FRIEDA RIVER

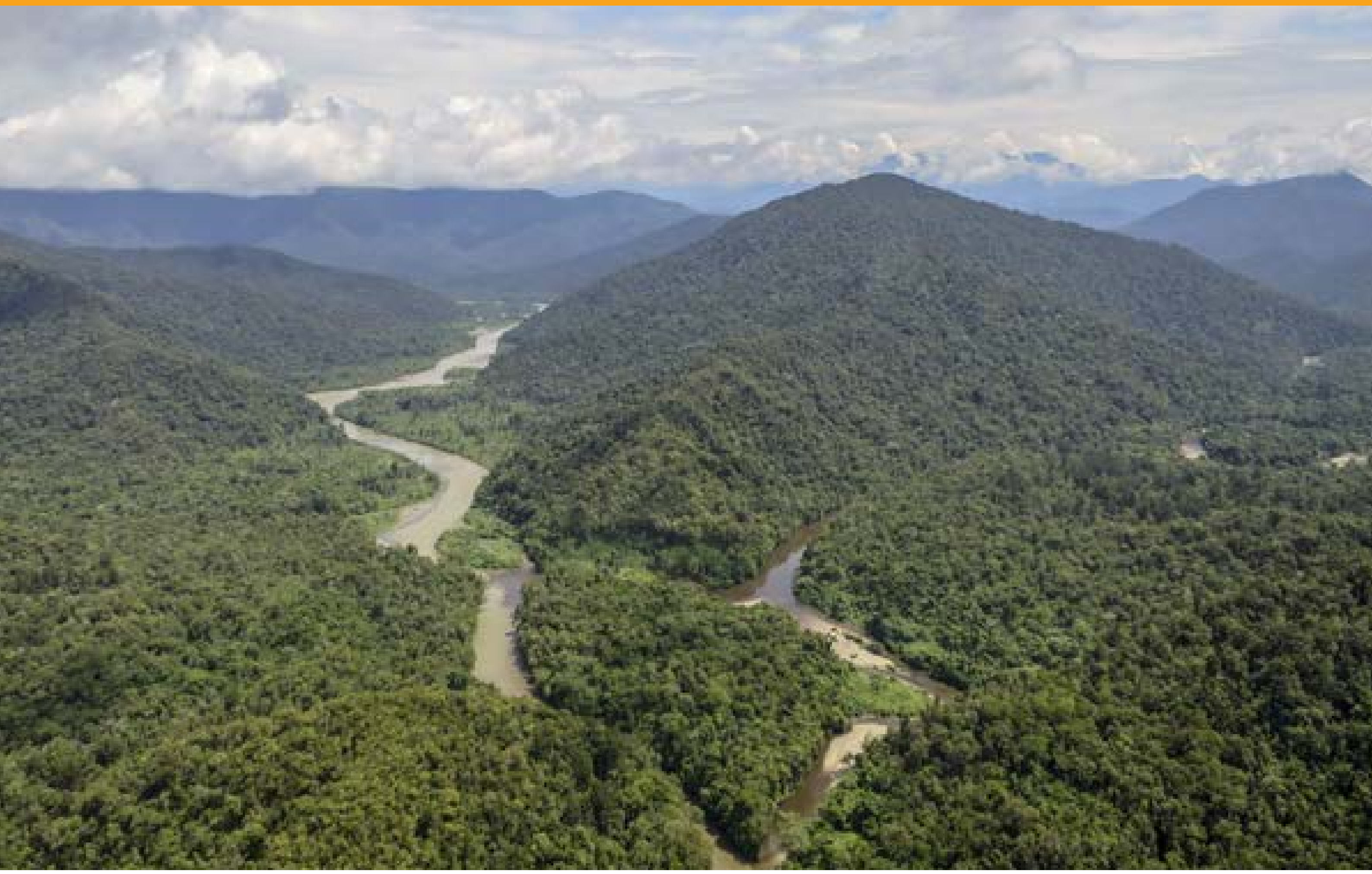
Frieda River Limited

Sepik Development Project

Environmental Impact Statement

Chapter 6 – Assessment of Alternative Development Options

SDP-6-G-00-01-T-084-008



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6. ASSESSMENT OF ALTERNATIVE DEVELOPMENT OPTIONS

Extensive work since 2014 has assessed many development options to determine the feasibility of the Project, minimise potential environmental and social impacts, and enhance potential social benefits. The development options considered prior to 2017 were focussed on the FRCGP but remain relevant to the Project. Key constraints considered in the assessment of alternative development options were:

- Economic constraints - driven by factors including the characteristics of the mineral deposits, Project development expenditure, fluctuating commodity prices and the need for the FRCGP to be in a position to extract and process the ore in a profitable manner throughout the commodity price cycle.
- Physical constraints - including the remote location of the mineral deposits, a lack of enabling infrastructure and the climatic, topographic and geotechnical constraints imposed by the landscape.
- Environmental constraints - prevailing environmental conditions and sensitivities of the Project’s setting.
- Social constraints - the locations, expectations, values and concerns of potentially affected communities.

The description of the Project contained in this EIS represents the current optimisation of the Project design, taking into consideration the economic, physical, environmental and social constraints. It is consistent with the Project as described in the feasibility study which will be submitted to the PNG Government as part of the Special Mining Lease application. It is anticipated that further optimisation will occur as the Project progresses through detailed design.

This chapter presents a summary of the main alternatives considered during design of the Project, focussing on those alternate development options with the greatest potential for environmental and social impacts.

6.1 Not Proceeding with the Project

The most fundamental alternative to consider is that the Project does not proceed. The direct consequences of not proceeding with the Project can be summarised as follows:

- The social and economic benefits described in Chapter 9, e.g., wages, royalties, training, community infrastructure, business development, community development programs and taxes, would be lost at all levels, i.e., landowner, and local, provincial and national governments. In particular:
  - Approximately 5,200 jobs at the peak of construction as well as direct employment for up to approximately 2,500 employees and contractors during operations would not be available. It is estimated that over 70% of these jobs would be for people from the Sandaun and East Sepik provinces.
  - Related to this, the training that these employees would receive and the experience they would gain during the Project would not occur, with the consequent reduced potential for employment on similar projects elsewhere in PNG should they so choose.

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- Significant economic benefits would be lost (ACIL Allen, 2018). These include an estimated increase to PNG's real GDP to the year 2060 of PGK96.5 billion[1] and increase real income by PGK84.7 billion. For the Sandaun and East Sepik provinces, the Project is estimated to increase real GDP by a cumulative total of PGK83.6 billion and increase real income by PGK39.2 billion. Large indirect economic impacts for supporting industries would also be foregone.

- The benefits to local communities through the development of infrastructure as part of the Project would not occur. This would include the extension of the existing road between Vanimo and Green River to Hotmin, upgrade of the airport at Green River, construction of bridges (including the bridge across the Sepik River) and the provision of power infrastructure for potential distribution to nearby communities.
- The FHREP would not be developed, which offers a renewable energy source for Sandaun and East Sepik provinces well beyond the expected operating life of the FRCGP and supports the PNG Government's development strategic plans.
- The consequent biophysical and social impacts described in Chapters 8 and 9 associated with the development of the Project would not occur.

6.2 Assessment Process and Methods

Since 2014, FRL has assessed the alternative options of the project in several phases. The primary phases of this assessment consisted of:

1. Initial assessment of alternative cases based on the information collected by the previous owner. A development concept was identified for 25 Mt/year of ore processing over 20 years supported by riverine transport logistics and a tailings storage facility in the Ok Binai Valley.
2. Re-evaluation of the previous owner's 2012 feasibility study findings including: review of the geological database; metallurgical test work to gather additional information on the likely first five years of mill feed for the proposed process plant; location of the ISF; open-pit hydrogeology; and, open-pit slopes.
3. Development of the 2016 feasibility study. The results from this re-evaluation led to the selection of a nominal 40 Mt/year FRCGP development scale and an ISF that provided limited hydroelectric power generating capacity (60% of the mine's power requirement from Year 5 of operations). During this assessment trade-offs between initial capital cost, long-term operating costs, scale, expansion and, importantly, risk profile, were examined. This Project scope was adopted for the 2016 feasibility study and subsequent 2017 feasibility study addendum.
4. Resource drilling program and inclusion of the Ekwai and Koki Mineral Resources in the mine plan for the 2017 feasibility study addendum.
5. Development of the nation building scope. This linked the FRCGP to regional development projects consistent with national and provincial government plans for the Sandaun and East

[1] An exchange rate of US1$ = PGK3.15 has been used.

Sepik provinces. This involved assessment of a shared use model for infrastructure, including: the hydroelectric power facility (FRHEP); ocean port, regional road and airport (SIP); and transmission line (SPGP). The FRCGP was then reassessed based on this shared use model.

The preferred option was selected by using multiple account analysis. This method is a multi-disciplinary, group decision-making tool to address the technical, economic, environmental and socio-economic factors for the options considered. Available options were first assessed in isolation for specific Project elements, some were then combined and the analysis was re-run to confirm the preferred option.

The key elements that influenced the selected Project design and layout, included, in order of importance:

1. Mineral Resource.
2. Mine scale.
3. Infrastructure requirements.
4. Mine waste storage.
5. Management of final open-pit void.
6. Mine waste transport.
7. Product transport and logistics.
8. Power supply.
9. Location of ports and airports.

The alternatives for each of these elements are discussed in the following section.

6.3 Alternatives Considered in Project Planning

This section describes the alternatives considered for key elements of the Project.

6.3.1 Mineral Resources

Four significant Mineral Resources, including combinations, were considered during the course of studies associated with the FRCGP:

- Horse-Ivaal-Trukai (HIT) porphyry copper-gold deposit.
- Ekwai porphyry copper-gold deposit.
- Koki porphyry copper-gold deposit.
- Nena epithermal copper-gold deposit.

The combination of Horse-Ivaal-Trukai, Ekwai and Koki (HITEK) deposits was selected as the preferred option. It provides a lower risk for mine operations by increasing the number of available work areas, allows reliable mill feed to be maintained and offers increased Mineral Resource extraction and mine life.

Alternative mining configurations, such as exclusive development of the HIT deposits, were excluded as preliminary mine planning indicated the resulting mill feed at 40 Mt/year was insufficient to generate acceptable economic returns. The Nena deposit was not included in the base case as it would require significant additional capital costs for dedicated mining facilities and an alternative ore processing method suited to the Nena deposit's mineralogy (which is significantly different to HITEK). There is an opportunity to develop the Nena deposit using alternative processing methods post-construction of the HITEK concentrator to increase Project value and Mineral Resource recovery. This approach leverages the shared facilities established for the Project and reduces the capital cost to bring the Nena deposit into production as a brownfields development.

6.3.2 Mine Scale

The scale of the mine was driven by the following key considerations:

- The FRCGP's remote location and resultant high infrastructure costs.
- The low-grade nature of the HITEK copper-gold porphyry deposits.
- The need for subaqueous deposition of the majority of mine waste rock and tailings to limit the potential for oxidation of sulphide material to generate acid and metalliferous drainage.
- Minimising the operating costs and all-in sustaining costs to ensure the Project is commercially sustainable throughout the commodity price cycle.
- Providing an acceptable economic return to investors and a reasonable payback period for financiers.

Careful consideration of a project's scale is required to avoid commercial and technical failure. Scaling a project too large requires greater upfront capital expenditure and exposes the project to greater construction and logistics requirements. Scaling a project too small, while reducing construction risk, exposes the project to increased economic risk, particularly with regards to metal price cycles. The smaller scale Project scope was burdened with similar initial fixed infrastructure capital expenditure, but has higher operating costs that decrease margins and lower revenue generation which reduces economic returns.

Lower operating costs are particularly important for a large low-grade deposit, such as HITEK. The grade distribution and geometry of these deposits allow the first stage of the FRCGP to source higher grade mill feed at a lower strip ratio. These conditions provide higher revenue and lower operating costs over the initial production years and support a sustainable operating cash flow. Conversely, margins will decrease over time as the copper grade declines, the ore hardness increases and the open-pit strip ratio increases. As such, lower grade porphyry deposits such as HITEK favour a lower operating cost framework to maximise resource exploitation.

A process plant with an average throughput of 44 Mt/year was selected and alternative scaled process plants with feed rates of 20, 25 and 65 Mt/year were rejected. The lower throughput options were rejected based on lower cash flow due to higher operating costs; the higher throughput option was rejected as a starter project due to high capital expenditure and greater construction risk associated with the complexity of constructing a larger project.

6.3.3 Infrastructure Use

Two alternatives were considered for the use of Project infrastructure including the hydroelectric power facility, ocean port, access road, airport and transmission line. These two alternatives were:

- Dedicated use of infrastructure for FRCGP.
- Shared use model for infrastructure.

The shared use model was selected as the preferred option as it has the potential to reduce the capital and operating cost of the FRCGP, aligns with the PNGDSP to develop an economic corridor in Sandaun Province (see Section 2.4) and offers a positive long term socio-economic contribution to the region.

As discussed in Section 6.3.2, capital and operating costs must be minimised to improve the financial viability of low grade deposits such as HITEK. Developing shared use facilities will reduce these costs for the FRCGP and allow the infrastructure facilities to function as independent operations with revenue from both the mine and other users.

6.3.4 Mine Waste Storage

Test work on mine waste has shown that the majority of tailings and waste rock that will be generated from the mine is potentially acid-forming (PAF). This is typical for large porphyry copper deposits.

Prior to 2014, a number of alternative options for tailings disposal were investigated at the pre-feasibility stage. Two options were assessed in more detail with a focus on minimising the exposure of acid-forming material. The first option was a large co-disposal facility in the Ok Binai valley to store all waste rock and tailings. The second option was a combination of a valley dam for all waste rock and approximately 10% of NAF tailings and a large tailings storage facility (TSF) on the Sepik River plain in the Kaugumi Creek area storing PAF thickened rougher tailings.

The latter option on the Sepik River plain in the Kaugumi Creek area consisted of a shallow, relatively flat facility containing thickened rougher tailings (approximately 60% solids by mass) with a beach slope of approximately 3%. This design would create a final landform that would naturally shed water but expose PAF material to the elements.

A TSF site on the Sepik River plain also presents additional risks and challenges due to the unknown depth of sediments and poor geotechnical ground conditions associated with the swampy setting. These conditions increase the potential risk of failure of a conventional TSF due to settlement and bearing capacity issues. To address these risks, the potential for paste thickened tailings, where the tailings slurry is dewatered using vacuum or pressure filters, was also investigated for a TSF on the Sepik River plain. The footprint for this facility would be in the order of 20 km^2. While this approach could improve the stability of the TSF, it would not address its long term geochemical risks.

The closure of either of these facilities would require construction of a cover over the tailings to limit the generation of AMD. In addition to the difficulty in constructing this final cover, this facility would occupy a large footprint in the Sepik River floodplain and present significant stability risks.

Some other mines in PNG use deep sea tailings placement (DSTP) to manage tailings: Lihir, Ramu and Simberi are operating mines with DSTP; Misima is a now-closed mine which used DSTP; and Woodlark is approved to use DSTP but the mine has not yet commenced construction. The concept of DSTP for the Project was considered but discounted for the following reasons:

- While there is deep water relatively close to shore off the north coast of PNG, this coastline is situated approximately 200 km from the mine area in a straight-line distance, and even further assuming a technically-viable overland pipeline route could be found.
- The capital cost to construct an overland tailings pipeline (which would likely be in the order of one metre in diameter) was prohibitive.
- The operating cost to pump the tailings slurry through the mountains from the mine area, across the Sepik River floodplains, up and over the Northern Coastal Range and to the north coast of PNG, while ensuring that the tailings slurry did not settle in the pipeline, was prohibitive. The overland tailings pipeline would also likely require replacement at least once during the life of the mine, at considerable cost to the operation.

- The Project would still be required to store PAF waste rock in a manner which would permanently limit the potential for AMD.

As a result, TSFs at Kaugumi Creek and on the Sepik River plains, and DSTP were discounted as tailings management methods for the Project.

Management strategies that would leave PAF waste rock and tailings exposed to air (commonly known as ‘subaerial deposition’) were rejected due to the high environmental impact arising from AMD. Further consideration focussed on management strategies that would leave the tailings and waste rock permanently submerged under water (commonly known as ‘subaqueous deposition’) to limit oxidation of sulphide material. FRL’s approach is to contain the Project’s mine waste rock and tailings within engineered structures within the practicable confines of the immediate Project area. This approach eliminates riverine tailings and waste rock disposal methods that have been, or are being, applied at other mines in PNG including Panguna, Ok Tedi, Tolukuma and Porgera.

FRL considered three alternative options for the location of the ISF to store tailings and waste rock using subaqueous management of PAF material as shown in Figure 6.1:

1. Frieda River catchment.
2. Nena Valley.
3. Ok Binai Valley.

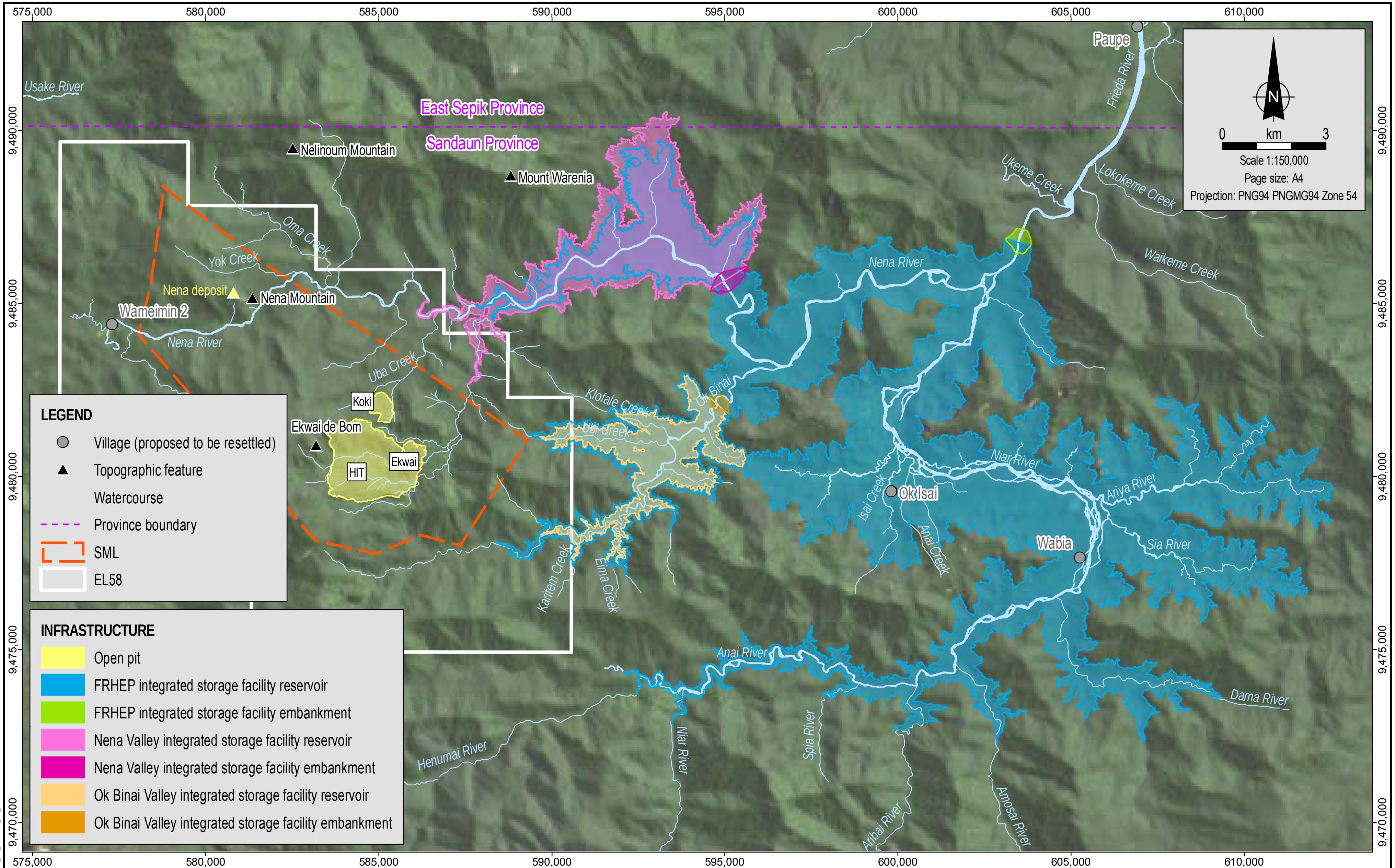
The Frieda River catchment was selected as it provided a higher power generation capacity, a large storage volume that supports an extended mine life and preferential geotechnical conditions for long-term stability of the ISF. An ISF located within the Frieda River catchment has the potential to store 4.9 billion tonnes of waste rock and tailings whereas the proposed Project design requires 2.9 billion tonnes of storage capacity. Hence the Frieda River location will accommodate a potential life extension of the FRCGP. The Frieda River catchment option will provide full power generation for the mine compared to the Nena Valley option that would only supply approximately 60% of the mine’s power requirements through hydroelectric power generation. The Ok Binai Valley ISF would support less than ten years of operation with no hydroelectric power generation and would require expansion to an additional ISF location and hence a larger footprint.

Several considerations influenced the selection of NAF waste material storage method.

1. NAF waste material properties. Some NAF waste material cannot be safely or efficiently passed through the primary crushing, conveying, stockpile and barge loading system. Organic material containing vegetation, topsoil and soft clayey materials are especially problematic and require waste dump placement by haul truck.

2. Timing. The primary crusher, conveyor and barge loading system will not be available during the pre-production period because of the lead time for mine pre-stripping ahead of process plant operation and the ISF water level being too low for barge operation. Pre-stripping will also occur as the open-pit is expanded laterally meaning that topsoil, organic material and soft NAF waste will be encountered periodically over the mine life.

3. Topography. The narrow undulating terrain between the HITEK open-pit and the ISF does not allow construction of a cost-effective road that accommodates large haul trucks.



MXD Reference: 11575B_11_GIS001_v0_5

Source:
Infrastructure, roads and tenements from FRL.
Villages, topographic features, watercourses and water bodies from FRL and Coffey.
Provinces from NMB.
Landsat satellite imagery from FRL (capture date unknown).
Hillshade DEM from SRTM.

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Integrated storage facility options

Figure No: 6.1

Three options to store NAF waste material were assessed:

1. Placement of all NAF waste rock in a waste spoil dump.

2. Placement of only organic material in a waste spoil dump with all other NAF waste rock placed in the ISF.

3. Placement of organic material, topsoil and NAF waste rock in a waste spoil dump with other NAF waste rock placed in the ISF.

Disposal of competent NAF waste rock in the ISF provides a higher production capacity and will have a lower operating cost. Therefore, it is preferable to place NAF material in the ISF. Option 1 was therefore rejected as it would not provide the necessary production rates and would incur a higher operating cost than the other options.

The properties of the organic material, topsoil and clayey NAF waste rock make it unsuitable for the primary crushing and waste handling system. Furthermore, the mechanised waste handling system will not be available for the pre-strip phase of open-pit mining which excludes Option 2. Therefore this material, including topsoil that will contain organic material such as tree roots, is proposed to be placed in the waste spoil dump. Periodic placement of NAF material in the waste spoil dump will also be required as the open-pit expands laterally and organic material, topsoil and clayey NAF waste rock is removed by future pre-stripping operations.

Option 3 was selected as it satisfied all considerations for waste material storage.

6.3.5 Management of Final Open-pit Void

FRL considered two options for the management of the final open-pit void:

1. Backfilling with waste rock.
2. Allowing the void to naturally fill with water.

Backfilling the large open-pit void with waste rock after the cessation of mining is not practically possible because of the subaqueous waste rock deposition plan and would impose a significant cost impost on the FRCGP that would severely impact its economics to the point where it would not be economic to proceed. Mine planning does not allow for the sequential backfilling of the open-pit and given the topographic setting and high rainfall it is not possible to store the large volumes of waste rock for the life of the mine to allow backfilling as part of mine closure without the risk of creating AMD. It would also impose significant cost on any future development of the deposits, should economic circumstances permit.

Allowing the open-pit void to fill naturally with groundwater and surface water runoff will:

- Limit the aerial extent of exposed open-pit walls that have the potential for the onset of acid-generating conditions, noting that significant wall exposures above the pit lake will exist even with flooding.

- Allow for relatively easy access to the deposits in the event of future development.

6.3.6 Mine Waste Transport

Options considered for transport of mine waste rock approximately 7 km from the open-pit to the ISF included the following:

- Crush, slurry and pipeline.
- Truck haul and direct tip to barge.

- Crush, convey (using a conventional conveyor) and barge.
- Crush, convey (using a rope-supported conveyor) and barge.

The crush, convey and barge option using a conventional conveyer was selected based on the following considerations:

- Lower capital and operational cost than the pipeline option.
- Lower environmental impacts of a conveyor compared to truck haulage due to the smaller construction footprint.
- Trucking large quantities of material across steep terrain would introduce safety risks and constrain operations during very wet conditions.
- Establishing a road that accommodates large haul trucks was found to be cost prohibitive due to topography.
- A conventional conveyor is proven at the proposed scale of operations and has increased operational reliability compared to a rope-supported conveyor.

6.3.7 Product Transport and Logistics

The location of the FRCGP and the FRHEP, and lack of existing infrastructure, will require a considerable amount of construction and operational equipment and materials to be imported. While this section describes the options considered for product transport and logistics, transport and logistical requirements for imported items were considered concurrently to ensure an optimal transport strategy for both import of equipment and materials and export of product.

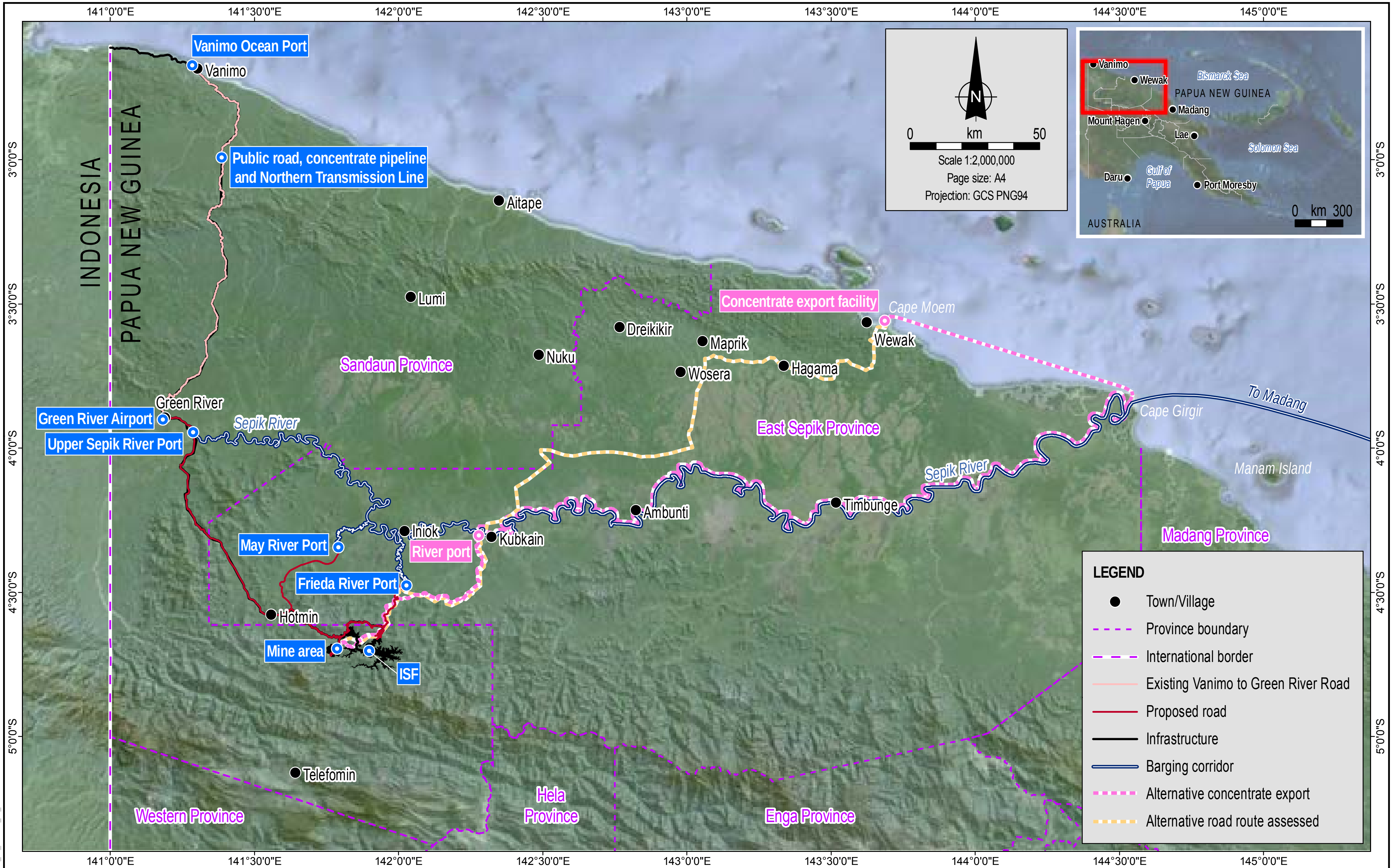
Figure 6.2 shows the alternative product handling options that were considered for overland transport of concentrate. These included:

- Pipeline to Vanimo.
- Road transport to Vanimo.
- Road transport and pipeline to Wewak.
- A combination of road, pipeline and riverine transport to Wewak.

A slurry pipeline that follows the road alignment to the Vanimo Ocean Port was selected as the preferred option due to the following considerations:

- Reduced disturbance footprint due to use of an existing road from Vanimo to Green River.
- Lower operating cost, complexity and time to market compared to concentrate trucking.
- Fewer transport nodes and better concentrate transport reliability compared to barging due to potential for disruption on the Sepik River and weather delays.
- Limited truck haulage improves road transport safety and limits disturbance to local communities located along the infrastructure corridor.
- Lower risk of concentrate loss and spill causing environmental or social impact.

An alternative road and pipeline from the mine site to Wewak was rejected due to high capital costs, extended construction timeframe, and significant environmental constraints. Figure 6.2 shows an indicative alignment for the road alternative to Wewak.



MXD Reference: 11575B_11_GIS002_v0_3

Source:
Infrastructure and roads from FRL.
Villages from FRL and Coffey.
Provinces from NMB.
Imagery from Google Earth (capture date unknown).
Hillshade DEM from SRTM.

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Date: 28.08.2018
Project: 754-ENAUABTF11575B
File Name: 11575_11_F06.02_GIS

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Product transport and logistics options

Figure No: 6.2

A road to Aitape was considered during a previous feasibility study for the FRCGP. This option was rejected as it would require a route through the Torricelli Mountains which are known to host a dense concentration of narrowly restricted endemic fauna, including three critically endangered mammal species. Abandoning this option was considered likely to reduce potential impacts on species of conservation significance. Also, Aitape does not provide suitable port facilities compared to Vanimo.

6.3.8 Power Supply

Power supply to meet the required demand of the FRCGP is one of the key considerations for the Project's viability. The total installed power generation capacity in PNG is approximately 738 MW (PNG Power, 2016), and existing transmission networks are isolated and provide localised power to few major towns and centres. As described in Chapter 5, the peak power demand for the FRCGP is 280 MW and approximately 2,200 GWh/a energy demand representing approximately 40% of the country's presently installed capacity.

Power supply options assessed for the Project have included thermal power generation and renewable power generation.

Thermal power generation options considered included:

- An intermediate fuel oil (IFO) power station located near the Sepik River, the ISF embankment or the process plant.
- The construction of a gas-fired power station located at the Stanley gas field to the south of the Project in the Western Province. An associated 150-km-long transmission line would be required across the Hindenburg Range to a substation adjacent to the mine area.
- The construction of a coal-fired power station near the Sepik River or at Wewak with an associated transmission line to a substation adjacent to the mine area.

Renewable power sources considered included:

- Hydroelectric power generation using a large reservoir located in the Frieda River catchment, independent of mine waste storage.
- Hydroelectric power generation making use of the water stored in the ISF.
- Run-of-river hydroelectric power generation in the upper catchment of the Nena River.
- Solar, wind and geothermal energy.

Solar and wind power supply are not suitable for total power demand given local climatic conditions. No viable local geothermal source has been identified. Therefore, these options were not considered further.

Studies confirmed that a hydroelectric power scheme or a gas-fired or coal-fired power station could be feasible. Power supply via a gas-fired power station was subsequently discounted as the required level of confidence in a suitable local gas resource could not be established and there would be a significant technical challenge in securing a route and constructing power lines over the Hindenburg Range. A coal-fired power station was discounted due to the higher capital cost, the need to import coal and dispose of ash, the higher operating costs and greenhouse gas emissions.

A stand-alone hydroelectric power generation scheme using a large reservoir was discounted for the current Project configuration because of high upfront capital costs. The run-of-river hydroelectric power option did not offer sufficient power generation capacity to pay back the capital within the life of the Project and required a supplementary power source to meet the Project's demand.

A hydroelectric power scheme using the ISF provides the lowest overall energy cost and reduces the greenhouse gas emissions over the life of the Project compared to thermal power options. The hydroelectric power station will provide 100% of total energy demand for the FRCGP and provides an opportunity to produce excess power for distribution via a transmission line to other customers (SPGP). The hydroelectric power scheme will provide a reliable source of renewable energy beyond the operating life of the FRCGP and therefore has the potential to provide a positive long term socio-economic contribution to the region.

6.3.9 Ports and Airports

Concentrate Export Facility

The following concentrate export facility options were considered (see Figure 6.2):

- Onshore facility located at the existing Port of Wewak, Cape Moem.
- Onshore facility located at east or west Vanimo.

Vanimo Ocean Port on the eastern side of Dakriro Bay was selected as the preferred option due to its sheltered position, synergies between concentrate and freight logistic activities, and alignment with the Vanimo City Master Plan.

The preferred option for freight and concentrate export is an onshore ocean port operated by a third party provider at Vanimo.

Airport

Four potential locations were considered for the airport:

1. Frieda River, i.e. upgrade of the existing Frieda River airstrip.
2. Hotmin.
3. Green River.
4. Kaugumi Creek.

The Green River Airport was selected as the preferred option as it can accommodate larger aircraft than the other locations, is less impacted by weather conditions, offers favourable terrain with fewer obstacles, and is more accessible for other users which aligns with the SIP objectives to provide shared use facilities. Upgrading the existing Frieda River airstrip only allows one-way landing and has higher capital costs and therefore was consequently excluded for use by large passenger aircraft during operations. However, this airstrip will be used for some personnel transport (e.g., management personnel on shorter rosters and some Zone 2 employees) and emergency purposes during construction and operations.