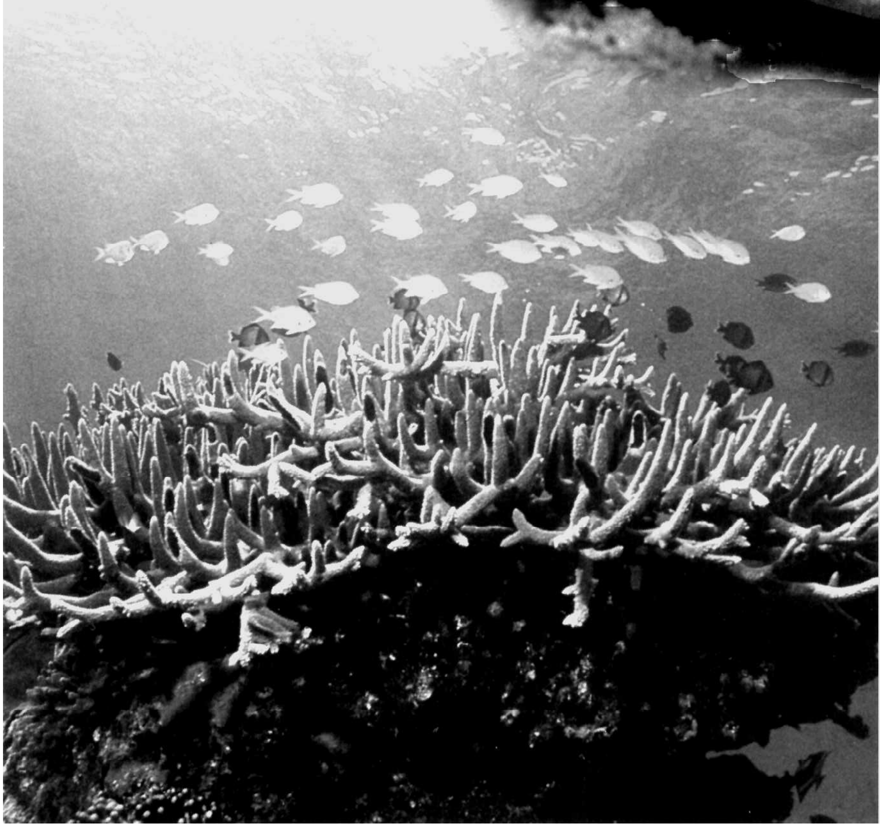
Environmental Risks associated with Submarine Tailings Discharge in Astrolabe Bay, Madang Province, Papua New Guinea.

A discussion paper commissioned by the Mineral Policy Institute, Sydney, Australia.

February 1999.



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THE MINERAL POLICY INSTITUTE

The Mineral Policy Institute was established in 1995 to address the rapidly increasing impact of minerals development world-wide, and specifically, the impacts of Australian minerals companies in the Asia Pacific region. It is a research and advocacy organisation based in Sydney, Australia.

Its principal goals are:

- Good mine management - To ensure that mining projects in Asia-Pacific comply with principles of ESD and social justice in their development, operation and closure.
- Preventing development of undesirable mining projects -To prevent the development of projects that would adversely effect areas of natural significance or are inconsistent with ESD principles and social justice.
- Mineral efficiency policies - To promote mineral efficiency (policy) as a means of reducing the number and impact of mineral exploration and mining projects.
- To provide support to communities requesting information on operations within the mining sector.

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INTRODUCTION

In late 1998, the Mineral Policy Institute (MPI) was approached by community groups in Papua New Guinea with concerns about the impact of waste from a proposed new mine on the environment in Madang Province. In response, MPI commissioned this scientific report. It examines the environmental risks which arise from proposed submarine tailings discharge (STD) from a nickel-cobalt mine near the Ramu River into the environment of Astrolabe Bay, Papua New Guinea.

SUMMARY

Highlands Pacific Limited is currently seeking finance for the development of a Nickel-Cobalt mine in Madang Province, Papua New Guinea. The mine will be located near the Ramu River, with processing facilities at Basamuk Bay on the Rai Coast. Basamuk Bay is a small embayment of the larger Astrolabe Bay. Highlands Pacific plans to dispose of mill tailings through a submarine outfall into Astrolabe Bay. Oceanographic conditions in Astrolabe Bay make this practise inadvisable if consideration is given to the ecological health of the Madang region.

BACKGROUND

A lateritic nickel deposit was discovered at Kurumbukari, a site south of the Ramu River, in the early 1960s and was owned by a succession of interests before the project was taken up by Highlands Gold in 1993. In 1997 the Highlands Pacific Limited Group, through its wholly owned subsidiary Ramu Nickel Limited, acquired Highlands Gold's 65% interest in the project and became manager of the Ramu Joint Venture.

A feasibility study indicating the technical and commercial viability has been completed and Highlands Pacific are currently seeking financial backing to allow the project to commence in mid-1999. Natural Systems Research of Hawthorn, Australia was commissioned by Highlands Pacific to prepare an Environmental Plan and this is expected to be released in February, 1999. In the Environmental Plan consideration is given to the problems facing the project in regard to the safe disposal of tailings material. In the assessment of this crucial subject, Natural Systems Research relied upon their own baseline studies, the work of Fluor Daniel Corporation, and that of other third parties.

Natural Systems Research (NSR) has provided environmental consulting services to the PNG mining industry for over 18 years. During this period they have been involved in various aspects of the Lihir, Misima, Porgera, Mt Victor, Walpolu and Chevron Gas Pipeline projects, amongst others. Fluor Daniel is one of the world's largest international engineering, construction, and diversified services companies, as well as having an important investment in low-sulfur coal. Fluor's coal operation, located in Central Appalachia, ranks among the top five U.S. coal companies and produces high-quality, low-sulfur steam coal for the electric-generating industry and industrial customers.

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In regard to the disposal of tailings from the Ramu Processing facilities, two options have been considered. These were to pump the tailings directly into the Ramu River or to release them as a submarine discharge into Astrolabe Bay. The latter proposal is now Highland Pacific's preferred option. There is substantial literature available on the environmental impact of riverine tailings disposal in Papua New Guinea, much of which has some bearing on the potential effects if used in the Ramu project. With regard to the small size of the Ramu River and the large human population dependant upon it, riverine discharge of mine wastes would be most inadvisable by any acceptable standards.

This analysis examines Highland Pacific's preferred option - the disposal of mill tailings into Astrolabe Bay. Highlands Pacific aims to place its processing plant at Basamuk Bay, a site on the coast some 40km south-east of Madang. At present Highlands Pacific favours the construction of a pipeline to 150m depth that will discharge over the 20 year life of the mine some 60 million tonnes of tailings into the ocean. This practise is known as Submarine Tailings Discharge and is now increasingly presented a safe and viable option by mining companies in the Pacific region.

Submarine Tailings Discharge

The aim of Submarine Tailings Discharge (STD) is to deposit wastes in stratified waters off continental slopes where it is likely the tailings will be trapped below the mixed surface layer and flow as a dense slurry to the deep ocean floor. It is vital that they will remain at this depth, as it is believed that they only present a serious threat to the environment if they enter the oxygenated, well mixed surface layers of the ocean. The loss and alteration of benthic (sea-floor) communities is considered one of the inevitable costs of STD, but in terms of significance it remains largely unquantified.

In theory STD can only be considered in areas that have no history of upwelling as such events could cause huge quantities of tailings to be brought to the surface of the ocean.

The direct disposal of mine tailings into the ocean has been practised in parts of the northern hemisphere for over 50 years. It is only in the last 25 years with the increase in environmental awareness and closer regulation, that mining companies have attempted to place tailings at depths below the well-mixed surface zone to mitigate adverse environmental effects. Recently new mines in the region have tended to discharge tailings at a depth of around 80-100m although some mines in the Indonesia/PNG region discharge below this level.

Submarine Tailings Discharge, or STD, has recently come into favour in Papua New Guinea where on-land disposal options are problematic. Two mines, Misima and Lihir, already use this technique. STD is an attractive option in PNG for several reasons. In comparison to on-land tailings retention, it is arguably safer both to local people and the environment. It is accepted that much of Papua New Guinea is unsuited to the construction of tailings dams due to rugged topography, seismic activity and high rainfall. These factors increase the likelihood of a disastrous dam failure. As tailings dams require continuous monitoring and post-mine remediation, STD is also cheaper in the long term.

In practice it is inevitable that STD operations will have adverse effects in the receiving environment

The mining industry considers STD to be a safe disposal option. The technique relies on the receiving waters being permanently stratified. That is, they have a distinct boundary between an upper well-mixed layer and a lower unmixed layer. If tailings are mixed to a density the same as that of the bottom water they will usually form a 'turbidity current' and travel to the bottom of the lower water body. Such turbidity currents generally require a seabed slope that is greater than 10-12° to occur on a continuous basis. In theory STD can only be considered in areas that have no history of upwelling as such events could cause huge quantities of tailings to be brought to the surface of the ocean (US Bureau of Mines, 1994).

In practice it is inevitable that STD operations will have adverse effects in the receiving environment (US Bureau of Mines, 1994). All STD operations around the world cause increases in suspended sediment, trace metals and residual milling reagent concentrations in the receiving waters. These components of the tailings can detrimentally affect or alter benthic invertebrates and fish, pelagic zooplankton and fish, and the phytoplankton and microbiota on which these animals rely.

THE ASTROLABE BAY SITE

Bathometry

The shoreline of Astrolabe bay is characterised by a series of canyons and intervening ridges. The canyons merge to form a single structure about 9km from shore at about 700m depth. Closer to shore the canyons are well-defined structures with steep sided walls. The average seabed slope to about 250m depth varies between 7° and 13°. Between 300m and 600m the average slope is around 3° and at greater depths the seabed slopes gently to the north at about 1°-2°.

In theory, submarine tailings discharges generally form a coherent density current on the seabed which transports the solids under the influence of gravity to greater depths. Deposition from these density currents generally occurs on seabed slopes less that 12° (NSR,1997b). In Astrolabe Bay these low slopes are reached at a depth of about 250m, and by 300m depth the slope is on average only 3°. It is therefore highly likely that substantial quantities of tailings material will be deposited in the vicinity of 300m depth, and will not be transported as a coherent flow to abyssal zones. The two other mines in PNG that use STD, Misima and Lihir, both have receiving submarine slopes that are far steeper than those in Astrolabe Bay. Misima is reported to be a model STD operation, largely as a consequence of the deep waters within a couple of kilometres from shore (Jones and Ellis, 1995). The same cannot be said of Astrolabe Bay. This difference is apparent in Figure 1 that shows diagrammatical cross-sections of the submarine slopes at the Misima, Lihir and Astrolabe sites.

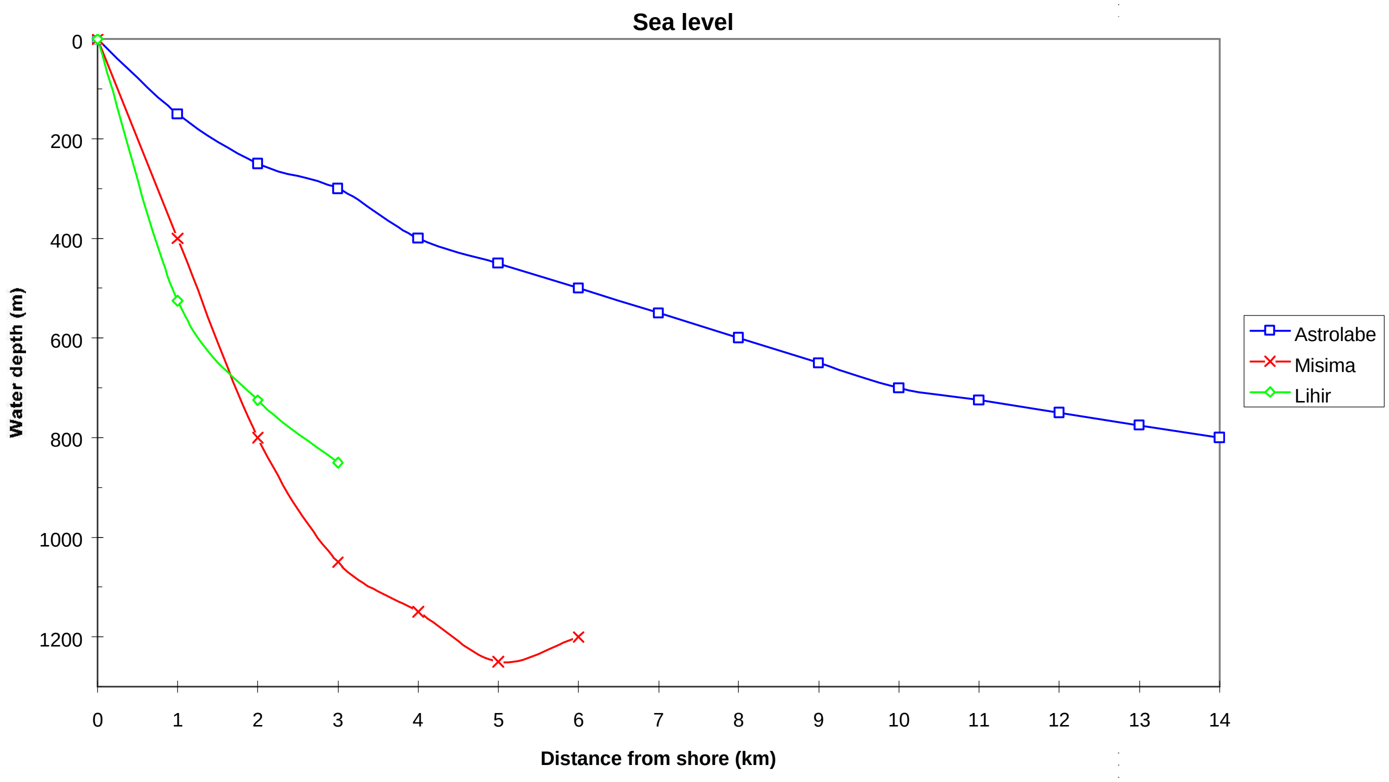

Figure 1. Cross section of submarine slopes at three mine sites in PNG (NSR, 1992, 1997a and 1997b).

While submarine canyons are undoubtedly major conduits through which turbidity currents, debris flows and slumps carry large volumes of continental sediments to the deep sea, it is naive to conclude that there is little resuspension of this material. For example in his study of Baltimore Canyon in the USA, Gardner (1989) found significant resuspension of sediment in the canyon axis in winter, early spring and sometimes over a whole year. There is no evidence that this resuspended material flows down the canyon floor - instead it generally flows away from the canyon along density discontinuities (the interface between two bodies of water with a different physical parameter, such as temperature or density, is called a discontinuity).

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Previous experience in the region with STD has shown that substantial quantities of tailings can separate from the primary tailings flow. This always occurs at the outfall site where the tailings generate turbulence in the water body, and usually occurs at discontinuities in the ocean water density profile. These 'plumes' of tailings disperse horizontally along these discontinuities. At Misima a significant quantity of tailings material has been found to separate from the descending density current and spread out horizontally. Although this metal-rich sediment remains trapped by thermal stratification below 150m depth it extends to a distance of 5km from the outfall (NSR, 1997b). There is every reason to suspect that this phenomenon will occur at the Astrolabe Bay STD site.

Oceanography

Natural Systems Research (1997a) in their inception report for the Ramu Nickel Mine stated that there is no information available on subsurface and bottom currents in Astrolabe Bay. This was incorrect. There is a modest amount of published research that calls into question the assumptions of Natural Systems Research, Fluor Corporation and Highlands Pacific concerning the safety of the STD proposal.

The oceanography of the northern New Guinean waters is dominated by a body of moving water known as the New Guinea Coastal Undercurrent (NGCU). The NGCU carries water from the Solomon Sea through the Vitiaz Strait and along the coastal region. The current has a maximum speed of 40-70cm per second (approximately 2kmph) at a depth of about 200m (Lindstrom et al, 1987; Butt & Lindstrom, 1994). The NGCU is a permanent feature of these waters despite reversals in wind and surface currents during the Northwest Monsoon. This water characteristically has high salinity, low tritium and high oxygen concentrations (Tsuchiya et al, 1990). It originates in the surface high-salinity cell centred around the Tropic of Capricorn in the South Pacific where it submerges and flows WNW in the South Equatorial Current (Church, 1987). This westward moving current hits the Australian coast at about 18ºS where it bifurcates, with the northward moving branch eventually becoming the NGCU. The location of the NGCU on the north coast of New Guinea in the vicinity of the development site is displayed in Figure 2. The NGCU flows along the Rai Coast and past the Basamuk Bay site. It continues on to the west and northwest, and in doing so generates a clockwise gyre in Astrolabe Bay.

Between June and August, South-East Trade winds generate surface currents along the Northern coast that flow from west to east; in the same direction as the sub-surface NGCU

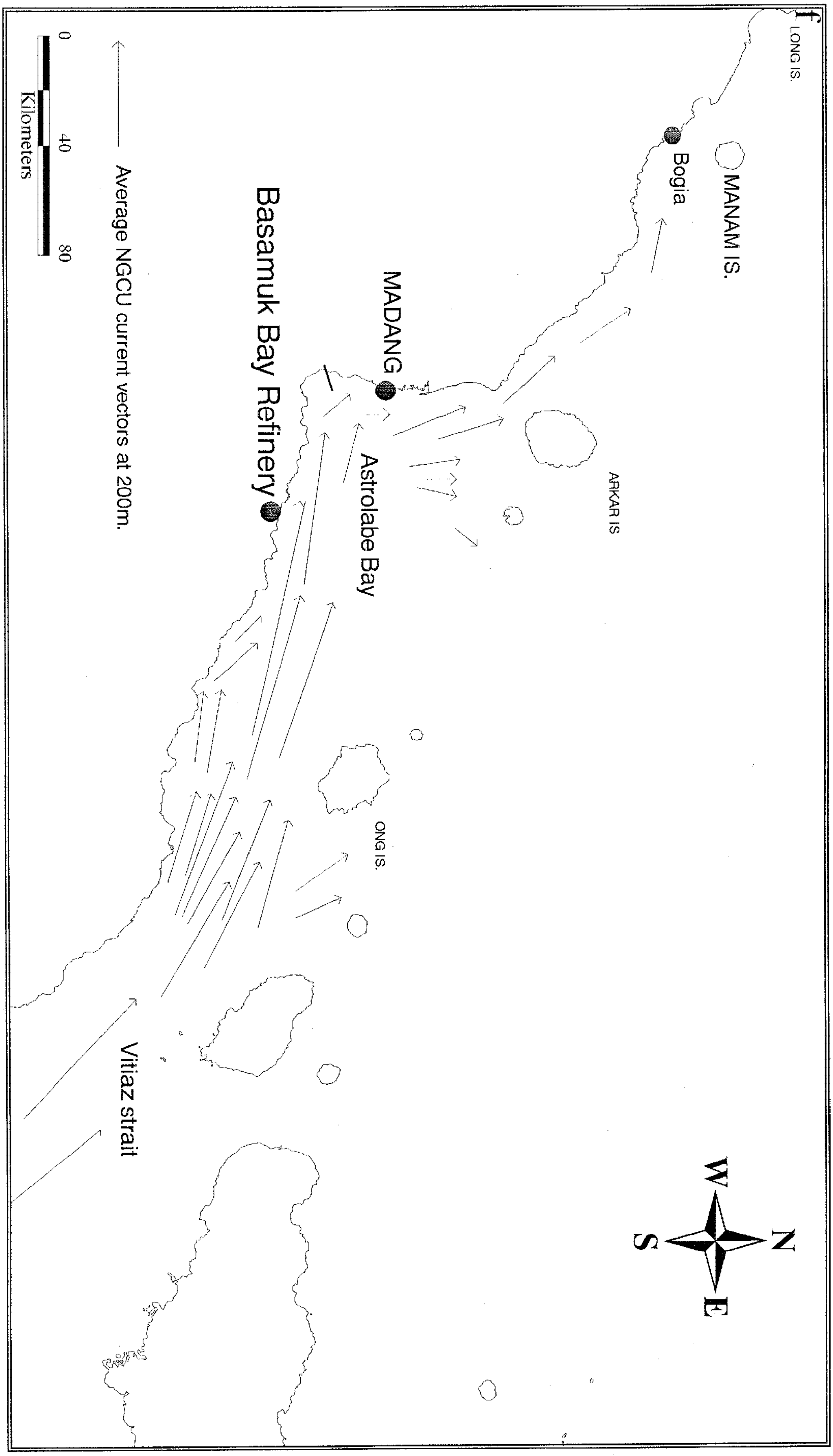

Figure 2. Current Map for the depth range 146-210m (Lindstrom et al, 1987; Butt & Lindstrom, 1994)

(Lukas, 1986). However during the North-West Monsoon (generally between December-March), an eastward moving surface current is generated that induces upwelling along the coast. Upwelling is the term used to describe the movement of water from deeper levels to the surface, a phenomenon that may be induced by several factors including offshore winds or where surface currents move in opposite directions. The upwelling water is of low temperature, high salinity and low tritium concentration (Colin et al, 1974), strongly suggesting derivation from the NGCU. It also gives rise to the high fertility of the Astrolabe Bay region (Colin et al, 1974). During the monsoon period the thermal structure of the coastal waters also clearly reflects coastal upwelling (Lukas, 1986). The onset of upwelling has been observed from the Christensen Research Institute at Nagada Harbour (15km north of Madang) where the NW Monsoon has been correlated with the distinct and rapid reduction in surface water temperature (CRI unpublished data).

DISCUSSION

The safety of Submarine Tailings Discharge depends upon the tailings being permanently deposited in a deep-water environment. It is not acceptable in areas where there is the risk of tailings upwelling to the surface layer of the ocean (US Dept of the Interior, 1994). This is because of the severe environmental impact of tailings when they enter the biologically active surface zones. Within the upper layers of the ocean, metals are easily oxidised and become readily available to biota. Further, high concentrations of suspended sediments also reduce fertility of surface waters through inhibition of photosynthesis and can directly effect the health of fish populations (Kline, E.R., 1994). Considering the nature of the Ramu ore body it is likely that the Ramu tailings will be rich in several metal species (cobalt, nickel and chromium) and will also contain high concentrations of reagents used in the extraction process. Several of the commonly used milling reagents are toxic in low concentrations. In this case it is likely that if upwelling carried mine-derived material into the upper layers of the ocean there will be a negative impact on the local marine ecosystem. Many, if not most locations in the Indonesian/Papuan Archipelago are relatively free of the risk of upwelling transporting tailings to the surface. The Astrolabe Bay site is however an exception.

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In comparison to other sites in the region, the submarine slope of Astrolabe bay is relatively flat making the development of a coherent density flow to deep waters unlikely. Consequently, significant quantities of mine wastes are likely to be deposited at depths shallower that 300m. Sediments at this depth are subject to irregular submarine storms that can cause resuspension. Further, the area within the 100-300m zone is subject to the permanent movement of the New Guinea Coastal Undercurrent that carries water along the New Guinean coast. It is highly likely that this current will carry with it tailings material and transport it to the west. While it is expected that tailings material will be rapidly diluted after its entrainment in the NGCU, on the basis of other STD case histories, one would expect high concentrations of tailings to be found in these waters for a considerable distance to the northwest of the site. During the NW monsoon, this water body, through its interaction with opposing surface currents, upwells along the coast. Consequently it is probable that tailings will be brought to the surface of the Astrolabe Bay coastline during the Monsoon period. If this occurs it will have a significant impact on the productivity and ecology of Astrolabe Bay and the Madang coastline.

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