslide and mudflows,
  - River blockage due to landslides,
  - Rock Avalanches.
- *Social:*
  - use of customary land tailings disposal,
  - displacement and relocation of communities,
  - contamination of the water source.
- *Flora:*
  - destruction of plant species,
- *Constructability:*
  - unavailability of suitable construction materials,
  - continuous rainfall makes construction challenging.

Drivers of Forest Change in PNG



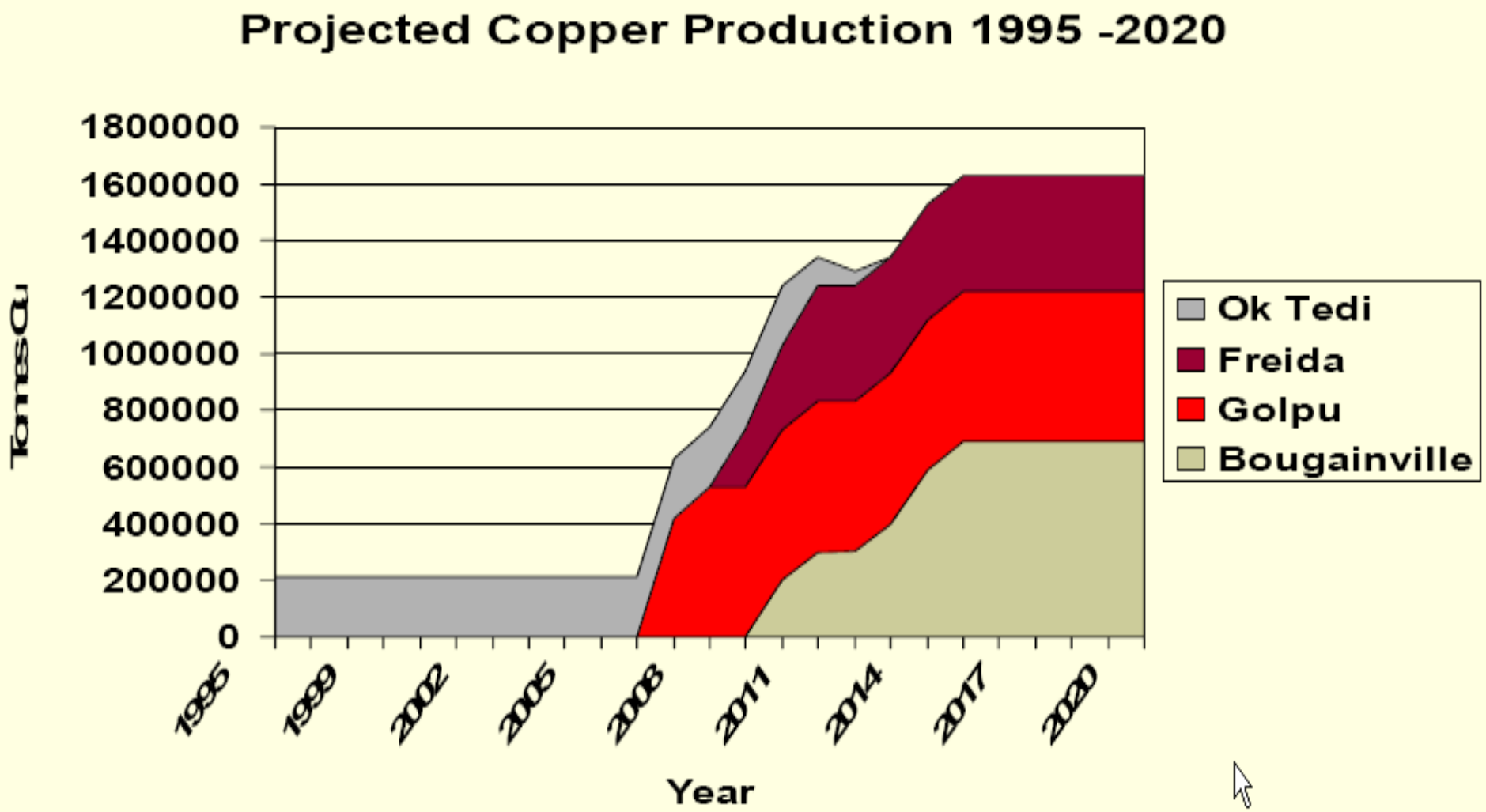
(Shearman et al, 2008)

Mining Waste Produced Depends on…



- Geological characteristics of the orebody,
- Type of mining (underground vs open pit),
- Minerals being mined (chemistry of the orebody and host rocks),
- Size of production.

PNG Copper Production Estimates



Waste Rock Characterisation

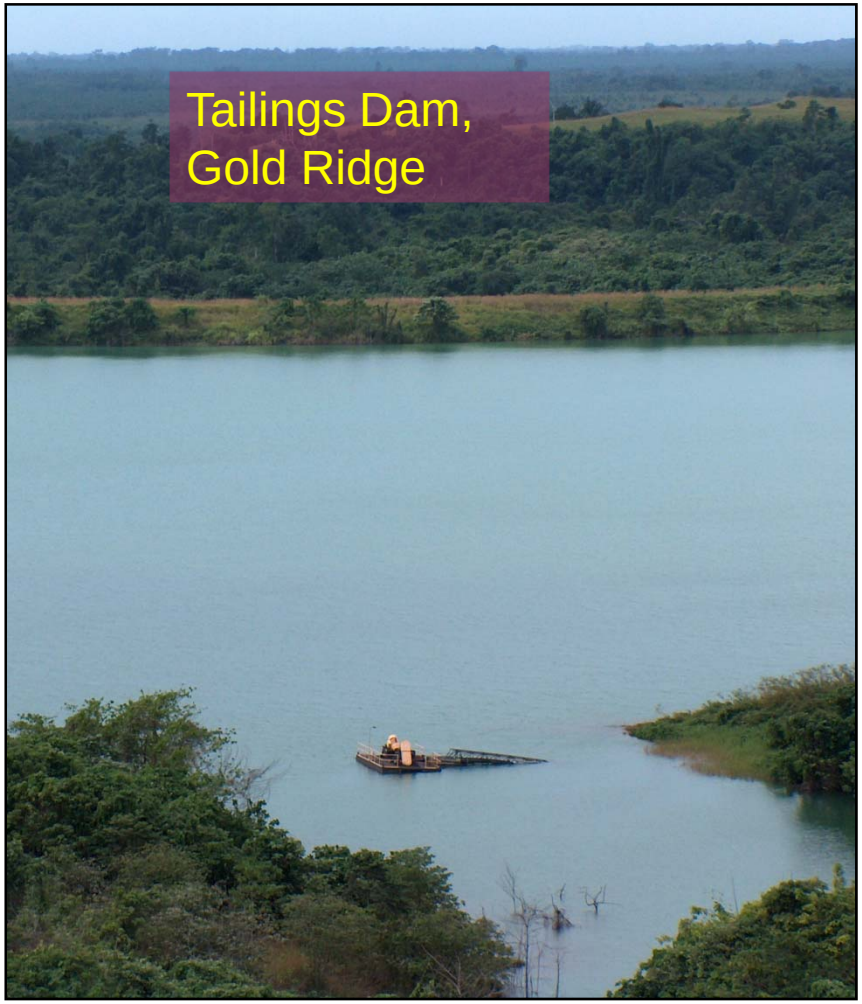
Waste Loading – Mt Sinivit Gold Mine, East New Britain

Waste Dumping

- Waste rock contains…..

  - hard and soft rocks,
  - small gold/copper etc concentrations too uneconomic to process,
  - fuel, oil and greases,
  - explosives,
  - measureable concentrations of other metals such as arsenic, cobalt, nickel, mercury, lead, zinc, etc.

Mine Tailings Characterisation



- Mine tailings contain…..

  - crushed rock,

  - processing chemicals such as acids, cyanide (used to liberate gold and silver) and lime,

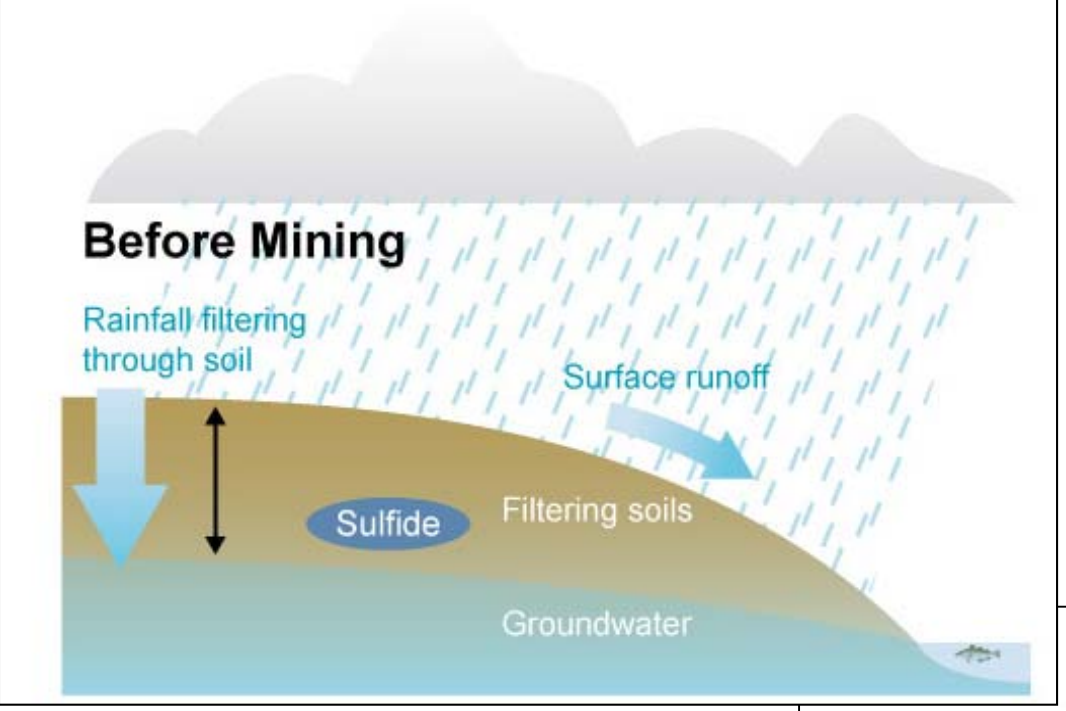
  - fuel, oil and greases,

  - explosives,

  - freshwater,

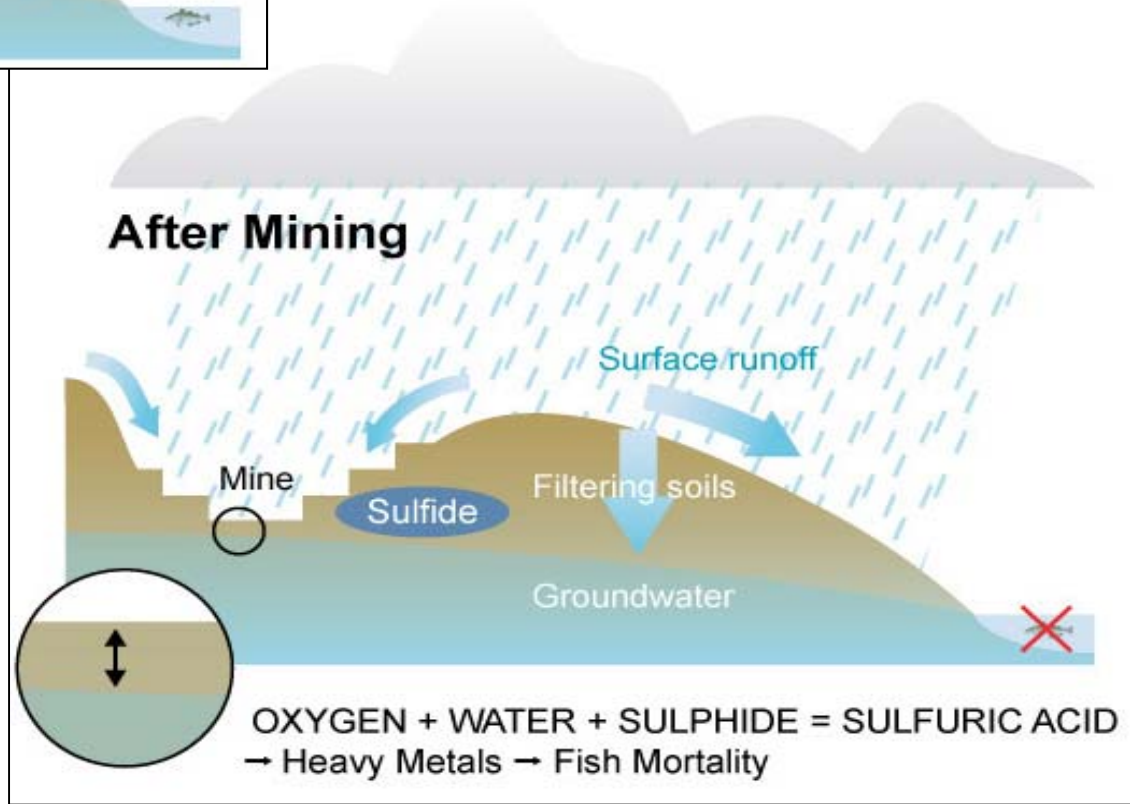
  - measureable concentrations of metals such as arsenic, copper, cobalt, nickel, mercury, lead, zinc, etc.

Mining effects on Rainfall Drainage

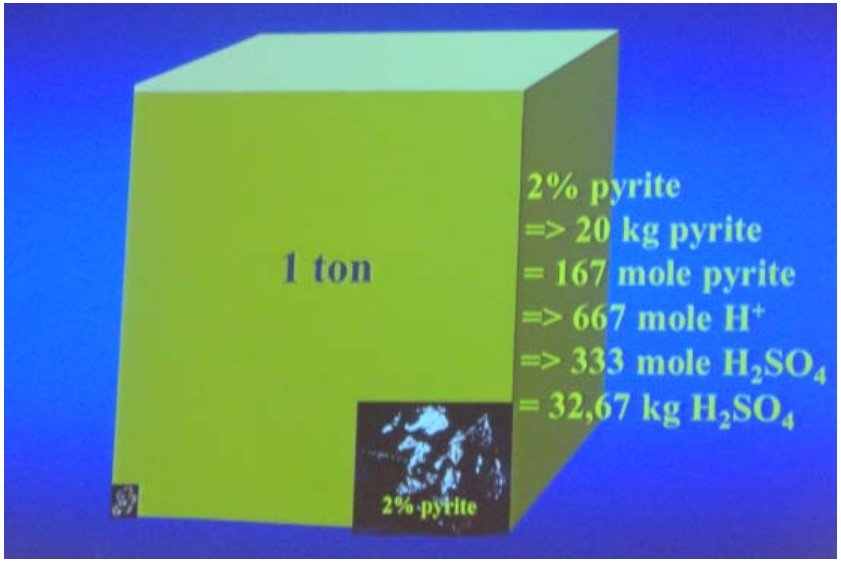


http://maps.grida.no/go/graphic/graphicid/CAC405C6-14BD-981C-634C-A29FC952D0EC

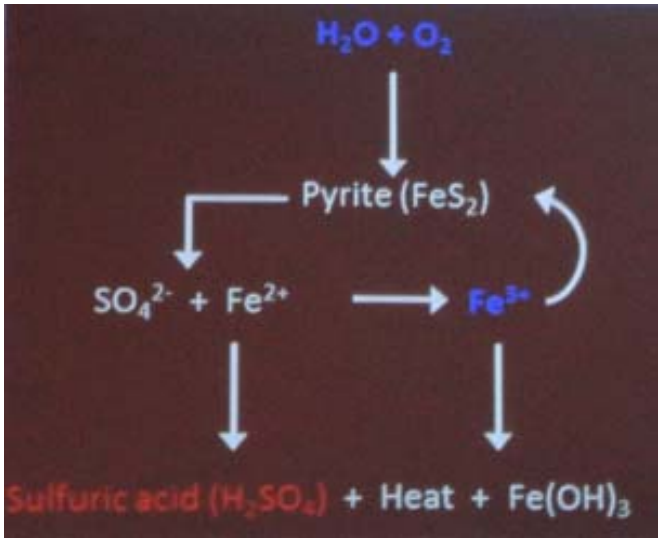
Extraction decreases groundwater depth and natural filtration, and increases groundwater contamination.



Acid Rock Drainage (ARD)



(Dold, 2012)



- Sources of sulphide: metalliferous mines that are associated with sulphide minerals (e.g. Cu and Au mines);
- Pyrite and Marcasite (FeS_2) crystals react with oxygenated recharge water percolating through the waste rock stockpile / overburden / pit wall to form sulphuric acid;
- Known long term impact of mining globally;
- Affecting water ways (rivers and streams) and ground waters.

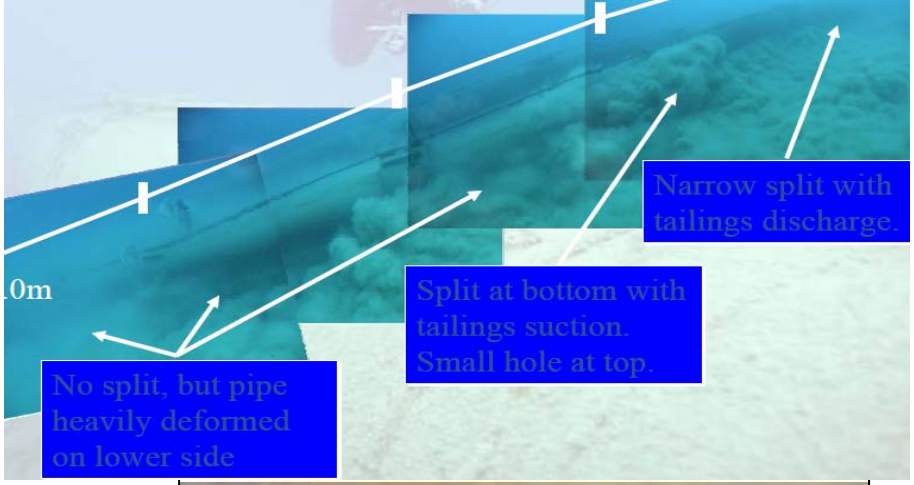
Where does ARD occur?

Common Impacts of Riverine Waste Disposal

- Significant increase in river sedimentation,
- Destruction of river biodiversity (e.g. fish species),
- Destruction of water source for local communities,
- Loss of productive wildlife habitat (e.g. vegetation dieback),
- Long-term impacts and recovery (e.g. ARD),
- Costly to address through remedial measures.

Common Impacts of Submarine Tailings Disposal

- Water turbidity,
- Smothering of the seabed and coral reefs,
- Increasing mortality of marine species
- Reduction in marine biodiversity in the impacted areas,
- Trace metal accumulation in marine species.



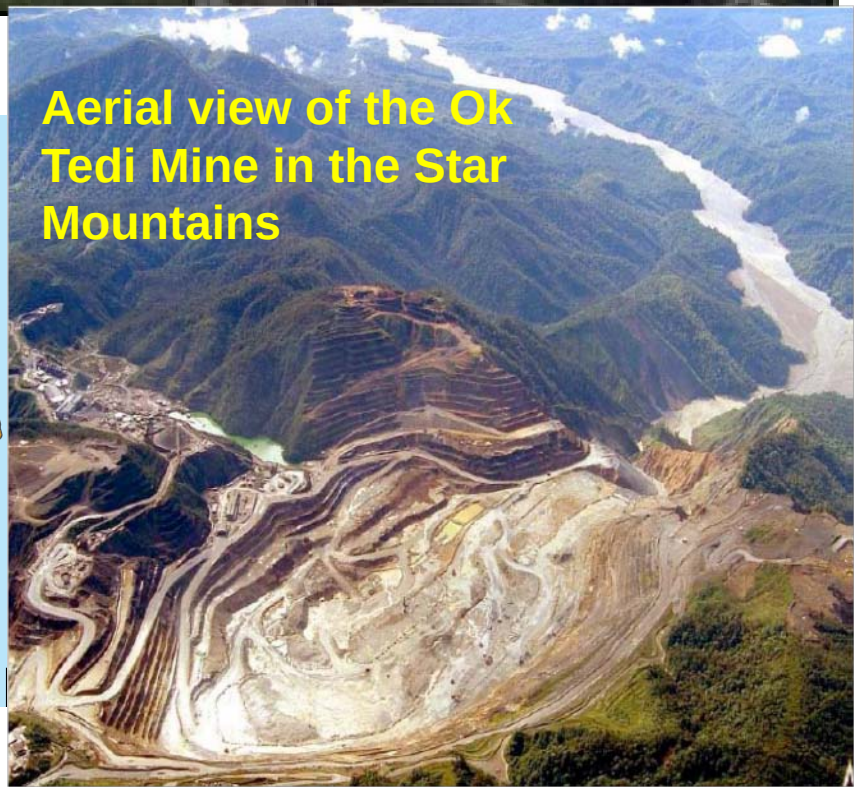
Three Case Studies of Mining Waste Disposal

Riverine: Ok Tedi Copper Mine, PNG

Submarine Tailings Disposal: Lihir Gold Mine, PNG

Tailings Dam: Gold Ridge Mine, Solomon Islands

1st Case Study: Ok Tedi Copper Mine



Aerial view of the Ok Tedi Mine in the Star Mountains

Background of Ok Tedi Copper Mine

Locality	Western Province, PNG
Year Started	1984
Year completed	Operating mine
Pit dimension	2.5km in Diameter 400m depth
Annual Production	180,000t Cu 500,000oz Au
Ore reserve	100Mt @ 0.8% Cu and 1.1g/t Au

2007 Ok Tedi Ore Composition Analysis

- Ore milled: 25,800,000t
- Production:

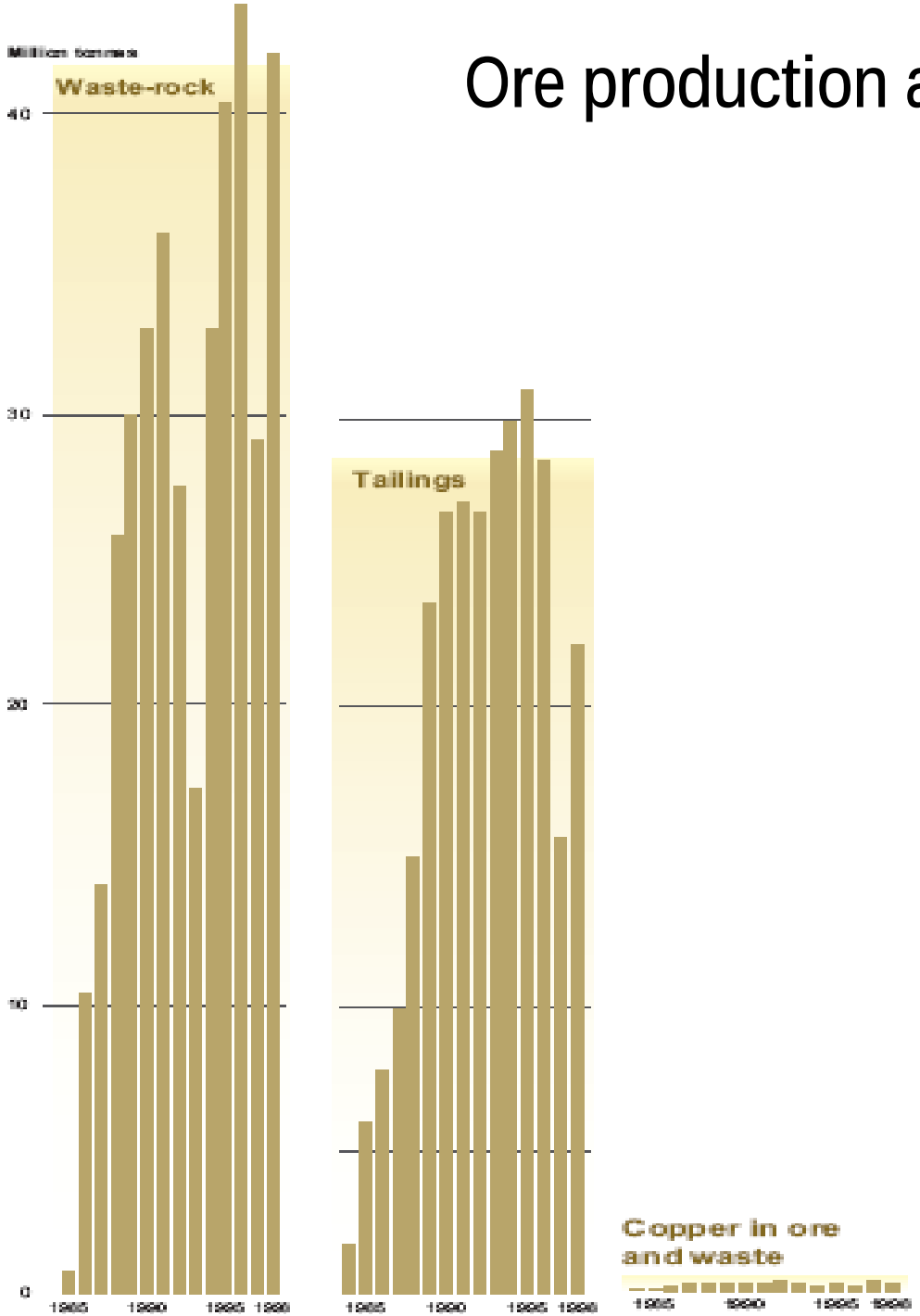
  - 180,000t Cu

  - 500,000oz Au
- Tonnes of Gold:

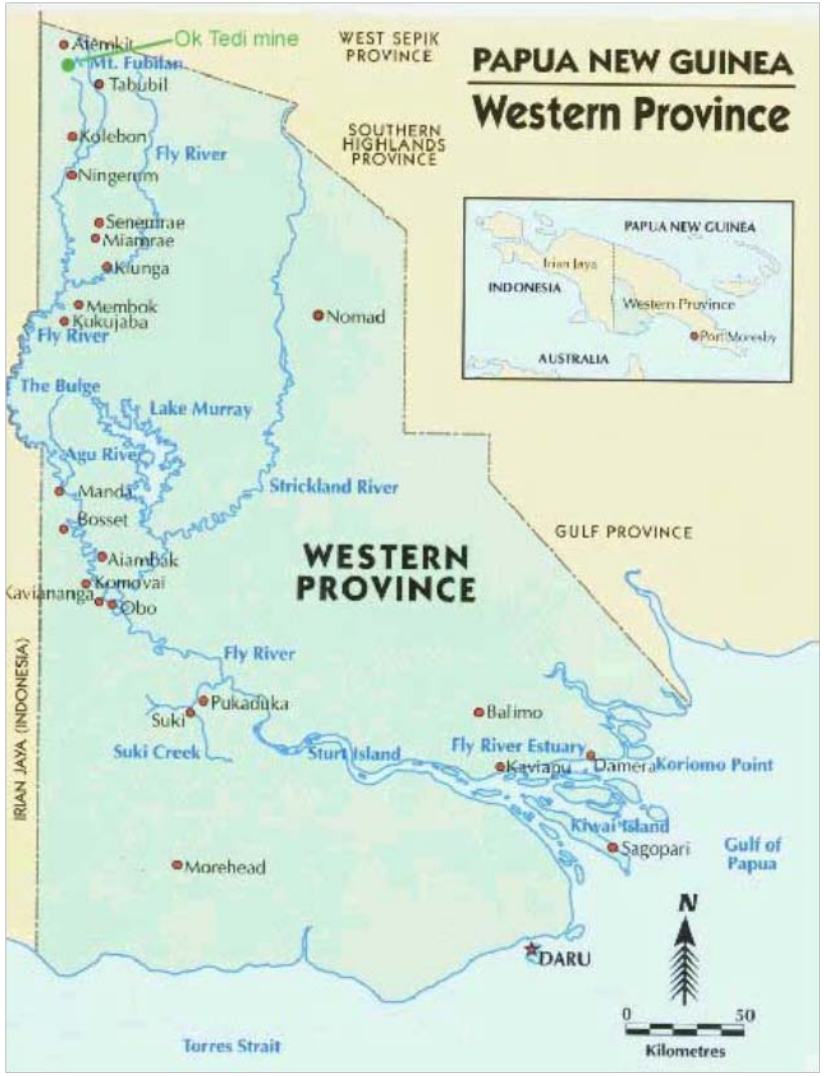
  - 500,000oz Au = 15,551,750g Au (1oz = 31.1035g),
- 15.5t Au (rounded off to one decimal point)

- Metals extracted = 180,000t Cu + 15.5t Au = 180,015.5t
- Tailings = 25,800,000t – 180,015.5t = 25,619,984.5t
- Tailings = 99.3%
- Metals extracted = 0.7%

Ore production and waste generation at Ok Tedi Mine



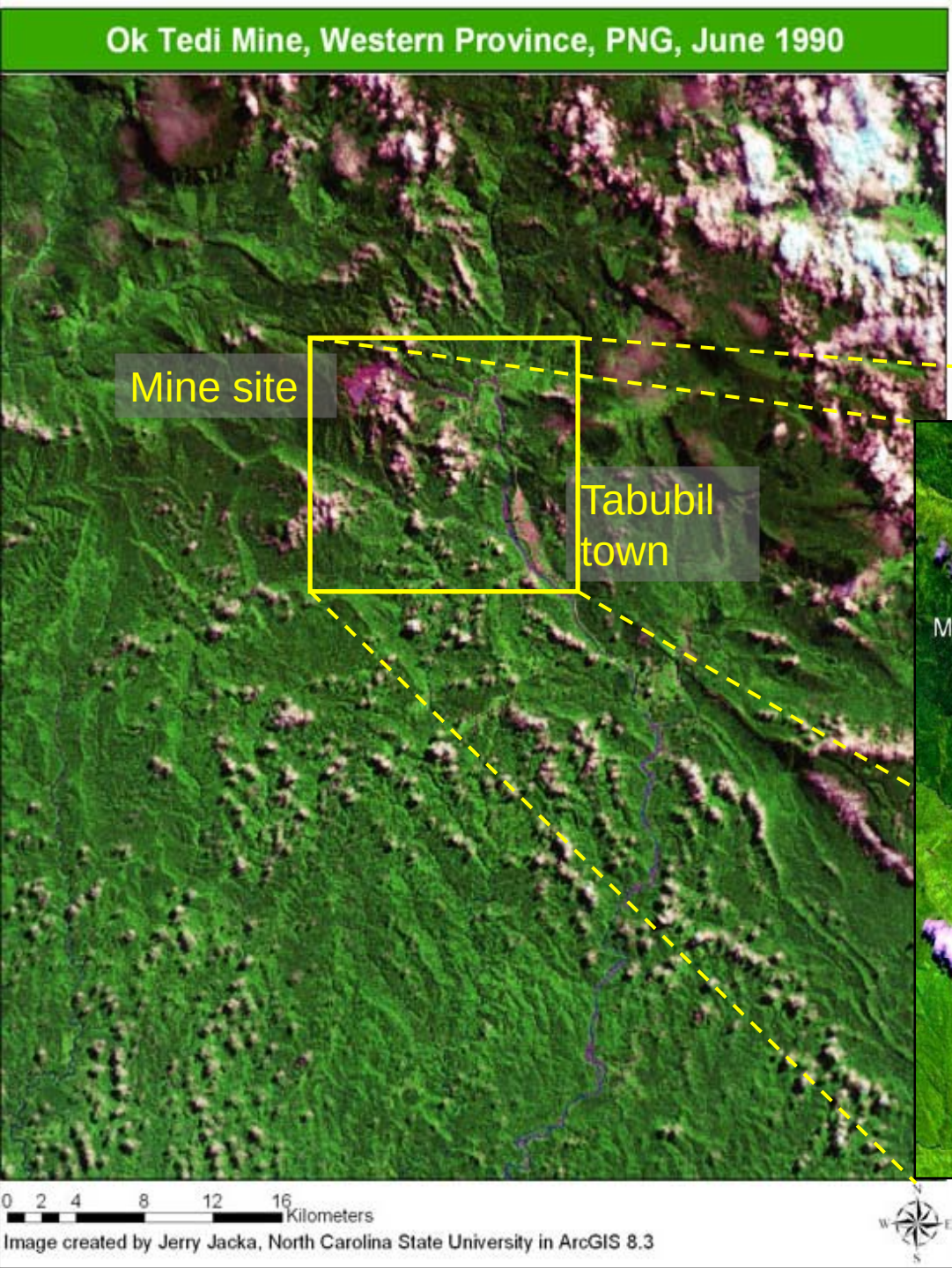
Ok Tedi Mines – Environmental Impacts

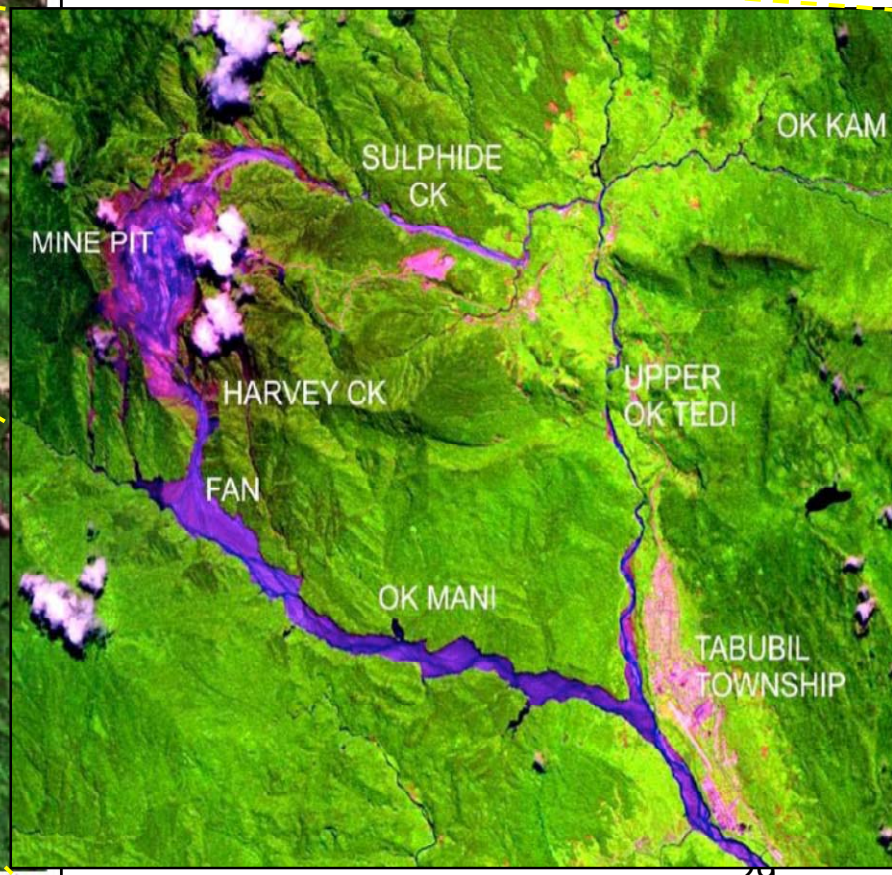


- increased sedimentation,
- degradation of the forest,
- toxicity,
- impacts on ground and surface waters, and
- decrease in fish communities.

1990 Landsat Image of Ok Tedi Mines PNG

http://www4.ncsu.edu/~jkjacka/oktedi.htm





2009 Satellite Image and photos…

Riverine Waste Disposal at Ok Tedi Mine

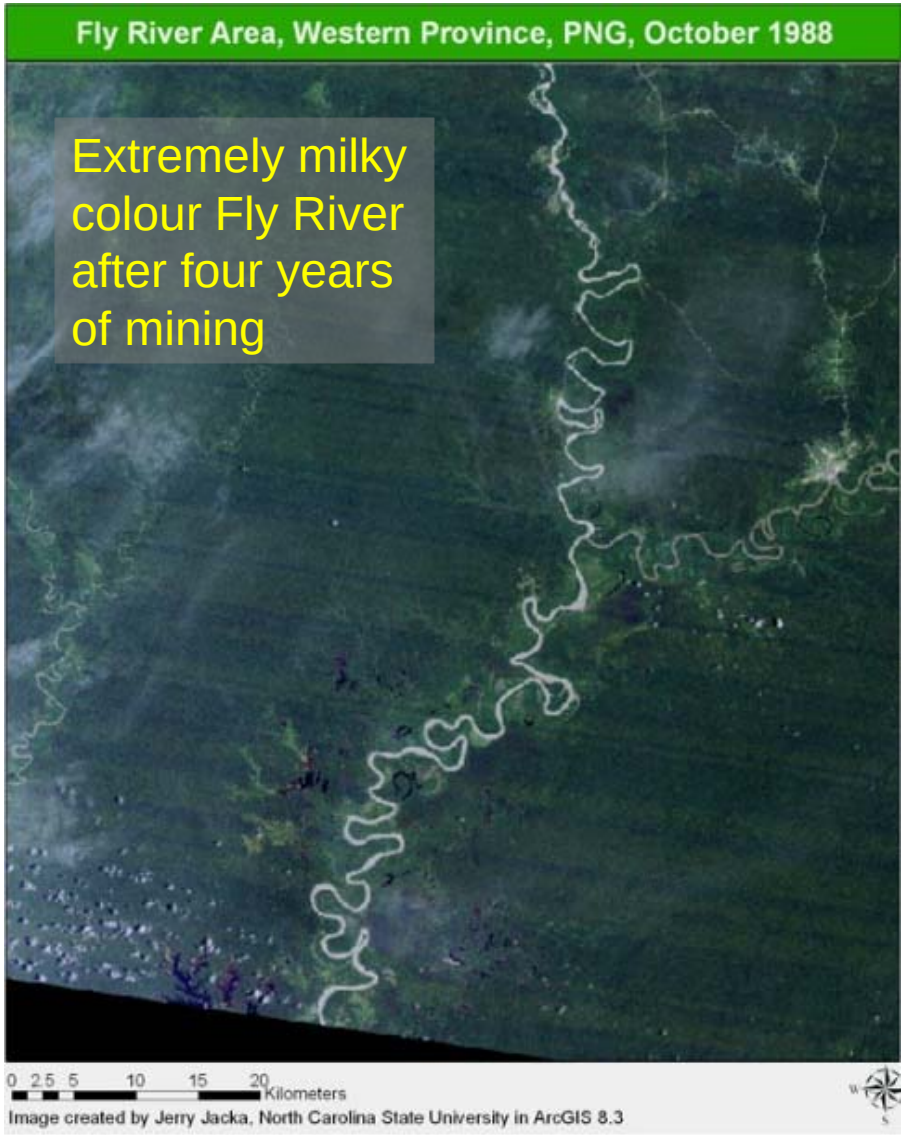
Vegetation Dieback…

- Most obvious consequence of sedimentation in the river system,
- Excess sedimentation has caused the reduction of oxygen levels in the roots killing vegetation,
- Estimated Vegetation dieback coverage:

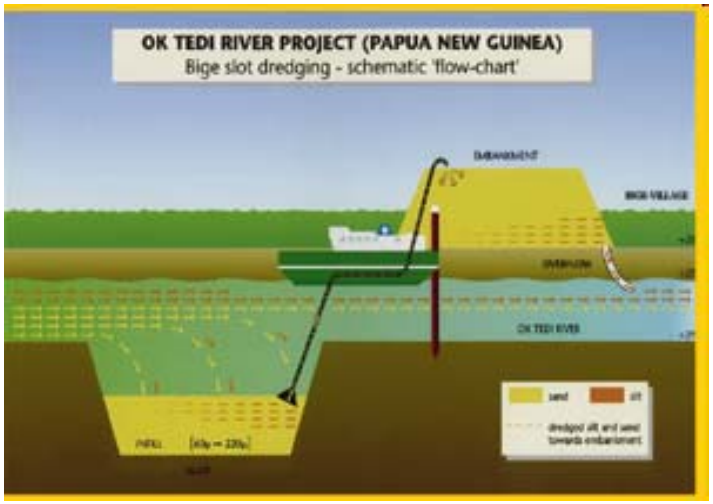
  - 1992: 18 km^2,

  - 2000: 480 km^2.

Landsat Images of the Downstream Fly River



Dredging as a remedial measure…



- Dredging commenced in 1998,
- To reduce flooding and vegetation dieback,
- Dredge 20Mt of sediment per year,
- Vegetation recovery has improved since the commencement of dredging.

2nd Case Study: Lihir Gold Mine

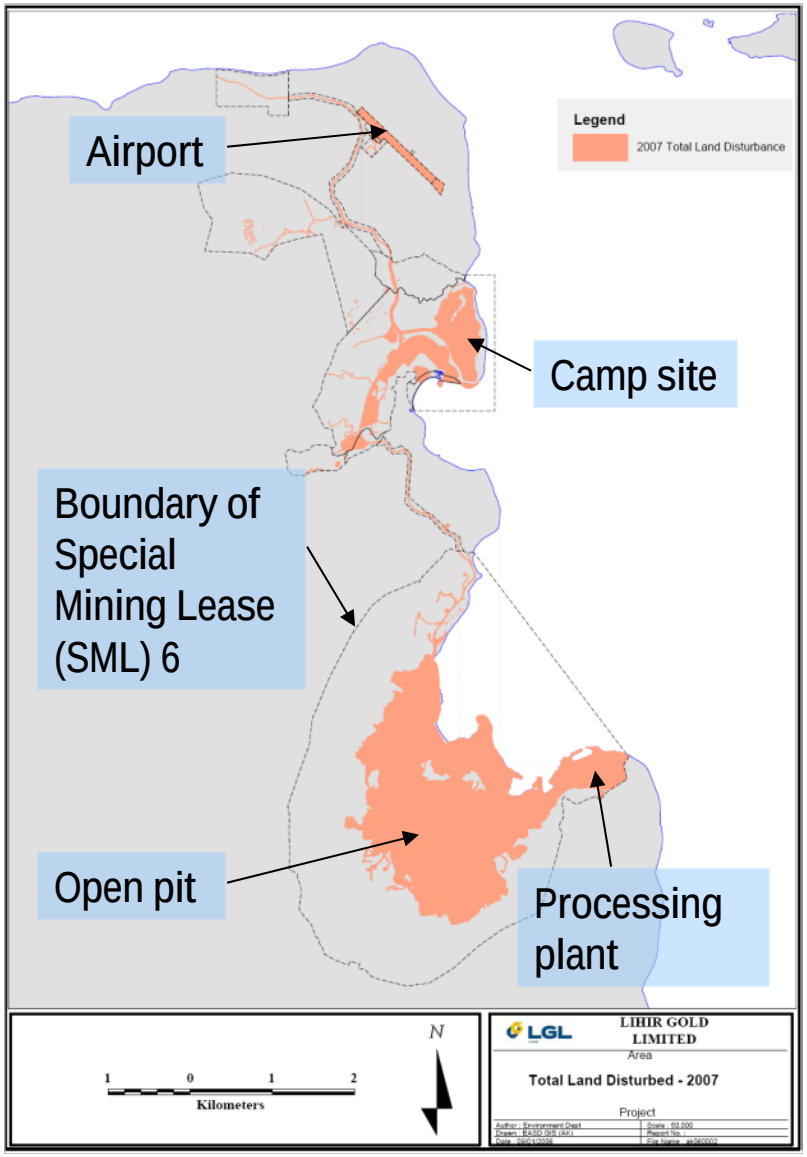
Locality	Lihir Island, New Ireland Province, PNG
Year Started	1997
Year completed	Operating mine
Mining method	Open pit
Annual Production	770,000oz
Ore reserve	23.6 Moz Au

Lihir Gold Mine – Open Pit

Mine Infrastructure

- Processing plant,
- Port facilities,
- Airstrip,
- Diesel and geothermal power stations,
- Water supply facilities,
- Camp and town site accommodation,
- Access roads,
- A communication system.

Land Disturbance at Lihir as at 2007



- Total land managed by LGL under the various leases and tenements is 2,527 hectares (ha),
- 699 ha are currently disturbed by mine related activities, including the town site and airport,
- Disturbed areas have consistently increased over the years due to pit expansion, land clearance for drilling, and new road construction,
- By 2007, a total land area of 565 ha was disturbed within SML 6,
- A total of 15 ha of disturbed land was rehabilitated within SML6.

Lihir Gold Mine – Waste Disposal

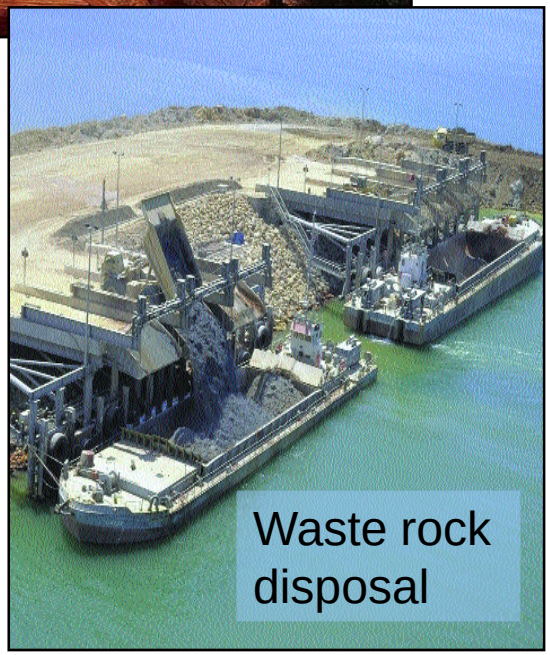
	Waste Rock	Tailings
Volume per annum	18Mt	3.5Mt
Method of Disposal	STD - Waste rock is discharged by bottom-opening barges into steep submarine canyons	DSTP – tailings is discharged at the 128 m depth via an underwater pipeline located below the biologically productive upper ocean layers
Potential Impacts	Sedimentation and suspended sediment plumes near the ocean surface that may impact the seawater, reef and fish	Pipeline breakage that results in tailings discharge into the surface waters.

Mining Impacts at Lihir…

Terrestrial and marine impacts

Massive clearing of vegetation

Significant infrastructure development

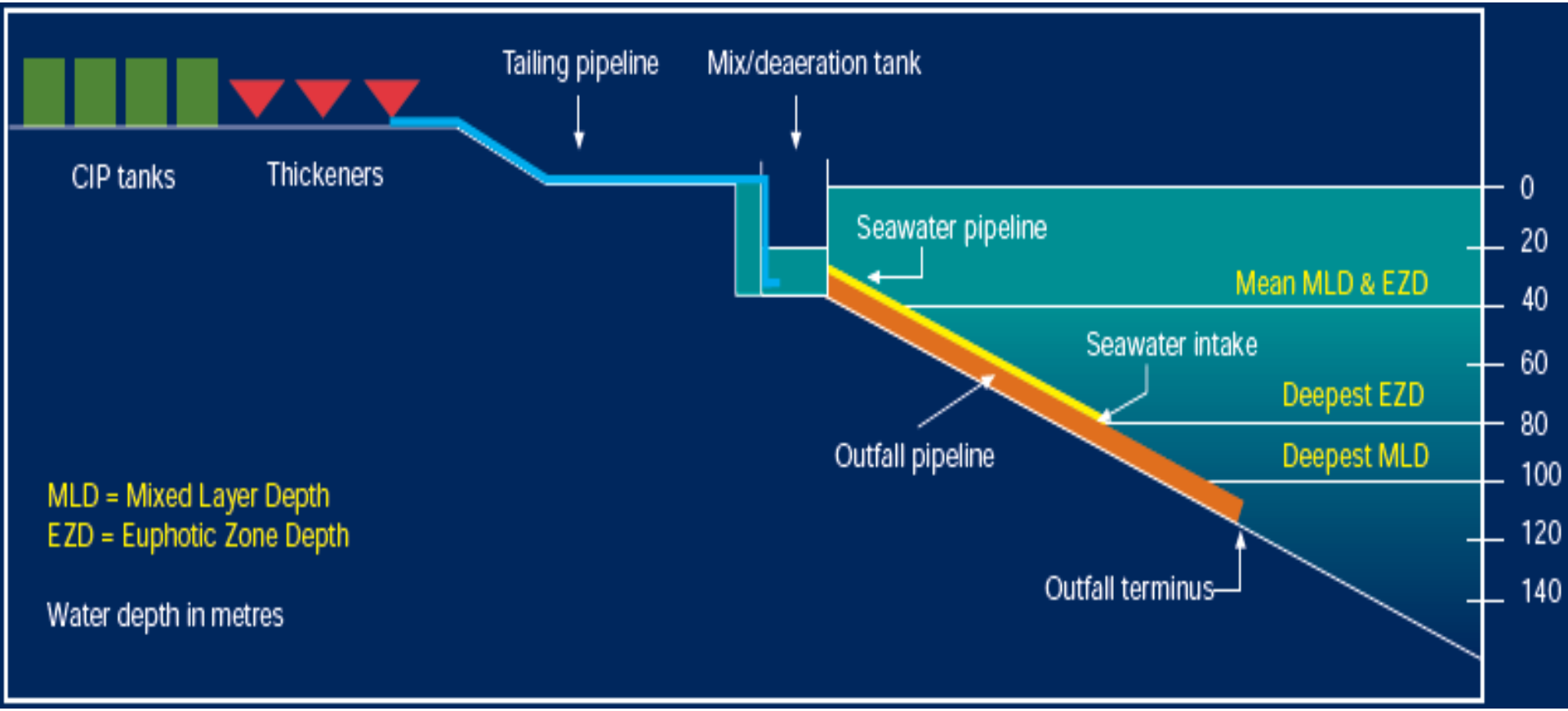


Waste rock disposal

Images of sediment plume in Louise Harbour

Deep Sea Mine Tailings Placement

Before tailing is disposed, seawater is mixed with the dissolved metals and the cyanide is mixed with iron to reduce toxicity



LGL – Geothermal Power Resource

- Supplementary power production using geothermal steam – a by-product of mining,
- Commenced in 2003 with a 6 MW geothermal power plant,
- The Lihir Geothermal Power Plant (LGPP) now produces 56MW power,
- Represents 75% of the 75MW power requirement of the mine.
- Save US$40 million in the cost of diesel fuel per annum.

LGL – Environmental Monitoring

Potential impacts

continue to be kept to a minimum through:

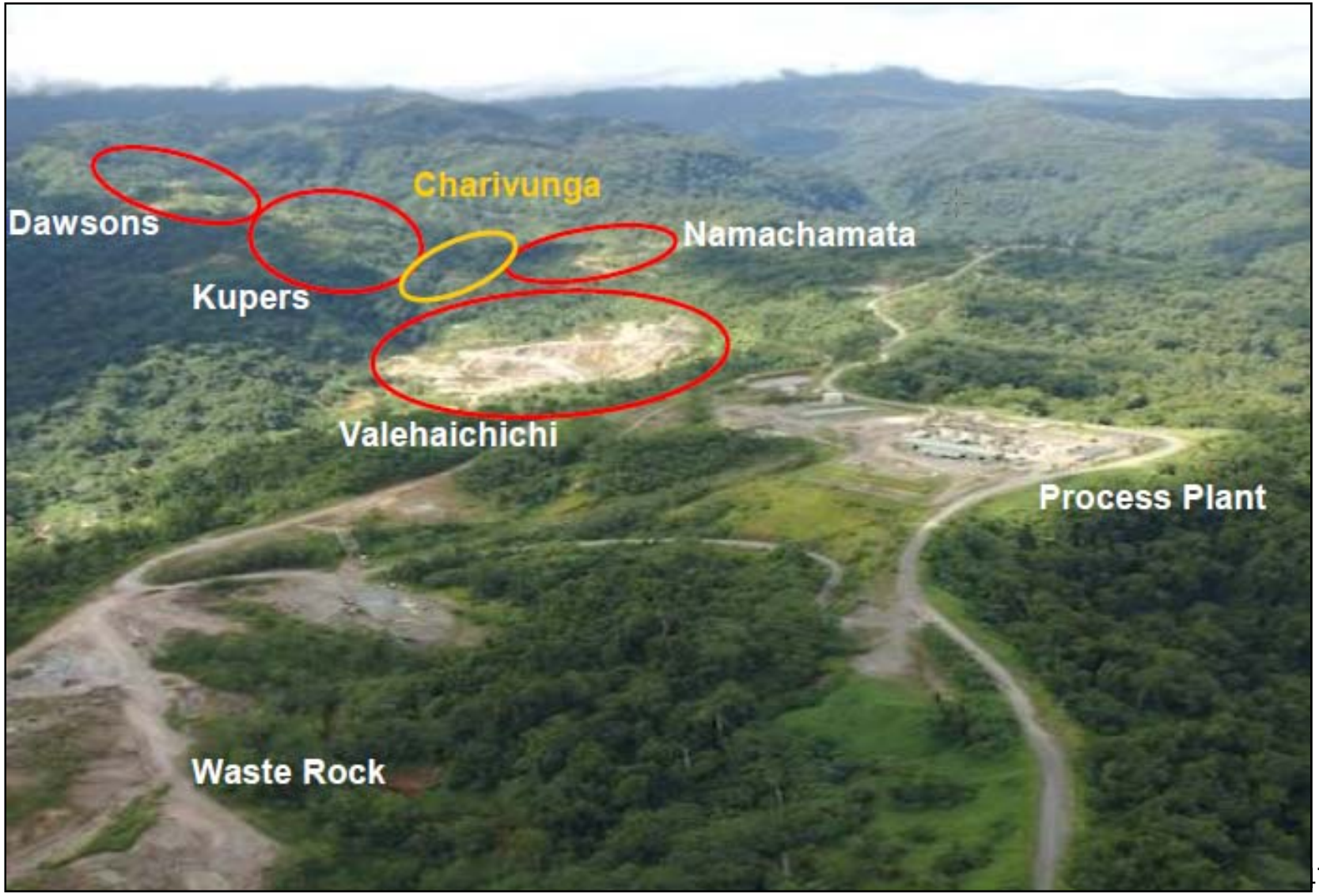
- Environmentally-responsible approach,
- Strict compliance with the PNG Government's environmental regulations,
- Rigorous and regular internal and external monitoring.

3rd Case Study: Gold Ridge Mine Solomon Islands

Locality	Guadalcanal Island, Solomon Islands
Year Started	1998 – 2000; 2011 - present
Year completed	Operating mine
Mining method	Open pit
Annual Production	60,000oz
Ore reserve	3.2 Moz Au

Google Earth image of the Mine Site

Aerial View of Gold Ridge



Mining at Gold Ridge…

Extraction

Haulage

Waste

Waste Stockpile

Ore

Processing Plant

Tailings Dam Disposal…

Tailings Disposal

Potential Impacts Associated with Deep Sea Mining – A Comparison

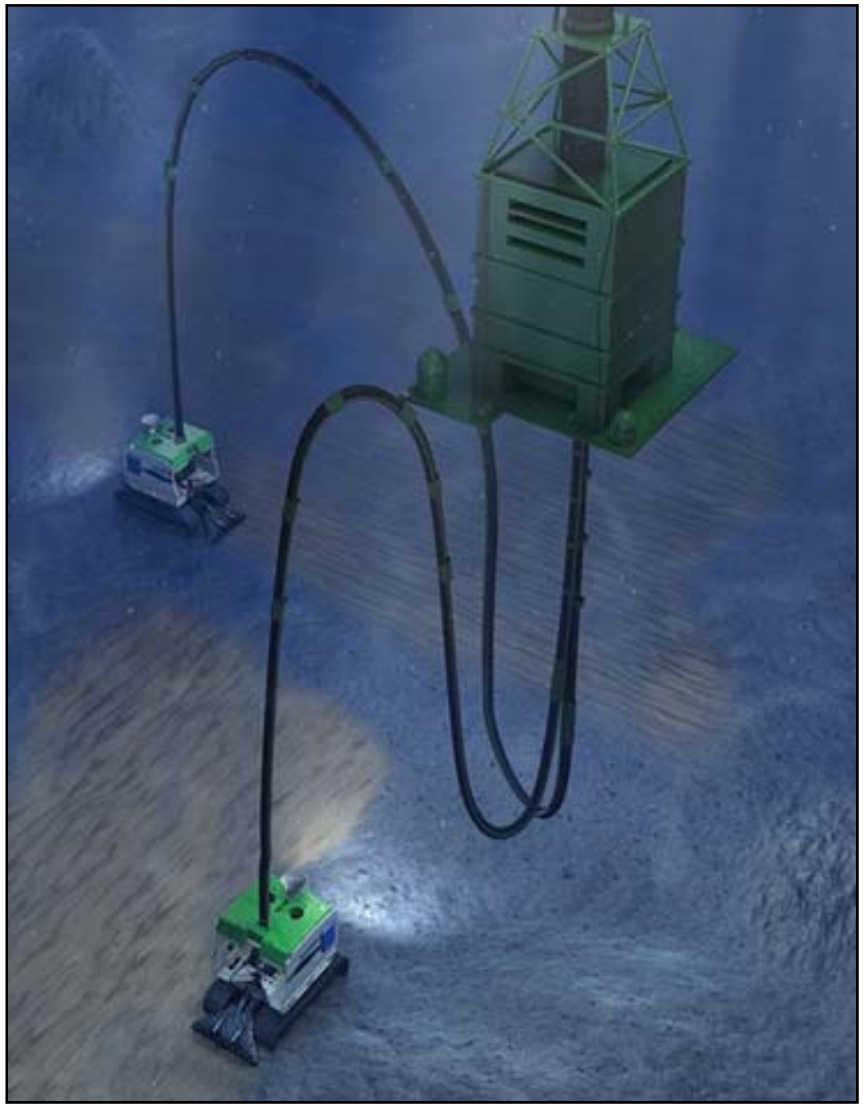
- Less infrastructure is required;
- No big open pits (different extent of disturbance of the seabed for SMS, CRC, MN);
- No or little overburden to be removed;
- Waste rock will be stockpiled on the seafloor - no need to transport waste rock materials;
- If on-land processing is considered, tailings dam disposal is preferred – no riverine and submarine waste disposal;
- Mining will occur within territorial sea and EEZ – common heritage of the nation;
- Far less resource ownership issues to be dealt with.

Likely Environmental Impacts of Deep-sea Mining

- *Unknown!*
  - New frontier
  - No benchmark
  - Solwara 1 Project EIS has predictions
- Pollution:

  - coastal areas, water column, seabed
  - Release of heavy metals
- Localised impacts
  - Loss & degradation of habitats and benthic communities
- Loss of knowledge
- Dispersal of sediments
- Risks – also unknown, e.g. spills, impacts on fisheries.

Ocean – the Overburden that won't go away



- Any mining operation has to constantly deal with the overlying huge body of seawater.
- Ocean cannot be shifted elsewhere for easy access to seabed minerals.
- Significant distance (i.e. water depth) separates the mineral deposit from the mining platform.
- Need to develop robust seabed mining tools including the ore lifting system to ensure environmentally sound mining practice.
- Mining and hoisting processes will demand reasonable amount of energy and time.

Deep Sea Mining Process…

If the SPS is efficient and robust, there is less likely to be any significant impacts of SMS mining.

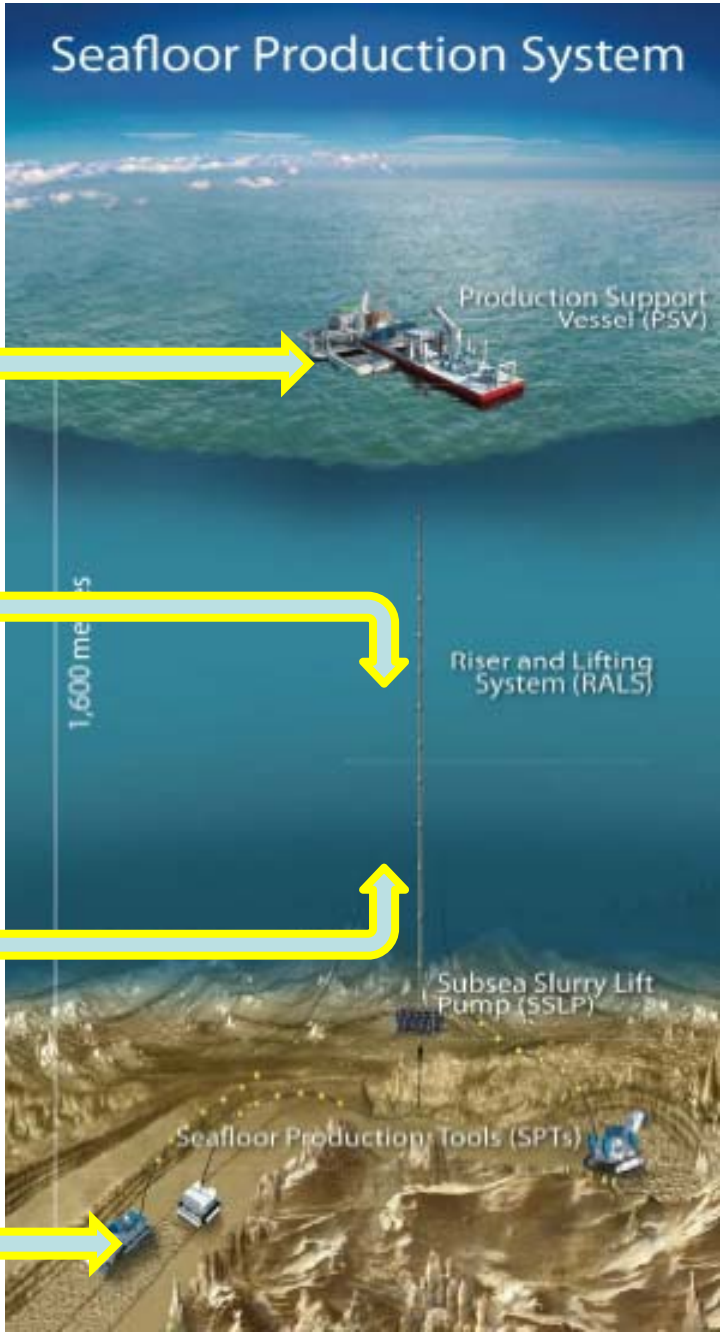
The performance of the SPS will only be known during actual mining

Slurry discharge, transfer of ore, and treatment of effluent

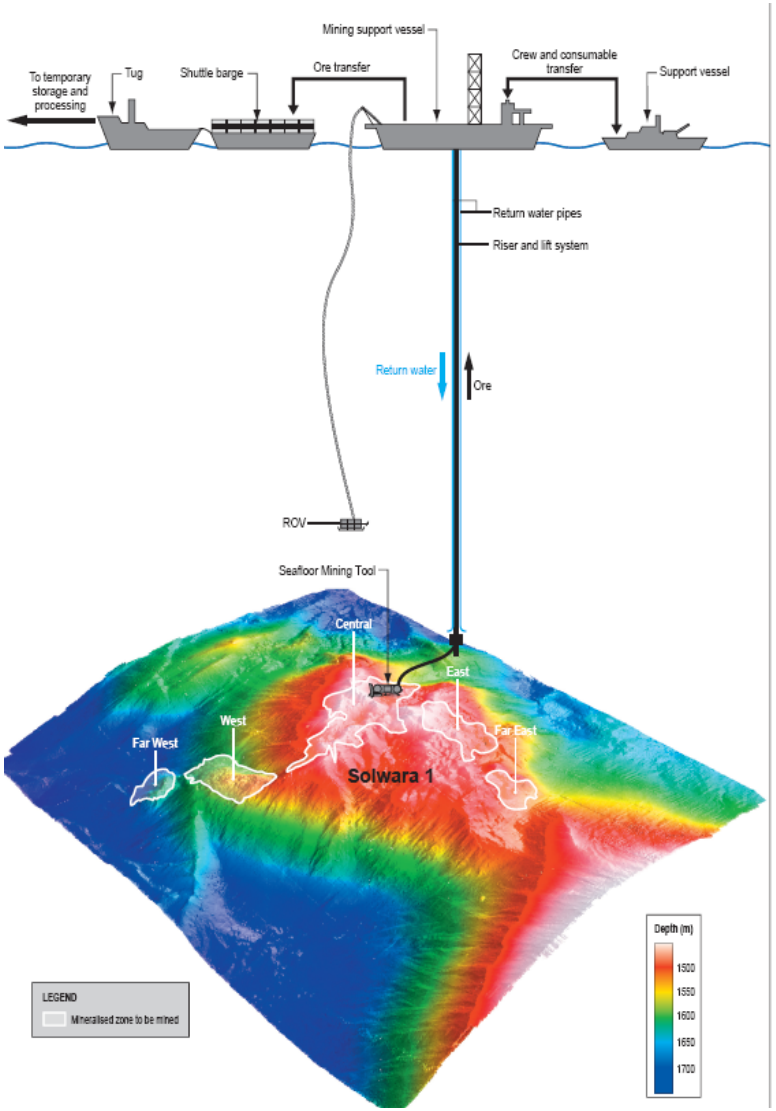
Return of treated effluent to the ocean floor

(Pumping of ore slurry (crushed ore materials + seawater)

Disaggregation, crushing and collection of ore



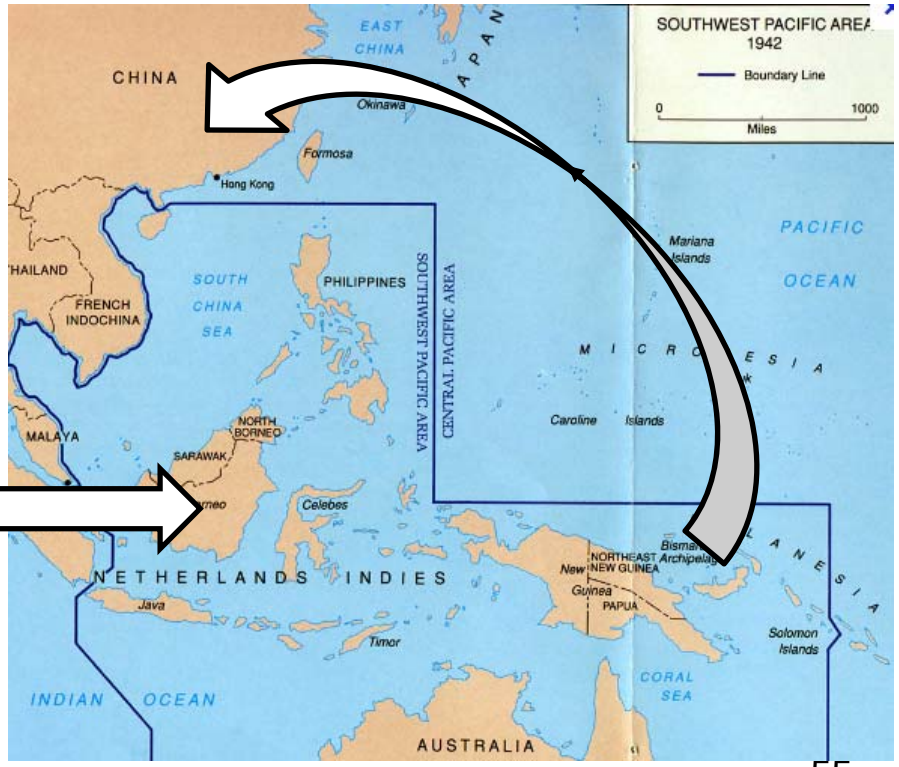
Potential Impacts of SMS Mining



- Destruction of biological communities associated with hydrothermal vents;
- Dispersal of fine sediments due to cutting, pumping and transfer of ore materials;
- Mining effluent may impact near surface organisms due to burst pipelines and/or prolong spillage;
- Availability of metal-rich fine sediments can cause bioaccumulation of metals through the food chain,
- The ocean has no physical borders hence mining of one area may affect other areas.

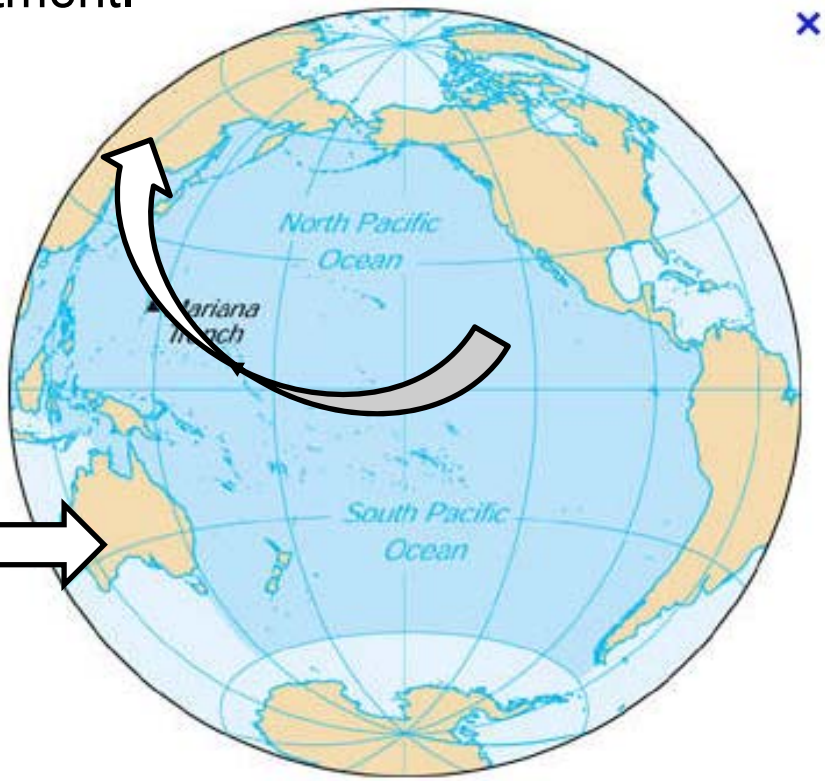
Proposed treatment of SMS ore

SMS ore will be de-watered and transferred to a ship to be transported to China for metallurgical treatment.



Proposed treatment of Manganese Nodules

Manganese Nodules will be washed and transferred to a ship to be transported to Asia for metallurgical treatment.



No treatment of Ore in the Pacific?

- The proposed shipment of deep sea minerals ore to Asia for treatment eliminates the challenges associated with waste management.
- Waste will be managed externally – in the country where ore will be processed;
- No need for a processing plant and tailings disposal in the region;
- Double handling of ore will be avoided (i.e. no ore stockpiling on-land).

Disadvantage of Overseas ore treatment

- Loss of downstream value addition:

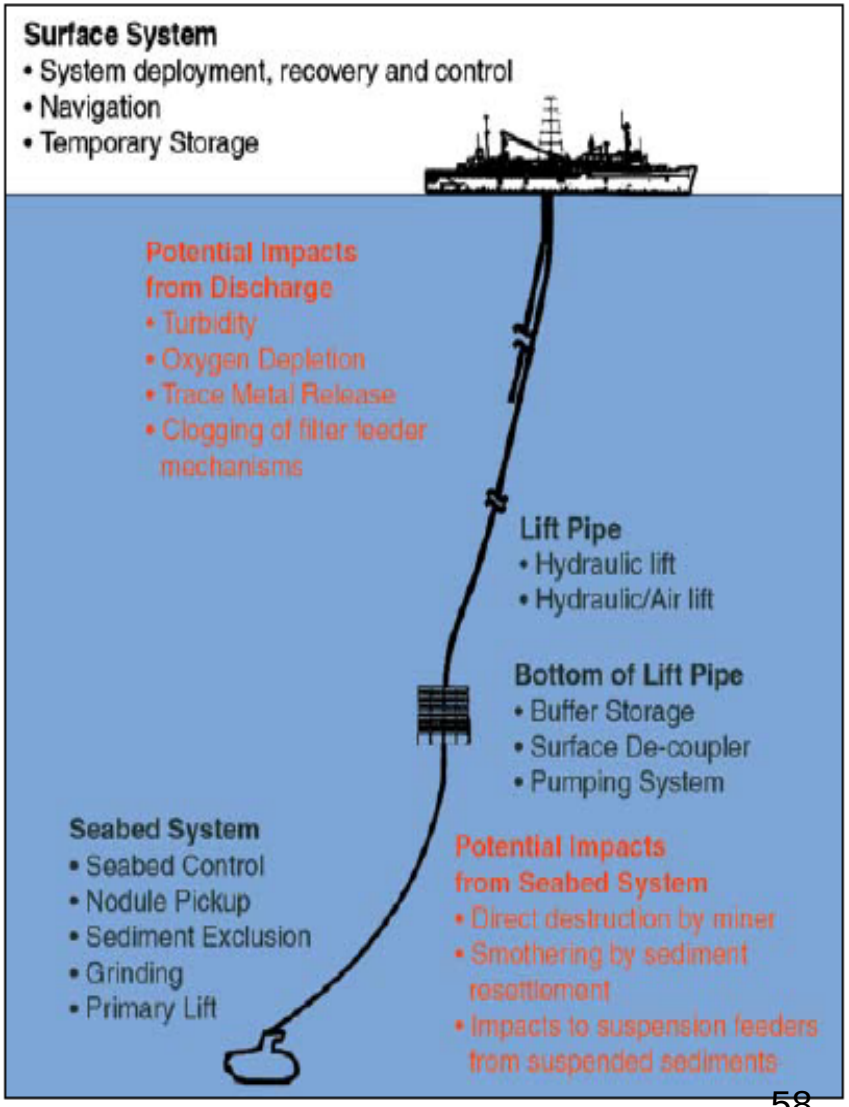
  - less Infrastructure

  - less employment

  - less indirect economic opportunities.

  - loss of additional revenue to the country

- This should be considered with the environmental costs of on-land ore processing in-country.



Comparison of Terrestrial and Offshore Mining

Terrestrial	Marine
Significant overburden	Huge water body (ocean) that needs to be dealt with
Generate significant amount of waste (overburden, tailings, leachates)	Reasonably less amount of waste generated
Huge footprint	Small footprint (SMS) Reasonable footprint (MN & CRC)
Often isolated and difficult to access	Located within territorial waters and EEZ
Huge infrastructure development	Far less infrastructure to be built
Acid Rock Drainage	Sulphuric acid cannot form in ocean (seawater being “alkaline”)
Complex resource ownership system	Common heritage of the nation
Reasonable knowledge of environment	Limited knowledge of environment

Ramu Nickel Mine