Attachment 3b: Siecap Taranaki VTM Project Pre-Feasibility Study Offshore Iron Sands Project 25 March 2025 - Part2

Distribution panels for 415 V and 230 V circuits will be equipped with small circuit breakers, located behind a door. They will be as much as possible grouped together and per deck on the same position.

Outgoing circuits such as switches in the distribution panels will be provided with an operation switch with control lamp “power on”. Nameplates will be provided for all devices on the door describing their function.

Power distribution panels
The necessary power distribution panels are installed. Each box will be provided with a main switch and a circuit breaker for each outgoing group. Each power distribution panel has one spare group. Power distribution panels are directly fed from the relevant switchboard. They will be provided with voltage available indication lamp and with earth fault indication lamps with test pushbutton.

Lighting distribution panels
For lighting the necessary lighting distribution panels are fitted. Each box has two spare groups. Lighting distribution panels will be provided with earth fault indication lamps with test pushbutton.

230 V UPS distribution panels
The required 230 V UPS distribution panels are provided with a main switch and with 2-pole circuit breakers. They are provided with earth fault indication lamps with test pushbutton.

24 V DC distribution panels
The required 24 V DC distribution panels are provided with a main switch and with 2-pole circuit breakers. They are provided with earth fault indication lamps, with test pushbutton.

518 Control desks and panels

At least the following control desks will be provided in the various control stations:

One (1) navigation desk shall be installed in the wheelhouse. The navigation desks shall be designed in such a way that one (1) single operator can operate all essential controls when seated. The navigation desk shall contain all necessary equipment to navigate the Vessel.

One (1) mooring desk shall be installed in the wheelhouse. The desk shall contain all necessary equipment for the mooring system, including read-out and control of all mooring winch parameters and thruster parameters.

One (1) communication desk shall be installed in the wheelhouse. The desk shall contain all necessary equipment for communication such as VHF radio, Inmarsat terminal radio terminal etc.

For the process plant Owner Furnished control desks with all relevant equipment will be installed in the process plant control room.

For the SSED’s two (2) production automation desk will be located in the crawler control room with all relevant read-outs and controls to monitor the crawler production process.

520 Communication system

All required radio equipment for GMDSS-area A3 shall be installed.

- Short-range communication systems

- GSM telephone
- Maritime safety information systems
- Emergency position indication beacon
- Search and rescue radar transponder
- Long-range communication
- Satellite communication system
- Portable communication system
- Three (3) GMDSS-VHF transceivers, complete with lithium batteries, three (3) spare batteries
- Emergency power source
- Radio console

For reception of off-air FM and AM signals a TV-FM omni-directional aerial together with an AM-whip aerial shall be installed. Also a satellite system with disc aerial and a head station shall be installed.

A 250-way exchange with a connection for outgoing calls from specified places, a possibility for priorities, four (4) simultaneous calls and wireless telephone system shall be installed. Connection for in- and out coming calls from GSM telephone, Inmarsat B-terminal, and when lying along quay wall public telephone net.

A public address system shall be installed with watertight loudspeakers in way of lifeboats, in stores, laundry, change room, common wash places and loudspeakers in the alleyways of accommodation, mess room, offices and public spaces.
The system can be operated from the automatic telephone system.
The public address system shall be connected to the 230 V 50 Hz emergency system and the 24 V DC system.

A docking talk-back system with a master in the navigation desk and substations on bridge wings and on the Forecastle and aft deck shall be installed.
System shall be connected to the 230 V 50 Hz emergency lighting system.

530 Navigation positioning system

530.1 Navigation system

The following navigation equipment shall be installed:

- GPS navigator, 24 V DC with antenna.
- Isolated NMEA distribution box for various users.
- Navigation echo sounder, with 50 kHz transducers, digital repeater in navigation
- For survey three (3) selectable transducers shall be fitted with cabling to the survey desk.
- Gyro compass system with control and transmission unit, automatic changeover relay, normal supply 230 V 50 Hz, backup supply 24 V DC.
- Electric magnetic speed log, water track.
- Dual antenna satellite based ship measurement system, for speed indication forward, aft wards and sideward fore-aft. Speed output on display in navigation desk, and to other users.
- Approved dual ECDIS system with two (2) monitors 21 inch high resolution. One system should be capable of operating as conning display for the display of gyro, rudder angle, rate of turn, speed over the ground, speed through water, rudder, depth, wind, zoomed ECDIS picture, wheel over point bearing, distance, ETA, waypoint name and time to waypoint, route name.
- Standard magnetic compass with binnacle with illumination 24 V DC, fluxgate transmitter and repeater in navigation desk and stepper output for gyro backup.

Navigation equipment shall be mounted on foundations, flexible where necessary, supported with brackets or braces to minimise vibrations.

One radar installation shall be installed, consisting of:

- One 3 cm X-band, 25 kW 3x 230 V - 50 Hz inter-switched full IMO ARPA radar (40 targets) with true motion, 6 foot antenna, performance monitor, 16 inch effective high resolution (1280x1024) colour display, power supply 230-Volt - 50 Hz and interfaces with Doppler log, DGPS ECDIS and gyro compass, located between the navigation desks.
- One 10 cm S-band, 10 kW 3x 230 V 50 Hz inter-switched full IMO ARPA radar (40 targets) with true motion 12 foot antenna, performance monitor, 23 inch effective high resolution daylight radar display, power supply 230 V - 50 Hz and interfaces with Doppler log, DGPS ECDIS and gyro compass, located next to the chart table.

The radars shall be supplied by the UPS-system and inter-switched.

530.2 Position keeping system

A positioning keeping system, including all required sensors, shall be installed to monitor and control the pre-defined mining pattern. The position keeping system includes both the 4-point mooring system with the mooring winches and the thrusters for the assisted mooring.

The system shall be designed to control the following thruster configuration:

- Four (4) mooring winches
- Six (6) azimuthing thrusters

The position keeping system shall have one main control system (duplex), one backup control system (simplex) and one independent joystick thruster control system. The position keeping control system shall be integral part of the Vessel Management System (VMS).

The position keeping control system shall be designed to operate in the following modes;

- Manual/joystick mode
- Auto tracking
- Auto heading

The following station keeping equipment will be provided:

- Positioning recorder
- Positioning sensors:
    - 3 master gyro compass sensors
    - 3 Wind sensors
    - 2 Differential Global Positioning Systems DGPS

Positioning sensors shall take power from a separate UPS system and shall be connected to the Vessel Management System.

540 Lighting system

540.1 General design

The lighting shall be designed for 230 V AC, 50 Hz, single phase.
Illumination intensity shall be in accordance with the Rules, but at least as follows:

- Galley, mess and recreation room, offices 250 lux
- Cabins and hospital 150 lux
- Bath rooms, toilets, laundry, stairs, corridors 100 lux
- Machinery spaces 200 lux
- Switchboard room, control rooms 300 lux
- Stores 100 lux

- Working areas on decks 200 lux
- Other areas on decks, walkways 50 lux
- Rescue zone 150 lux

All illumination levels shall be determined by applying a maintenance factor of 75% to initial values, to allow for deterioration of lamps, reflectors, enclosures and painted surfaces.

Four (4) remote control searchlights shall be provided on the top deck, two forward and two aft. Remote control shall be from wheelhouse consoles.

540.2 Navigation lighting

The Vessel shall be equipped with the following navigation and signal lights as per class rules and IMO requirements:

- Statutory Navigation lights
- Statutory Signal lights
- Morse / manoeuvring light
- Day light signalling lamp
- Search lights at relevant locations such as SSED area, off-loading area, refuelling stations etc.

540.3 Emergency lighting

The following lighting fittings shall be supplied from the 230 V emergency supply system, but will function as part of general lighting:

- Machinery spaces: Approximately 20 % of all fluorescent fittings.
- Accommodation: Approximately 50 % of all fluorescent fittings in alleyway and stairways.
- Accommodation exits: Low wattage fluorescent fittings (supplied from UPS).
- Deck: low wattage discharge fittings at ladders (supplied from UPS).
- Emergency generator room: deck head fluorescent fittings.

All fittings shall be suitably marked to indicate that they are supplied from the emergency supply system.

Transitional / escape lighting and lighting at embarkation stations shall be supplied from 230 V UPS. Overboard lighting at embarkation stations shall be fitted with supports suitable for stowing inboard when not in use.

560 Alarm, monitoring and control system

560.1 Alarm system

The Vessel shall be equipped with at least the following alarm systems:

- General alarm
- Engine alarm and monitoring (part of VMS)
- Fire detection/alarm (alarm broadcast over PA system)
- MOB alarm
- Fire suppression system gas release alarm
- Watertight door alarm
- Cold stores alarm
- Hospital call system

The general alarm shall be operated from the wheelhouse and the Engine Control Room. The general alarm shall be broadcast over the PA system.
The system shall be provided suitable for unmanned operation of the engine room, in accordance with Classification Society Requirements and National authorities.

The alarm system shall be designed for an anticipated number of 3000 I/O's. Final number to be verified in a later stage. At least the following I/O's are foreseen:

1572 hardware I/O's comprising:

- Digital inputs	1134
- Analog inputs	336
- Relay outputs	54
- Analog outputs	48

1280 software I/O's comprising:

- 1x VDR Serial link via NMEA183	40
- 6x Main Engine Serial Link via MODBUS RTU	390
- 2x Aux Engine Serial Link via MODBUS RTU	100
- 1x Fire alarm System Serial Link via MODBUS RTU (on dedicated control processor)	50
- 1x Vessel management link via MODBUS TCP (incl dedicated switch)	650
- 1x Process management Serial Link via MODBUS RTU	40

All sensors and actuators will be connected to the DPU's for alarming, monitoring and control.

MOB (man overboard) alarm shall be operated from the wheelhouse and pushbuttons at working areas of the Main Deck aft.
Release of fire suppression system gas shall operate an audible and visual alarm in the protected space in accordance with Class rules. An alarm shall also be provided on the bridge.
Watertight door open/closed indication shall be provided on the bridge. If a self-closing door does not close within a pre-set time an alarm shall be given on the Wheelhouse. Means of remotely closing watertight doors shall be provided from the Wheelhouse and the Engine Control Room.
Hospital and cold rooms shall be provided with alarms in accordance with Class and National regulations.

560.2 Vessel Management System

A Vessel Management System shall be provided, comprising:
- Power management
- Position keeping system
- Alarm management
- Thruster and mooring management
- Machinery management
- Fire and Safety System Indication
- Tank Gauging
- Valve Remote Control
- Other systems as appropriate

The system shall preferably consist of a fibre-optic cable network which is physically segregated and which is fault tolerant with no degradation of system performance caused through a single failure to maintain the requirement for redundant operation of the Vessel.

All alarms related to the mooring, propulsion and main machinery shall be analogous when relevant. Instruments, sensors and control equipment shall be of simple, robust and standardized design. Transmitters shall be used in order to avoid sensing lines carrying fuel, oil, steam or water being led into the control room.

Local instrumentation, such as thermometers, pressure gauges, etc., shall be provided as necessary for manual start-up, control, and monitoring of equipment in the machinery spaces. Scale engraving shall be in metric units.

All sensors shall be installed in places where there is a minimum risk for damage during normal operation, overhaul and maintenance. Sensors and instruments shall be mounted in such a way that shock and vibrations of the sensor body with connections are avoided. Cables for sensors shall have sufficient length allowing for withdrawal during replacement or calibration. Shut off and test valves with standard test flange connection shall be fitted for all pressure regulating and measuring units as well as for local instruments.
Pressure sensors exposed to shock and large vibrations in their working medium shall be protected by damping chambers. Temperature sensors shall be installed in wells and be capable of being withdrawn for replacement or calibration.
Test equipment for temperature and pressure sensors shall be suitable for connection to the respective sensor types.
All components and wires shall be marked with number codes in accordance with the instrumentation list and installation drawings.

The Alarm Monitoring and Reporting System shall monitor and report all alarm conditions (instrumented as contact closures) driven by alarm circuits external to the system. In addition, the system shall permit the calculation of high and low level or deviation alarms for every integrated measurement signal, and the assignment of an alarm condition to any status input signal. It shall also be able to issue an alarm when a measured state fails to agree with commanded state within an operator adjustable time interval.

The convention to be adopted for field alarm signals shall be normally closed, open on alarm condition.

Alarm occurrence shall be indicated to the operator by an audible signal, by flashing visual indication at the control station and by a printed record. Visual and printed indications shall clearly identify the point in alarm, the alarm condition, and the time of alarm occurrence.
Visual alarm indications shall remain flashing until acknowledged by the operator and shall remain illuminated for each alarm occurrence until the occurrence is acknowledged by the operator and the alarm condition has been eliminated, at which time the printer shall record the time of return to non-alarmed condition.

The operator shall not be able to acknowledge an alarm without first calling the description of the alarm to the display screen. When a Vessel alarm occurs, the system shall flash an alarm symbol on the VDU. The display shall clearly indicate those points in alarm states. In addition, the Vessel Management System shall maintain a record of all active alarms. From the alarm list each alarm might be acknowledged separately or all alarms on the VDU page might be acknowledged at the same time.

6 ENGINE ROOM

600 General

The engine room will be separated in 2 compartments for reasons of redundancy, separated by the fuel treatment room. In each compartment four (4) main generator sets will be located. On Main Deck an emergency generator room will be provided with the emergency generator.

600.1 Operating conditions

Engine outputs are maximum continuous ratings developed under the following conditions:

- ambient engine room temperature	45	°Celsius
- seawater temperature	23	°Celsius
- air pressure	100	kPa
- relative humidity	80	%

600.2 Fuel requirements

Heavy Fuel Oil (HFO) with a maximum viscosity of 380cSt at 50 °Celsius (according to ISO 8217:2010 with designation RMG 380) will be used for:

- main generator engines
- auxiliary generator engine
- oil fired thermal oil boiler

Marine Diesel Oil (MDO) (according to ISO 8217:2010 with designation DMA) will be used for :

- main generator engines
- oil fired thermal oil boiler
- emergency generator engine

610 Main Power Generation System

Six (6) identical main diesel generator sets will be fitted, supplying power to the main switchboards. Each engine will run on HFO and will be provided with built-on cooling water and lubricating oil pumps. Alternators will be water cooled.

<u>Main particulars engine</u>

– Make	MAN B&W Diesel or equivalent	
– Type	20V32/44CR	
– Maximum continuous rating	12000	kW
– Speed	750	r.p.m.
– Fuel	HFO or MDO	
– Certificate	by Class for unmanned engine room Tier II certificate according to IMO MARPOL 73/78 as amended by the protocol of 1997, Annex VI, Regulation 13 (NOx)	

Two (2) identical diesel generator sets will be fitted, supplying power to the main switchboards. Each engine will run on HFO and will be provided with built-on cooling water and lubricating oil pumps. Alternators will be water cooled.

Main particulars engine

– Make	MAN B&W Diesel or equivalent
– Type	12V32/40
– Maximum continuous rating	6000 kW
– Speed	750 r.p.m.
– Fuel	HFO or MDO
– Certificate	by Class for unmanned engine room Tier II certificate according to IMO MARPOL 73/78 as amended by the protocol of 1997, Annex VI, Regulation 13 (NOx)

The main diesel engines are started and stopped from the ECR and locally close to each engine. Speed control for the main engines is possible from the ECR and locally for start-up. Speed control is possible between idle speed (about 50 %) and 100 % speed. Speed control for synchronizing is provided as described in 560.2.

630 *Emergency Generator*

One (1) emergency generator set will be fitted according to Class requirements, serving all equipment that is required to maintain operable in an emergency condition and to start up from dead ship. The engine will be air started and the alternator will be air cooled by a radiator.

Main particulars engine

– Make	t.b.d.
– Type	t.b.d.
– Maximum continuous rating	1000 kW
– Speed	1800 r.p.m.
– Fuel	MDO
– Certificate	by Class for unmanned engine room Tier II certificate according to IMO MARPOL 73/78 as amended by the protocol of 1997, Annex VI, Regulation 13 (NOx)

The emergency diesel generator is started and stopped locally close to the engine. The engines will start automatically when the 690 V 50 Hz system fails. Speed control for the emergency generator is possible locally.

640 *Main thrusters*

For thruster assisted mooring six (6) identical azimuthing rudder propellers will be provided. The thrusters will be located at the fore and aft end of the Vessel where the keel is raised to assure that the thrusters will not protrude the base line. The thrusters will be mounted under an angle to minimize the interference with the hull. All thrusters are arranged in such way that they can be under water mounted, so no docking of the Vessel is required for servicing a thruster unit.

- Power at propeller:	5000	kW
- Propeller diameter:	4.0	m
- Propeller type:		fixed pitch with VSD
- Speed primary:	750	rpm
- Propeller speed:	ca.150	rpm
- Propeller fitted in Nozzle		
- Steering angle:	360	°

The thrusters will be electrically driven in an L-type configuration. The electric motors will be of the squirrel cage type and shall be driven through a variable speed drive. They will be water cooled.

The propellers shall have four (4) blades with an optimal skew and will be made of Nickel-Aluminium Bronze. The propeller will be designed for position keeping performances.

660 Thermal oil installation

The Vessel will be provided with a thermal oil installation which is capable of heating the heavy fuel oil and sludge systems and which will also be used for the central heating of technical spaces. The system will consist of at least the following components:

- oil fired thermal oil heater
- exhaust gas thermal oil heaters
- circulation pumps
- system filling pumps
- system drainage pumps
- interface to hot water system with heat exchanger
- thermal oil storage tanks with a capacity of at least 120% of a complete refill of the system.
- drain and expansion tanks

The thermal oil system will supply heated thermal oil to at least the following system or components:

- HFO bunker tanks
- HFO settling tanks
- HFO day tanks
- HFO overflow tanks
- heaters of heating system
- HFO pipe tracing
- Sludge pipe tracing

The heavy fuel oil (HFO) piping and sludge transfer piping with diameters above 50 mm shall be traced by thermal oil piping, fuel oil and sludge transfer piping with diameters below 50 mm may be traced electrically by means of electric cabling. The trace piping shall be fitted with couplings (fitted in way of the flanges). Also the HFO booster / service Vessel for main engines, auxiliary engine and oil-fired thermal oil heater may be traced electrically by means of electric cables.

660.1 Thermal oil design conditions

The final capacity will be based on a heat balance that shall be prepared for at least the following conditions:

- normal mining operation with the Vessel moored on its 4-point mooring system
- normal mining operation with thruster assistance in higher sea states
- reduced engine power due to failure or maintenance
- starting up duty

The system will be designed for the following temperatures:

Ingoing thermal oil temperature	approx. 140 °C
Outgoing thermal oil temperature	approx. 190 °C

660.2 Oil fired thermal oil heater

The Vessel will be provided with oil-fired thermal oil heaters. Number and capacity to be decided based on the heat balance calculations. The heaters shall be suitable for burning both HFO and MDO. The boilers shall be accessible for inspection and cleaning.

Starting and shut-down of the oil-fired thermal oil heating system shall be locally. When started up the thermal oil system shall be working fully automatic.
The control system shall be designed in such a way that in case of extreme heat demand when the exhaust gas heaters cannot supply sufficient heat to the consumers, the oil-fired heater shall automatically assist the exhaust gas heaters.

660.3 Exhaust gas heaters

An exhaust gas thermal oil heater shall be fitted in the exhaust gas pipes of each main engine. Each exhaust gas thermal oil heater to comply with the following specification:

<u>Main particulars:</u>

- Heating capacity	t.b.d	kW
- Thermal oil temperature in / out	140-190	°Celsius
- Set-point internal bypass	190	°Celsius
- Min exhaust gas temp heater outlet	250	°Celsius

The final capacity of the exhaust gas heaters will be demonstrated with heat balance calculation. Tolerances on capacity as indicated by tolerances on flow rate and temperature of exhaust gasses of main engines. The size of the heater shall be based on:

- the exhaust gas quantity of a main generator set running on 85% maximum continuous rating (MCR)
- ambient air temperature of 25 °Celsius
- cooling-water temperature through air cooler 40 °Celsius
- barometric pressure 1 bar and
- maximum exhaust gas back-pressure of 0,03 bar

The heater shall be of the vertical cylindrical type of steel welded construction. The heating surface consists of concentric heating coil sections which are wound tight on top of each other. The coils fabricated of smooth steel piping.

An exhaust gas bypass control system shall be arranged, comprising two (2) flaps directing the exhaust gasses to the heating coils of the heater and/or to its internal bypass (excess heat). The system shall be control air actuated controlled by a thermal oil temperature controlled pressure regulating valve fitted in the supply line of the actuating system of the flaps.

By means of the exhaust gas bypass control system the thermal oil supply temperature to the consumers shall be regulated automatically at a constant value. In case of too high exhaust gas temperature the bypass flaps of the exhaust gas thermal oil heater shall be controlled in open bypass position respectively closed heater position.

The exhaust gas heater shall be fitted with a thermal oil thermostat, a differential pressure switch with orifice (flow sensor) and an exhaust gas safety thermostat for alarm connected to the alarm and monitoring system. For soot blowing several water nozzles shall be arranged with hose connection to the technical water system. The piping and the nozzles inside of the exhaust gas thermal oil heater shall be made of stainless steel.

7 PIPING SYSTEM

700 Engine room piping general

The Vessel shall be provided with all systems required for safe operation. All piping and fittings related to these systems shall in general comply with the following specifications:

- The pipe systems with pipes, valves, fittings etc. shall be in accordance with the requirements of the Class Society and ISO standards, including design, manufacturing and testing.
- All pipes shall be fastened in a suitable manner. Exhaust pipes shall be specially considered to prevent vibration and to allow for sufficient expansion.
- Piping shall be designed in such a way that stress levels due to thermal expansion will be limited. This shall be achieved by flexible couplings or expansion loops when necessary.
- All equipment shall be provided with isolating valves to allow for easy maintenance
- Piping shall be routed as direct as possible to restrict the pressure drop over the pipe line as much as possible.
- All piping shall be suitably supported to avoid vibration.
- Galvanized pipes shall have galvanized supports, clamping devices, bolts and nuts. Hot dip galvanizing shall be carried out after pre-fabrication.
- All piping shall be marked with coloured rings and flow arrows according to the coding system as approved by the Owner

Engine room systems shall be designed in compliance with the Class requirements and will be provided with sufficient redundancy to maintain operating with the loss of single system components. The system design shall follow the split between SB and PS to create inherent redundancy with sufficient means of standby options to take over functionalities in case of a single component failure.

The following materials for the piping shall be applied:

System	Material	Joint type
Starting air	Seamless steel, galvanized	Steel flanges / couplings
Working & control air	Seamless steel, galvanized Stainless steel in exposed area	Steel flanges / couplings Stainless steel
Fuel oil	Steel with tracing	Steel flanges / flexible couplings
Lube oil	Steel	Steel flanges / couplings Screwed couplings for DN<20
Sludge / dirty oil	Steel with tracing	Steel flanges / couplings Screwed couplings for DN<20
Sea cooling water	Steel, galvanized, schedule 80 Carbon steel with Rilsan coating	Steel flanges, flexible couplings Steel flanges
Fresh cooling water	Steel	Steel flanges, flexible couplings
Exhaust	Welded steel	Steel flanges

702 General pumps

This paragraph shall be applicable for electrically driven pumps. Each pump shall be driven by a squirrel cage electric motor, coupled to the pump via flexible coupling of suitable size fitted with a safeguard. All flexible couplings shall be of the same make. Bearings will be arranged with a lifetime of at least 20.000 hours.

702.1 Centrifugal pumps

The construction of each pump shall be arranged in such a way, that the impeller can be removed without dismantling of the electric motor and the pipelines.
To remove the impeller from small pump sizes the complete pump unit shall be demounted. The power rating of the electric motors shall be sufficient for the complete pressure / flow rate curve of the pump for relevant speeds.

<u>Materials</u>

For freshwater pumps following materials shall be applied:

- Casing	cast iron
- impeller	bronze RG 5
- wear-rings (if applicable)	stainless steel AISI 316L
- shaft	stainless steel
- seal	mechanical seal

For seawater pumps following materials shall be applied:

- casing	bronze RG 10
- impeller	bronze RG 10
- wear-rings	stainless steel AISI 316L
- shaft	stainless steel AISI 316L
- seal	soft packed seal
- shaft bush in way of seal	nitrated stainless steel AISI 316L

702.2 Rotating positive displacement pumps

The pumps shall be of the screw or gear type and fitted with built-on relief valve with manually operated setting possibility.

<u>Materials</u>

- casing	cast iron
- screws / gears	carbon steel
- shafts	carbon steel
- seals	mechanical seal

703 Heat exchangers

Heat exchangers shall be of the plate or tubular type. A minimum fouling margin of about 15% shall be included for each heat exchanger.

Tubular type coolers

Baffles shall be arranged outside the tubes to provide efficient heat transfer.

Materials **tubular type** coolers		
	Seawater-cooled (not applicable)	Thermal oil / freshwater
Shell		steel
Tubes		steel
Tube plates		steel
Baffles		steel
Covers		steel

Plate type coolers

Materials **plate type** coolers		
	Seawater-cooled	Freshwater / freshwater Oil / freshwater Oil / oil
Plates	Titanium	stainless steel
Gaskets	nitril rubber	Nitril rubber or as required with regard to prevailing temperatures
Frame	Steel	Steel

710 Starting air, working air and control air system

710.1 Starting air

The Vessel shall be equipped with a starting air system, in compliance with the requirements of Class and the engine supplier. The system will consist of at least the following components:

- starting air compressors
- starting air vessels
- emergency air compressor
- emergency air vessel

The system will provide starting air to:

- main generator sets
- working air system

Each compressor and electric motor are flexible coupled and mounted on a common steel base plate. The compressors are arranged for automatic operation. One (1) starting air compressor can be started on the emergency generator for starting from “dead ship”.

Starting air receivers will be installed that are suited for 30 bar working pressure. The capacity of each vessel will be in compliance with the requirements from Class for the number of starts as well as with the requirements from the engine supplier.

For emergency situations, a hand driven air compressor for starting from “dead ship” will be provided. The compressor will be mounted on an air receiver, complete with pressure gauge and safety valve. The compressor will be installed in the emergency generator room. The vessel will be kept pressurized [under normal circumstances] by the Vessels main starting air system.

710.2 Working air

The Vessel shall be equipped with a working air system. The system will be designed for 10 bar working pressure and will consist of at least the following components:

- working air compressors
- working air vessel
- working air dryers

The system will provide working air to:

- Air driven equipment
- all equipment that require air for operation
- sea chests
- working air connections in all technical spaces, working decks, process plant area and crawler area

Working air will be provided by electrically driven working air compressors. Final number and capacity t.b.d. Each compressor and electric motor is connected with a flexible coupling and mounted in a noise reducing enclosure. The compressors are arranged for automatic operation.

Sufficient working air receivers will be installed throughout the Vessel. The vessels will be suited for 10 bar. The capacity of each vessel will be based on a simultaneous load of a set of pre-defined equipment which will be determined in the basic design phase.

710.3 Control air

The vessel shall be equipped with a control air system (specifications to be confirmed in basic design phase, presented values are indicative). The system will be designed for 12 bar or the highest pressure +10% required by any control air user. It will consist of at least the following components:

- control air compressors
- control air treatment units (filters and oil separators)
- control air dryer
- control air vessels

The system will provide control air to at least the following systems or consumers:

- control systems
- air clutches
- air power brakes
- separator and booster units
- oily water separator units
- emergency shut-off valves

Control air will be provided by electrically driven control air compressors. Final number and capacity t.b.d. The capacity of the compressor is sufficient to supply all required operating air, with the compressor running maximum 25 % of the time.

Each compressor and electric motor is flexible coupled and mounted on a common steel base plate. The compressors are arranged for automatic operation.

Each emergency shutoff valve shall be fitted with a control air line fitted with a manually operated control unit. A manually operated compressor with accumulator shall be installed.

An adsorption type air dryer is installed in the system, capacity sufficient for a dew temperature of -20 °C. The dryer is fully automatic and regenerates automatically. Before the dryer, a filter and oil separator is installed.

As a back-up, the system can also be supplied from the 30 bar starting air system, via a reduction valve.

Near all important users a buffer tank is installed.

720 Fuel oil system

The engine room will be provided with two independent fuel oil systems, one for MDO and one for HFO. The emergency generator room will be served by an independent MDO service system.

Pumps in fuel oil systems shall be of the positive displacement type, with built-on pressure safety device and mechanical seals. Body nodular cast iron. Bunker lines provided with mass meter and sampling devices.

720.1 Heavy fuel oil system

A common HFO overflow tank system will be arranged (specifications to be confirmed in basic design phase, presented values are indicative). HFO will be purified from the settling tanks to the service tanks, which overflows back into the settling tanks. For the heavy fuel oil system the following tanks shall be provided:

- three (3) HFO bunker tanks
- four (4) HFO settling tanks
- four (4) HFO service tanks
- one (1) HFO overflow tank
- two (2) FO drain tanks

The bunker tanks shall be filled from the filling station at the bow or the side of the Vessel. The transfer of fuel oil will be done with two (2) electrically driven screw type HFO fuel pumps. One pump will be operating and one will be stand-by. The stand-by HFO transfer pump will also serve as stand-by MDO transfer pump.

The transfer pumps will take suction from:

- the bunker tanks
- overflow tanks
- settling tanks
- day tanks

and will be able to discharge to:

- each bunker tank
- each HFO settling tank
- each HFO service tank
- the deck connection

The settling tanks will be kept filled by the automatic operating transfer pump. Pumps are switched automatically on/off by means of the level measurement in the respective settling tank, when automatic mode is selected. Near the deck connection, a remote start/stop for each transfer pump is provided.

Heated service tanks will be suitable for at least 8 hour uninterrupted service at 100% MCR of all main generator sets, thermal insulated and will not have common boundaries with for instance fresh water tanks.

720.2 Fuel treatment system

The separator plant shall consist of five (5) automatic self-cleaning HFO separators, splitting the SB and PS engine room supply for redundancy reasons. Two (2) will purify the HFO from the SB engine room settling tanks and discharge into the service tank for the SB generator sets and two (2) will purify the HFO from the PS engine room settling tanks and discharge into the service tank for the PS generator sets. One (1) separator will be standby for the other separators and will serve as a standby separator for the MDO system by means of a change-over elbow.

Each separator will be able to take suction from the HFO settling tanks and discharge in the HFO service tanks. Residues will be discharged into the sludge tanks.

Each separator shall be provided with a suction pump and built in discharge pump. The capacity shall be based on the maximum anticipated total power requirement with the fuel consumption as specified by the engine supplier plus 5% tolerance.
Each heavy fuel oil (HFO) separator shall be fitted with automatic system of controls, arranged in panels on the separator unit.

720.3 Booster system

In the fuel treatment room two (2) fuel oil booster systems will be fitted according requirements of engine supplier and/ or Owner. Each booster will serve the four main engines in each engine room compartment.

Each booster unit shall consist of at least the following components:
- switch-over valve MDO - HFO
- one heated duplex filter
- two feed pumps, one in service, on stand-by
- one heated, automatic operating back-flush filter
- one fuel oil consumption meter
- one fuel oil mixing tank
- two circulating pumps, one in service, on stand-by
- two fuel oil final heaters, one in service, on stand-by
- one viscosity control system
- air coolers where required, preventing over-heating
- water cooled MDO cooler

Fuel lines to the engines will be fitted with heated duplex safety filter and pulsation dampers.

721 Marine diesel oil system

A common MDO overflow tank system will be arranged (specifications to be confirmed in basic design phase, presented values are indicative). MDO will be purified from the settling tanks to the service tanks, which overflows back into the settling tanks. For the marine diesel oil system the following tanks shall be provided:

- one (1) MDO bunker tank
- one (1) MDO settling tank
- one (1) MDO service tank in the engine room
- one (1) MDO service tank for the emergency diesel generator
- one (1) MDO service tank for the incinerator
- one (1) MDO overflow tank

Draining of the MDO system will be done in the combined fuel oil drain tanks.

The MDO bunker tanks shall be filled from the filling station at the bow or the side of the Vessel. The transfer of fuel oil will be done with one (1) electrically driven screw type MDO fuel pump. The stand-by HFO transfer pump will also serve as stand-by MDO transfer pump.

The transfer pumps will take suction from:

- the bunker tanks
- overflow tanks
- settling tanks
- day tanks

and will be able to discharge to:

- each bunker tank
- each MDO settling tank
- each MDO service tank
- the deck connection

The settling tanks will be kept filled by the automatic operating transfer pump. Pumps are switched automatically on/off by means of the level measurement in the respective settling tank, when automatic mode is selected. Near the deck connection, a remote start/stop for each transfer pump is provided.

Heated service tanks will be suitable for at least 8 hour uninterrupted service at 100% MCR of all main generator sets, thermal insulated and will not have common boundaries with for instance fresh water tanks.

721.1 Fuel treatment system

The separator plant as described in 720.2 will also include one (1) automatic self-cleaning MDO separator. The stand-by HFO separator will also serve as stand-by MDO separator. Switching duties shall be performed by changing pipe pieces. Arrangement, execution and anticipated particulars will be similar to that as specified in 720.2.

The separator will be able to take suction from the MDO settling tanks and discharge in the MDO service tanks. Residues will be discharged into the sludge tanks. The separator can also serve as standby lubrication oil separator of the main engines, however with reduced capacity.

The separator shall be provided with an electrically driven suction pump and built in discharge pump. The capacity shall be based on the maximum anticipated total power requirement with the MDO consumption as specified by the engine supplier plus 5% tolerance.

The separator shall be fitted with automatic system of controls, arranged in panels on the separator unit.

725 Refuelling station

Refuelling will be done by means of ship to ship transfer in compliance with the OCIMF requirements. Two (2) refuelling locations on deck will be provided; one (1) at the bow of the Vessel and one (1) at the side of the Vessel. At each station a fuel hose reel will be provided with a capacity of storing 150 m fuel hose. Each hose reel will be electrically driven with a local start/stop.

The filling station will contain approved deck connections for the MDO and HFO system, including drip trays. At each filling station the emergency shut-off valves for the fuel systems will be located.

730 Lubricating oil system

A common lubricating oil system will be arranged for the engines, propulsion equipment, compressors etc., comprising at least:

- clean LO storage tanks, number and size depending equipment
- LO service tanks main and auxiliary generators
- LO service tank emergency generator
- LO drain tanks
- dirty oil storage tanks
- clean lubricating oil transfer pump
- air driven hand pumps
- dirty oil transfer pump

Lubricating oil systems for the process plant and for the crawlers will be provided separately with interfaces to the Vessel LO system where necessary.

The transfer of lubricating oil will be done with two (2) electrically driven screw type LO pumps with 100% capacity each. Each transfer pump will serve one engine room section with stand-by option for the other engine room section. The pumps will take suction from:

- LO storage tanks
- wet sumps from the main and auxiliary engines in each engine room section

and will discharge to:

- dirty oil tanks
- wet sumps from the main and auxiliary engines in each engine room section

The pumps shall be started and stopped locally.

A piping system shall be arranged to connect storage tanks and consumers in a practical way.

The main engines will be of the wet sump type, with built-on, engine driven lubricating oil pumps. The main generator engines will be provided with at least the following components in compliance with the requirements from the engine supplier:

- electric driven stand-by pump
- main engine separator pump
- fresh water cooled lubricating oil coolers
- automatic filter
- fine filter

For each main engine one (1) electrically driven screw type LO pump will be provided in compliance with the requirements from the engine supplier.

730.1 Lubricating oil separators

For each main engine an automatic operating, self-cleaning lubricating oil purifier will be provided. The capacity will be in compliance with the engine supplier requirements.

Each lubricating oil separator will be able to take suction from the wet engine sump and after separation will discharge the lubricating oil back into the wet sump. The residues will be discharged into the separator sludge tank.

For each engine room section the main generator engine LO purifiers will be arranged for connecting to at least one other main generator engine. In each of the engine room sections one of the main engine lubricating oil purifiers acts as stand-by for the MDO purifier.

Each lubricating oil separator shall be fitted with automatic system of controls, arranged in panels in the separator unit.

740 Sludge / dirty oil system

A sludge / dirty oil system will be provided for clean discharge of sludge or dirty oil consisting of at least the following components:

- one (1) sludge tank
- sludge separator
- sludge pumps

The transfer of sludge will be done with two (2) electrically driven screw type sludge pumps. Each sludge pump will take suction from:

- sludge tanks
- dirty oil tanks
- sludge discharge tank
- fuel oil drain tank
- bilge water collecting tank

and will discharge to

- sludge tanks
- dirty oil tanks
- sludge discharge tank
- HFO settling tanks
- Incinerator

The pumps can be started and stopped locally. A remote start/stop for the pump is provided near the deck connection.

740.1 Sludge separator

A sludge treatment unit is installed for separation of oil/water/solids from the Vessel's sludge.
The system consists of :

- one self-cleaning automatic separator ; capacity t.b.d.
- one electrically driven screw-type supply pump
- thermal oil heated sludge heater, with temperature control equipment
- sedimentation tank, with thermostatic heating, with overflow to the sludge tank
- electrically driven screw-type pump, for discharge of concentrated sludge
- control unit, for fully automatic operation
- combined alarm, with separate indication of each alarm on the unit.

The separator will take suction from :

- sludge tank of LO separators
- sludge tank of FO separators
- Vessel's sludge tank

and will discharge to:

- separated FO to the FO settling tank
- separated LO to the dirty oil tank
- separated FO and LO can be returned to the sludge tank or to the incinerator's sludge tank as well

740.2 Incinerator

One (1) incinerator shall be installed in the incinerator room, suitable for burning of sludge and wastes. The burning capacity will be based on the anticipated sludge to be burned.
The incinerator shall be arranged with pilot burner, suitable for burning of marine diesel oil (MDO). An exhaust fan shall be installed for cooling air supply and exhaust gasses. An electric pilot oil heater shall be installed and mounted on the incinerator. The incinerator shall comply with the relevant IMO resolution.

A sludge mixing tank unit of suitable capacity shall be installed for the incinerator. The tank unit shall comprise a sludge tank, thermal oil heating coil, an electrically driven sludge circulating pump and necessary supply and discharge connections. Also a high- and low-level alarm sensor shall be provided connected to alarm and monitoring system.

Controls and alarms shall be fitted on a control panel fitted on the incinerator and with common alarm to alarm and monitoring system.

750 Sea cooling water system

For the sea cooling water system the sea water pumps from the process plant will be used. The sea water will run through the engine coolers to warm up before going to the desalination plant.

One or multiple cross-overs of adequate size with sand traps at each inlet will be fitted between the SB and PS sea chests. Maximum speed in the cross over will not be higher than 1 m/s. The sea cooling water pumps will take suction from the cross-over and will supply sea cooling water to the coolers which will then be discharged overboard. In each supply line an automatic sand filter will be provided.

750.1 Sea cooling water pumps

The sea water pumps will be part of the Owner Furnished process plant and will be installed in the vertimill pump room area. The pumps shall be electrically driven, VSD controlled, non-self-priming centrifugal sea water pumps will be provided.

750.2 Sea cooling water coolers

All coolers shall be designed for the following temperatures:

- sea water in	23	°C
- sea water out	not to exceed 45	°C
- Fouling margin	not less than 15	%.

Special attention shall be paid to the pressure drop over the coolers. Cooler plates shall be made of titanium. Sea water piping to coolers shall be arranged for back-flushing.
The coolers shall allow for transit of the Vessel from the building yard to the mining site. The coolers will be designed to operate in the sea water temperature at the yard location.

For the main engines two (2) sea water coolers shall be provided per two (2) main engines for the low temperature cooling water circuit. Each coolers will be designed for 75% of the total cooling water load. For the engine room auxiliaries, the process plant auxiliaries and the SSED auxiliaries separate sea water coolers shall be provided with adequate capacity for each cooling system.

760 Fresh Cooling water system

A fresh cooling water system shall be provided. Fresh cooling water circuits shall be separated to the following functionalities:

- Fresh cooling water system for main engines
- Fresh cooling water system for mooring and propulsion MCC's, transformers and drives and engine room auxiliaries
- Fresh cooling water system for SSED MCC's, transformers and drives and auxiliaries
- Fresh cooling water system for process plant MCC's, transformers and drives and auxiliaries which will be Owner Furnished

The system will consist of at least the following components for each of the sea cooling water systems:

- fresh cooling water pumps
- expansion tanks
- temperature control valves to regulate the pressure and flow
- provisions for chemical dosing
- provisions for filling with technical water
- fresh cooling water drain tanks

Each main engine will have its own built-on high temperature cooling water pump and will be provided with its own electrically driven non-self-priming centrifugal HT cooling water standby pump. Each main engine shall be provided with pre-heating facilities in compliance with the engine supplier. Capacity shall be according the requirements of the engine supplier. If necessary jacket water heat can be used for evaporators.
For the high temperature cooling water circuit each main engine shall be provided with its own HT cooler in accordance with the requirements from the engine supplier which will be cooled by the fresh cooling water Low Temperature circuit.

Each main engine will have its own built-on low temperature cooling water pump. For the main engines a low temperature cooling water circuit shall be provided per two (2) main engines. Each circuit shall consist of two (2) electrically driven non-self-priming centrifugal LT cooling water circulation pumps of 100% per pump.

The emergency/ harbour generator will have its own, independent, radiator cooled cooling water circuit.

In each engine room compartment an auxiliary fresh cooling water circuit will be provided to supply cooling water to all water cooled mooring and propulsion related MCC, transformers and drives and auxiliary engine room equipment. The system shall be provided with electrically driven non-self-priming centrifugal fresh cooling water circulation pumps. The number and size of these auxiliary fresh cooling water pumps shall allow for continuous operation of the Vessel with one pump out of order.
Auxiliary coolers shall be provided for the auxiliary circuits with sufficient redundancy in the system to allow for continuous operation.

For the process plant and for the SSED a separate auxiliary fresh cooling water circuit will be provided to supply cooling water to all water cooled process plant or SSED equipment. The system shall be provided with electrically driven non-self-priming centrifugal fresh cooling water circulation pumps. The number and size of these auxiliary fresh cooling water pumps shall allow for continuous operation of the process plant with one pump out of order.

770 Exhaust gas system

The necessary exhaust gas lines will be arranged for all generator sets, oil fired boilers and incinerator. In the engine exhaust lines spark arrestors and silencers, having a minimal sound attenuation of 35 dBA, will be fitted. Provisions preventing ingress of rain and condensation collecting provision will be arranged. Special attention shall be paid to the proper discharge of the exhaust gasses.

Exhaust lines shall be acoustically and thermally separated from construction parts by means of flexible mountings. All exhaust lines will be thermal insulated, minimal 75 mm thick, and covered with aluminium plating.

In dedicated main engine exhaust gas lines an economizer will be installed; final number and capacity yet to be decided.

A Class Approved exhaust gas monitoring system shall be installed to monitor engine, incinerator and thermal oil heater exhaust gas emissions for compliance with MARPOL Annex VI. Diesel engine exhaust gas sampling points shall be located at points in the exhaust casings PS and SB above the area allocated to the exhaust gas scrubbers. The system shall monitor the NOx, SOx, CO2 and Particulate Matter content of the exhaust gases.

Provisions for future installation of a wet scrubber installation and an SCR installation shall be taken into account in the design.

8 VESSEL PIPING SYSTEM

800 Vessel piping general

System	Material	Joint type
Bilge water	Steel, galvanized	Steel flanges
Ballast water	Steel, galvanized with Rilsan coating Alternative GRE piping	Steel flanges
Fire fighting	Steel	Steel flanges inside ER Steel flanges, flexible couplings outside ER
De-aeration and sounding pipes from: Sea water tanks Fresh CW tanks Oil tanks Potable water tanks	 Steel, galvanized Steel Steel with tracing Steel, galvanized	 Steel flanges Steel flanges Steel flanges Steel flanges
Potable water Cold water Hot water	 Stainless steel, galvanized Copper for DN<40 Stainless steel, galvanized Copper for DN<40	 St. Steel flanges, flexible couplings Couplings, screwed sockets St. Steel flanges, flexible couplings Couplings, screwed sockets
Sewage Above main deck Below deck	 Loro, galvanized or coated Steel, galvanized	 Pipe ends with rubber Steel flanges
Scupper	Steel, galvanized	Steel flanges, flexible couplings
Hydraulic Inside Exposed	 Seamless steel precision pipe Stainless steel precision pipe	 Steel flanges, couplings Stainless steel flanges, couplings

810 Bilge , ballast system

810.1 Vessel bilge system

A bilge system in accordance with the requirements of the Classification Society and with the SOLAS will be provided, consisting of at least the following:

- bilge pumps
- bilge water separator
- bilge water collecting tanks

Three bilge pumps, complete with priming equipment, will be arranged, two in the engine room and one in the dry concentrate room. Each bilge pump will have a capacity of at least 50% of the required total capacity. The bilge main system will be arranged as a ring, serving SB and a PS areas. The system will be remote controlled from the wheelhouse as well as from the engine control room.

For daily service, in the engine room and in each thruster room, an air driven diaphragm pump with a capacity of 5m³/h @ 4bar will be fitted. Each pump will serve local bilge wells and will discharge to a common bilge water holding tank in the engine room.

The bilge water holding tank will be of the two stage execution. In the first stage, a high tank, the effluent will be collected. Separated oil will be sucked off by the sludge pump. Cleaned water will be stored in a collecting tank for final treatment by the bilge water separator, with a capacity of 5m³/h.
Both tanks will be heated and also connected to the sludge pump. Oily water interface level to be detected by an specialized sensor.

810.2 Process plant bilge system

In order to capture spillages from the process plant separate sumps are provided in the vertimill area, the dry concentrate area and the surge tank area. These will collect the wash down of spills which will be pumped to the course tails tanks by means of dedicated sump pumps which are part of the Owner Furnished process plant. The capacity of each bilge will be based on a hosing capacity of 2 time 2 litres/sec.

810.3 Ballast system

A ballast system will be provided to control the heel, trim and the draught of the Vessel. The controls shall be incorporated in the Vessel Management System. It will consist of at least the following equipment:

- water ballast pumps
- sand filters
- dedicated water ballast tanks as indicated on the tank capacity plan

Two (2) electrically driven centrifugal pumps with self-priming devices shall be installed with the following anticipated capacity (specifications to be confirmed in basic design phase, presented values are indicative):

Required capacity	4000	m^3/hr
Pressure head	approx. 5	bar

The pumps take suction from the sea chests and shall discharge overboard via discharge lines, with hull valves, one at portside and one at starboard. Pumps and system will be optimized for optimal suction performance. Remote start and stop will be arranged from the wheelhouse and the engine control room.

The system will incorporate a built-in sediment filtration system, reducing the amount of built-up sediment in the ballast tanks.

A ballast main ring line shall be installed, divided into a portside part and a starboard part with section valves. All ballast tanks shall be connected to the ring main via a branch suction/discharge line, each with a shut off valve. Valves will not be fitted inside tanks.

No water ballast treatment unit will be provided.

813 Fire-fighting system

A pressurized fire-fighting system in accordance with the requirements of the Classification Society and with Solas will be provided. The system will be filled with fresh water and will be kept under pressure by means of two (2) electrically driven centrifugal jockey pumps.

The capacity and pressure of the jockey pumps shall be balanced in such a way that in case one fire hydrant is used for deck wash purposes, the main fire pump shall not be switched on. The Jockey pumps do not run continuously, they have an accumulator and an automatic pump stop/start system. A relief valve shall be mounted in the ring main.

Three (3) electrically driven centrifugal main fire-fighting pumps shall be installed; one (1) in each engine room compartment which will also serve as general service pump and one(1) in the surge tank area. The latter shall be dedicated as the emergency fire-fighting pump and connected to the emergency switchboard. The engine room fire-fighting pumps will also serve as emergency bilge pumps. The pumps shall take suction from a cross-over and discharge into a fire main.

The system will consist of a fire-fighting ring with sectional shut-off valves at the engine room bulkheads. Fire-fighting lines with hydrants at sufficient locations shall be branched from the ring main line. Hydrants shall also be used for main deck washing.

International shore connections, one portside and one starboard, shall be installed to the ring main.

813.1 Helicopter fire-fighting system

A helicopter fire-fighting system shall be provided which will consist of at least the following:

- manually operated foam/water monitors
- a foam concentrate storage tank for AFFF type of foam liquid
- two (2) booster pumps

The booster pumps shall be fed by a separate supply line branched from the fire main line and shall supply water to the foam system at the required pressure at the monitor nozzle. The foam shall be added by means of an in-line proportioner for each monitor.

Starting and stopping of the pumps and opening of the valves to the monitors shall be remote with the option to start the pumps locally. Remote control will be located close to the helideck platform.

840 Hydraulic oil system

Hydraulic systems for the mining installation, including power pack with storage tank and swell compensator with expansion vessels will be Owner Furnished as part of the mining installation. Hydraulic consumers in the process plant area will also be Owner Furnished stand-alone units and will be part of the process plant package.

For the Vessel an hydraulic system is installed for following users :

- hydraulically operated valves
- auxiliaries in the crawler and process plant systems
- any other users mentioned in this specification

All different users are operating independently from any pressure adjustments or other adjustments for other users.

Maximum working pressure is 250 bar. Testing pressure for complete installation at least 1,25 times the working pressure

After completion, the whole system will be thoroughly flushed with oil and tested. The installation will be handed over with clean filters.

An electrically driven gear pump is installed as hydraulic oil transfer pump. The pump draws from :

- hydraulic oil storage tank
- hydraulic unit tank

and discharges to :

- hydraulic unit tank
- dirty oil tank

An hydraulic power pack unit will be installed, consisting of at least the following:

- hydraulic oil tank
- main pump set
- auxiliary pump set
- emergency pump set

The hydraulic oil tank will be made of stainless steel and shall have a capacity of at least 3 times the total pump delivery per minute and provided with level switches and a level glass for level alarming and thermostats for temperature control. The tank will have manholes for access, de-aeration pipe and a drain connection with valve to drain to the dirty oil tank.

860 Filling, sounding and de-aeration system

860.1 De-aeration system

All tanks will be provided with ventilation-overflow lines and approved type tank ventilation / check valves as per Solas requirements.
Systems containing oil will have ventilation-overflow lines to special overflow tanks, which will have a common ventilation line to outboard. Overflow will be detected and alarmed. These de-aeration lines will be located in properly sized spill trays.

860.2 Filling system

Filling/ discharge connections will be arranged for loading/ discharging liquids. Where required standardized connection [Marpol] will be provided. Lines connecting to oil tanks, or tanks containing residues of oil, will be located in properly sized spill trays.

860.3 Sounding system

All tanks will be provided with class approved tank level gauging system.
For water ballast tanks, fuel bunkers and service tanks and potable water tanks, an approved remote gauging system will be fitted.
Fixed sounding pipes on open decks shall be fitted with bronze caps. Inside the vessel sounding pipes shall be fitted with quick closing valve and vent / check cock.

861 Scupper system

On weather exposed decks, scuppers will be arranged, discharging to lower decks or overboard. Wet interior spaces will be discharged via the grey water system.

870 Hot and cold potable water system

870.1 Hot and cold water system

For domestic duty a sanitary system will be arranged, mainly consisting of:

- potable water tank
- cold water hydrophore
- cold water circulation pumps
- potable water treatment equipment
- calorifiers
- hot water circulation pumps
- hot water boilers

Fresh water will be generated from the desalination plant. Water intended for potable water will be disinfected and re-hardened before storing it in fresh water tanks. For distribution of one (1) fresh water hydrophore with one (1) running and one stand-by (1) pump and a stainless steel expansion Vessel will fitted. In the discharge an active carbon filter will be fitted.

Cold fresh water will be distributed via a ring type system, comprising two circulating pumps and a UV-sterilizer.
Special attendance will be paid to legionella prevention:

- no dead pipe ends will be allowed
- temperature rise will be avoided
- international guides and rules will be applied

Hot fresh water will be obtained from the cold fresh water hydrophore and will furthermore comprise of a ring type system with two calorifiers and two circulating pumps.
Special attendance will be paid to legionella prevention:

- no dead pipe ends will be allowed
- temperature will be maintained at minimum 60°C
- international guides and rules will be applied

At dedicated locations in the process plant and where required elsewhere eye-showers will be arranged which will be supplied with hot and cold water.

870.2 Technical water system

For technical duties a technical water system will be arranged, mainly consisting of:

- technical water tank
- technical water hydrophore

The technical water hydrophore will take suction from the technical water tank and will supply technical water to at least the following consumers:

- separators
- fresh cooling water expansion tanks
- urinals and toilet flushing
- taps for washing [cleaning] interior and exterior spaces
- window wipers
- turbo chargers

880 Sewage system

A sewage system based on vacuum extraction will be provided for collection and clean discharge of sewage. The system will be designed for a complement of 120 persons and will consist of least the following components (specifications to be confirmed in basic design phase, presented values are indicative):

- sewage tanks for remote toilets and sinks
- one (1) sewage collecting tank
- sewage pumps
- sewage treatment unit

Local sewage tanks will be provided at locations where hotel services are provided that are too far away from the sewage collecting tank. Transfer of this sewage will be done with electrically driven sewage pumps with the following anticipated capacity:

As an emergency means of discharge the collected sewage can be discharged by one (1) electrically driven sewage pump. The sewage pump will take suction from the sewage collecting tank and will discharge to the discharge connection with Marpol flange at deck level.

The pumps can be started and stopped locally. A remote start/stop for the pump is provided near the deck connection.

880.1 Sewage treatment unit

A sewage treatment unit with integrated vacuum system for black water and grey water is installed in the engine room. The system will be in full compliance with the relevant regulations, esp. Annex IV of Marpol 73/78 with amendments, MEPC 2 (VI), MEPC 115(51).

The installation uses biological oxidation to purify the sewage and is designed specifically for marine applications.

Effluent discharge shall not contain more than :
- 50 mg per l of Biological Oxygen Demand
- 50 mg per l of suspended solids
- 250 coliforms per 100 ml

or to the latest IMO and Maritime New Zealand rules and regulations.

The system is suitable for discharge within the 12 miles from the nearest land zone. The sewage/vacuum installation is suitable for a total of 120 persons.

The unit will be complete with:
- three (3) compartments for collecting, aerating, settling.
- two vacuum ejector pumps and ejectors, one acting as standby.
- electrically driven air blower(s)
- two electrically driven discharge pumps, one acting as standby, of sufficient capacity and head to discharge overboard, assuming a draught of 12 m.
- all required appendages
- control panel, level switches, etc... for fully automatic operation
- disinfecting unit, by means of chlorination (with chlorine dosage pump, with chlorine low level alarm).
- The unit is arranged with disinfection arrangement and comminuting arrangement as required by Class.

The installation is provided with connections for flushing the tanks.

For operation where no discharge is allowed, a sewage collecting tank is installed. This collecting tank can be emptied by means of the sewage discharge pump to a deck connection (Marpol) or to outboard. Tank provided with high level alarm. The sewage treatment plant can either discharge overboard or into the collecting tank. The discharge pump of the sewage unit has a capacity sufficient for discharging the completely filled sewage collecting tank within 4 hours.

APPENDICES

APPENDIX A

MAKER'S LIST

(3 pages)

CALCULATION SHEET VUYK ENGINEERING ROTTERDAM	**Project:** Mining Vessel **Client:** TTRL **Date:** Mar-14 **Name:** Sbo **Subject:** Maker's list **Remarks:**	**Proj. nr:** 13.300 **Chkd:** **Revision:**

Group	Item	Preferred supplier
0	Classification	American Bureau of Shipping
		Maritime New Zealand
	Model tests	Marin
	Basic design	Owner Furnished / IHC Mining
	Detail design	Yard
1	Painting	Hempel
		Jotun
		International paint
		Sigma
	Cathodic protection	MME
2	Watertight / sliding doors	Aludoor
		Winel
		IMS
	Main cranes	Liebherr
		Dreggen
		TTS
		Hydralift
		NMF
		Hagglund
	Mining installation	Owner Furnished / IHC Mining
	Booster unit	Owner Furnished / IHC Mining
	Process plant	Owner Furnished / TTR
	Tailings disposal	Owner Furnished / IHC Mining
	Desalination plant	Wartsila - Hamworthy
		Osmoflow
		Nubian
		Alfa Laval
	Offloading reel	IHC Mining
3	Mooring winches	Owner Furnished / IHC Mining
	Swivel fairleads	Owner Furnished / IHC Mining
	Stevpris Anchors	Vrijhof
		Wortelboer
		Stevin
	Life boats and rescue boats with davit	Umoe Schat Harding
		Ernst Hatecke
		Norsafe
		Fassmer
	Safety equipment	Unitor
		Koepke
		Autoflug
		DSB
	Fire suppresion system	Novec
	Fire detection	Consilium
		STN Atlas
		Siemens
		Ajax de Boer
		Unitor
	HVAC installation	Heinen & Hopman
		York
		Flakt
		Frima
	Overhead cranes	Demag
		Stahl
		van Leusden

Group	Item	Preferred supplier
4	Interiour designer	
	Insulation	Rockwool
		Kaefer
		Paroc
5	Generators	Owner Furnished / IHC Mining
	E-motors thrusters and mooring winches	Owner Furnished / IHC Mining
	Power distribution	Owner Furnished / IHC Mining
	Trafo's	Owner Furnished / IHC Mining
	Mooring winch and thruster drives	Owner Furnished / IHC Mining
	Batteries	Mastervolt
		Varta
	UPS system	Owner Furnished / IHC Mining
	Lighting	Aqua signal
		Seemantz (TTT)
	Cables	Draka
		Untel/Nexans
		BICC
		Pirelli
	Communication equipment	Owner Furnished / IHC Mining
	Positioning system	Owner Furnished / IHC Mining
	Navigation equipment	Owner Furnished / IHC Mining
	Loading condition monitoring system	Owner Furnished / IHC Mining
	Alarm & monitoring	Owner Furnished / IHC Mining
	Power management system	Owner Furnished / IHC Mining
	Vessel automation system	Owner Furnished / IHC Mining
6	Main generator sets	Owner Furnished
	Gearboxes	Siemens
		Lohman & Stolterfoht
		Renk
		ZF
		Janel Kesterman
	Planetary gear boxes	Lohman & Stolterfoht
		Zoellner
		Brevini
		Siemens
	Couplings	Bosch Rexroth
		Lohman & Stolterfoht
		Vulkan
		Centaflex
	Propeller with nozzle	Wartsila
		Thrustmaster
		Rolls Royce
		Schottel
		Rolls Royce Marine
	Thermal oil installation	Konutherm
		Aalborg
		Wiesloch

Group	Item	Preferred supplier
7 / 8	Pumps	Azcue
		Allweiler
		Warman
		Hamworthy
	Air compressors and dryers	Atlas Copco
		Ingersoll Rand
		Sperre
		Hatlapa
		Sauer
		Wartsila - Hamworthy
	Fuel oil & Lub oil separators	Alfa Laval
		GEA / westfalia
	Booster unit	Alfa Laval
		Westfalia
		Marin Control
	Sludge incinerator	Alfa Laval
		Westfalia
		Wartsila - Hamworthy
		Teamtec
	Heat exchangers	Sondex
		NRF
		Alfa Laval
		GEA / westfalia
	Oily water separator	RWO
		Facet
		Jowa
	Sewage treatment units	Wartsila - Hamworthy
		Jowa
		Aquamar

Appendix 19.14 - ST500 Gas Turbine Specifications

SGT-500 Industrial Gas Turbine

Power Generation: (ISO) 18.47 MW(e) Base Load, 19.38 MW(e) Peak Load

The Siemens SGT-500 industrial gas turbine is a highly dependable gas turbine with excellent fuel flexibility. It combines the reliability and robustness of an industrial design and low emission levels of the latest turbine technology for a wide variety of fuels and applications at low operational costs.

The SGT-500 gas turbine has been serving the industrial power generation segment for over 50 years. Introduced in 1955, the turbine was designed for heavy oil operation under tough conditions. It is used widely in industrial power generation, marine as well as oil and gas applications, whether onshore or offshore, floating or fixed.

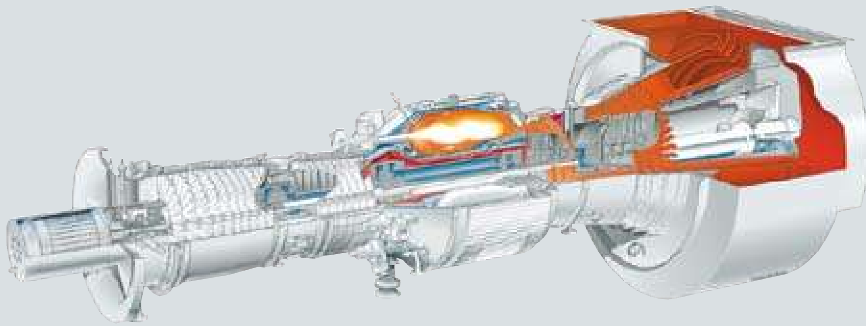
Due to its large roomy combustors and low firing temperature, the SGT-500 has the capability to operate on a wide range of fuels. Experience includes gas and heavy fuel oils, naphtha, crude oil, high aromatic and hydrogen-rich gases, as well as gases with high content of sulfuric acid.

In addition, the combustor and fuel system have the potential for easy adaptation to additional liquid and gaseous fuels, including the growing flora of environmentally friendly fuels. The SGT-500 can be equipped with several emissions reduction alternatives, including Dry Low Emissions (DLE) combustion.

Outstanding operational reliability

With world class start-up and operation reliability performance, the SGT-500 is an excellent solution for emergency power applications. Its low firing temperature contributes to an impressive maintenance program. At operation on full load the standard time between major overhauls is 80,000 hours. At 94 % load the interval can be extended to 160 000 hours, equal to 18 years of operation.

SGT-500 Industrial Gas Turbine



SGT-500 core engine in workshop.

Technical specifications

Overview

- Power generation: 18.47 MW(e)
- Electrical efficiency: 32.9 %
- Heat rate: 10,946 kJ/kWh (10,375 Btu/kWh)
- Power turbine speed: 3,600 rpm
- Compressor pressure ratio: 13:1
- Exhaust gas flow: 96.4 kg/s (212.6 lb/s)
- Exhaust temperature: 376° C (709° F)
- NO_x emissions (with DLE corrected to 15 % O_2 dry)
  - Natural gas: ≤42 ppmV

Axial Compressor

- Two multi-stage (10 + 8 LP/HP) axial flow compressors
- Compressor rotors of bolted design
- Corrosion-coating available

Combustion

- 7 can-annular combustion chambers
- Conventional combustion system
  - Steam or water injection for emissions control and power augmentation
- Dry Low Emissions (DLE) combustion system option (gas only)

Turbine

- Two compressor turbines (1 + 2 HP/LP)
- Free power turbine of axial-flow design
- 3-stage 3,600 rpm turbine

Fuel System

- Natural gas - Liquid fuel - Dual fuel - Heavy fuel
  - Other fuel capability available on request
- Fuel-changeover capability at any load
- Load-rejection capability
- Fuel-supply pressure requirement: 18.0 bar(a) ±0.5 bar (261 ± 7 psi(a))

Bearings

- Hydrodynamic radial- and thrust bearings of tilting pad type
- Vibration and temperature monitoring

Lubrication

- Lubricating oil tank integrated into gas turbine skid
- AC-driven auxiliary pump
- DC-driven emergency pump
- AC-driven lube oil pumps with DC backup
- Air- or water-cooled lube oil coolers

Gearbox

- Parallel-shaft gear of double helical design
- High-speed shaft 3,600 rpm (nominal speed for PG)
- Low-speed shaft 1,500 rpm (50 Hz) or 1,800 rpm (60 Hz)
- 4 radial bearings of sleeve type

Generator

- 4-pole design
- Rated voltage: 10.5 kV/11.0 kV/13.8 kV
- 50 Hz or 60 Hz
- Protection IP54
- PMG for excitation power supply
- Complies with IEC/EN 60034-1 standard

Starting

- Start and barring motor connected to the LP rotor via a ratchet coupling

Control System

- Siemens Simatic control system
- Distributed inputs/outputs

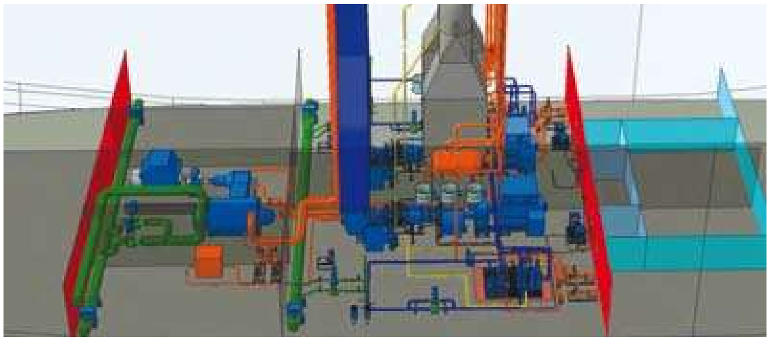
Gas turbine:

Key features

- Robust design – long engine life
- High availability/reliability
- Low fuel-gas pressure requirement
- No advanced sealings, resulting in minimal deterioration and maintained efficiency
- Dry Low Emissions (DLE) system option
- Low starting power (<160 kW)
- Fast start capability (~3 minutes)
- Dual-fuel
- Competitive with dual-fuel reciprocating technology
- Marine classified
- No methane slip

Maintenance

- Extremely low and predictable maintenance costs
- Easy on-site maintenance possible
  - complete modules can be swiftly exchanged
- Direct exchange of gas generator possible
  - Core can be air-freighted
- First overhaul after 40,000 hours (80,000 hours between major overhauls)
- Lease-engine availability for planned overhauls
- Online wash available
- Standardized concepts for time-based and cycle-based maintenance
- Staff training in operation and maintenance
- 24/7 Siemens support
- Remote diagnostics



SGT-500 package in combined cycle configuration.

Four SGT-500 units installed in Egypt to power an LNG plant.

Package:

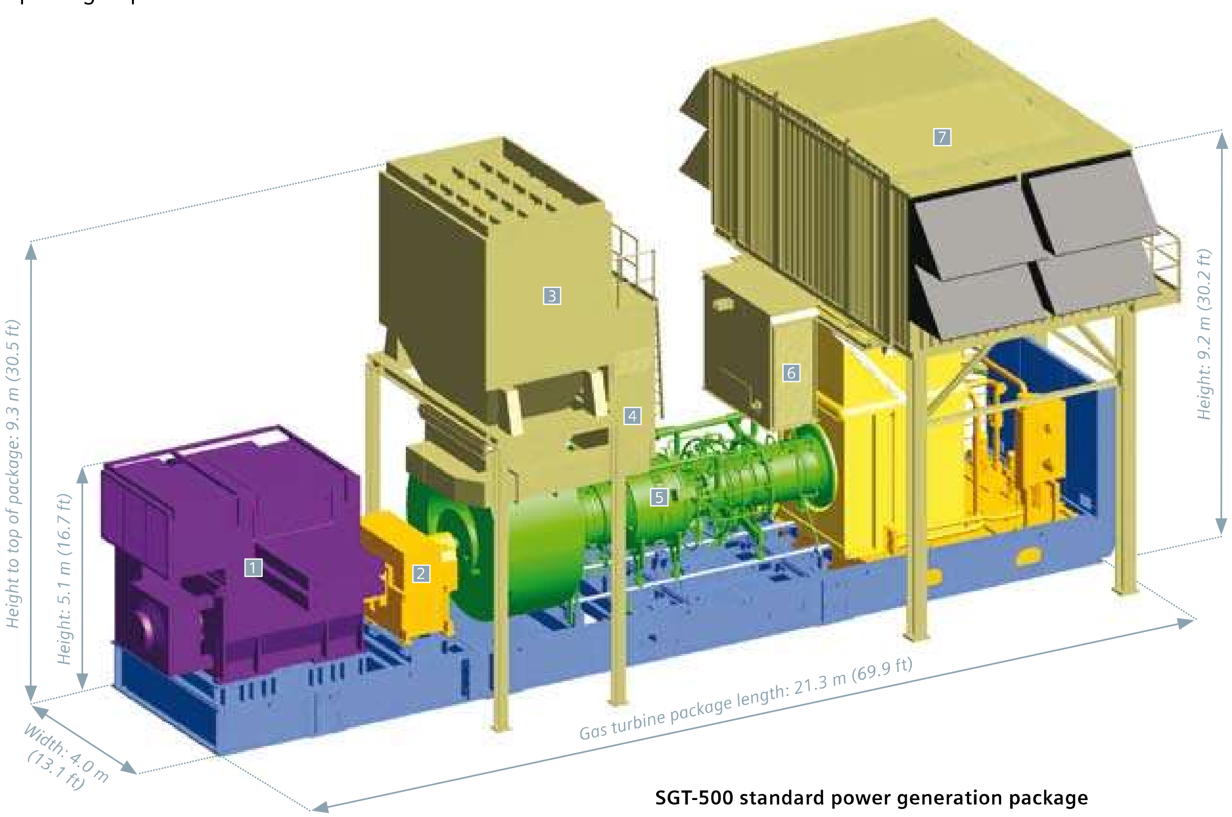
Key features

- Compact layout
- State-of-the-art control system fulfills all requirements for control and safety
- Can easily communicate with other control systems
- DNV, LR and ABS certified packages
- Marine package with auxiliary drive system on lightweight frame
- FPSO package (Floating Production, Storage and Offloading) option
- ATEX package option

Cogeneration and combined cycle

The SGT-500 is easily adapted to any cogeneration or combined-cycle plant layout. It has very low environmental impact in both configurations. Thanks to high air flow, the SGT-500 has excellent steam-raising capability which yields high total efficiency in cogeneration.

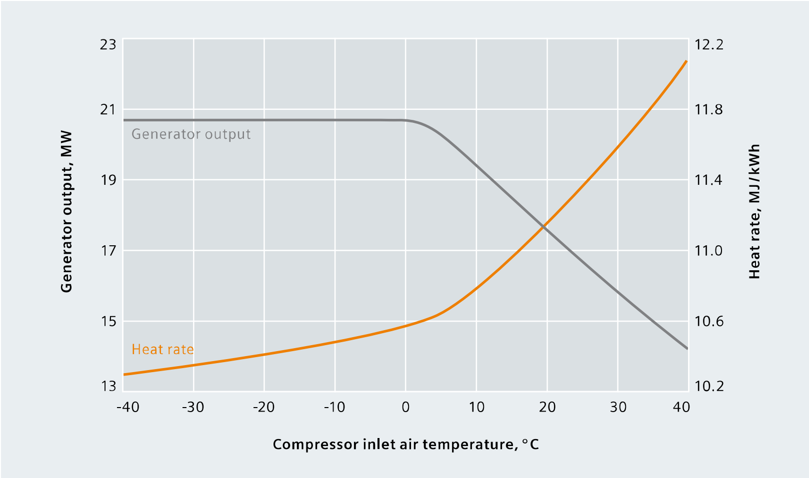
In combined cycle, the SGT-500 has very high total efficiency independent of the fuel used. When using HFO (heavy fuel oil) the SGT-500 offers outstanding emission performance and half the maintenance cost compared to competing technologies.



SGT-500 standard power generation package

1 AC generator
2 Speed reduction gear
3 Combustion exhaust
4 Enclosure air outlet
5 Core engine
6 Enclosure air inlet
7 Combustion air inlet

SGT-500 Performance



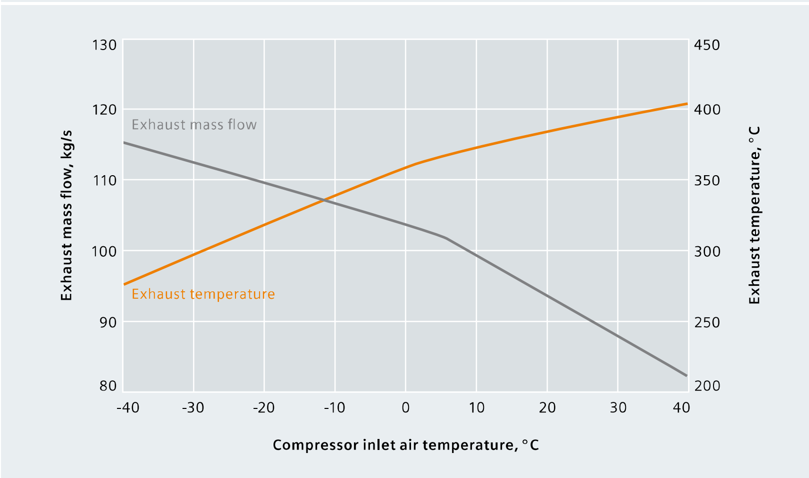
Nominal generator output and heat rate

Conditions/assumptions:

Fuel:	Natural Gas LHV, 46,798 kJ/kg (20,118 Btu/lb)
Altitude:	Sea level
Ambient pressure:	1,013 bar (a) (14.7 psi (a))
Relative humidity:	60 %
Inlet pressure loss:	5 mbar (2″ H_2O
Outlet pressure loss:	5 mbar (2″ H_2O)
Fuel temperature:	5° C (41° F)

Diagram conversion factors:

To convert	To	Multiply by
°C	°F	(°Cx9/5)+32
MJ/kWh	Btu	949



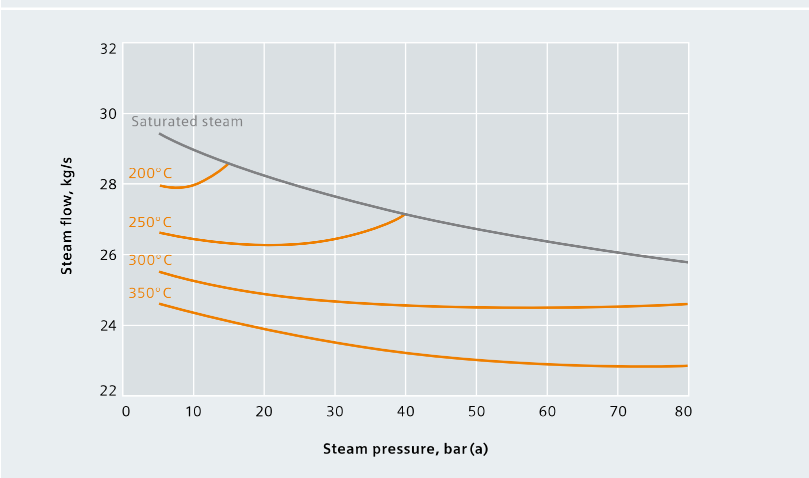
Nominal exhaust mass flow and temperature

Conditions/assumptions:

Fuel:	Natural Gas LHV, 46,798 kJ/kg (20,118 Btu/lb)
Altitude:	Sea level
Ambient pressure:	1,013 bar(a) (14.7 psi(a))
Relative humidity:	60 %
Inlet pressure loss:	5 mbar (2″ H_2O)
Outlet pressure loss:	5 mbar (2″ H_2O)
Fuel temperature:	5° C (41° F)

Diagram conversion factors:

To convert	To	Multiply by
°C	°F	(°Cx9/5)+32



Supplementary-fired heat-recovery steam generation

Conditions/assumptions:

Fuel:	Natural Gas LHV, 46,798 kJ/kg (20,118 Btu/lb)
Altitude:	Sea level
Ambient pressure:	1,013 bar(a) (14.7 psi(a))
Ambient temperature:	15° C (59° F)
Relative humidity:	60 %
Boiler pinch point:	8 K (14 F)
Boiler approach point:	5 K (9 F)
Inlet pressure loss:	5 mbar (2″ H_2O)
Outlet pressure loss:	25 mbar (10″ H_2O)

Diagram conversion factors:

To convert	To	Multiply by
°C	°F	(°Cx9/5)+32
kg/s	lb/s	2.2046
bar	psi	14.5

Published by and copyright © 2010:
Siemens AG
Energy Sector
Freyeslebenstrasse 1
91058 Erlangen, Germany

Siemens AG
Energy Sector
Oil & Gas Division
Wolfgang-Reuter-Platz
47053 Duisburg, Germany

Siemens Energy, Inc.
10730 Telge Road
Houston, Texas 77095, USA

Siemens Industrial Turbomachinery AB
SE-612 83 Finspong, Sweden

For more information, please contact our Customer Support Center.
Tel: +49 180 524 70 00
Fax: +49 180 524 24 71
(Charges depending on provider)
E-mail: support.energy@siemens.com

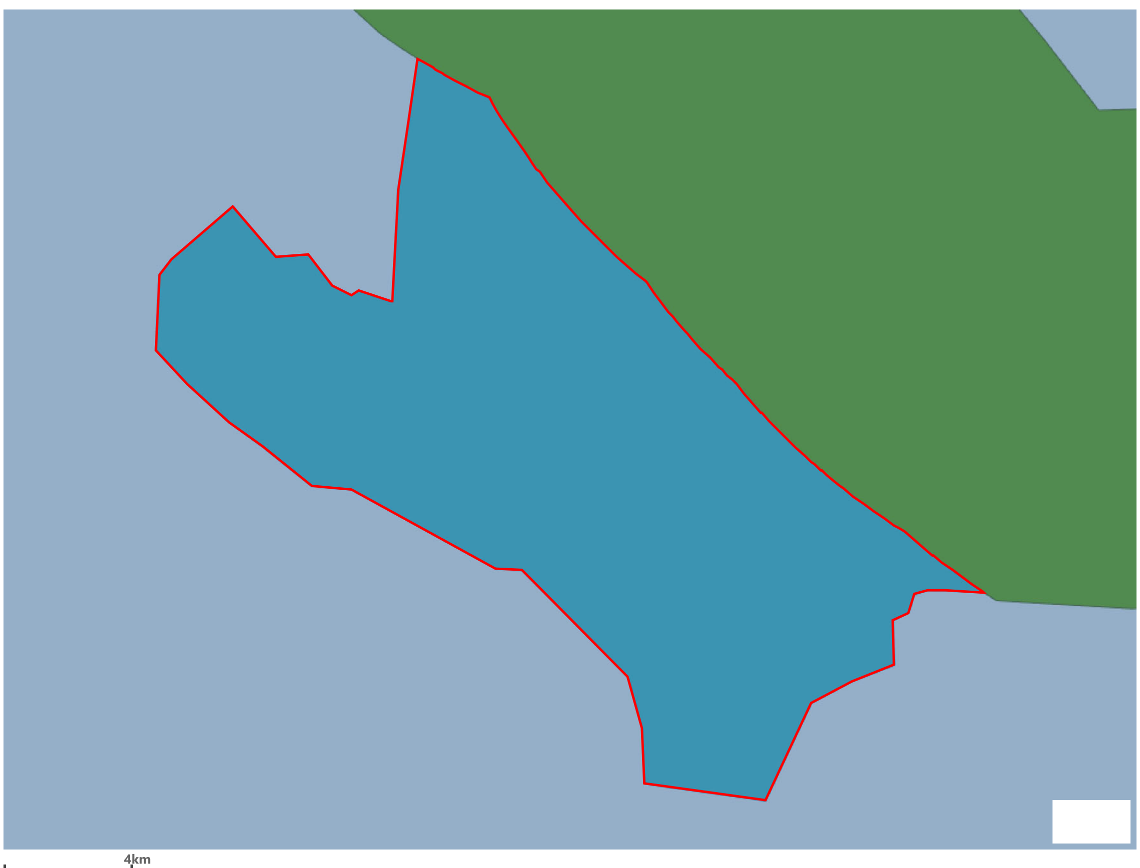
Oil & Gas Division
Order No. E50001-W430-A111-X-4A00
Printed in Germany
Dispo 34806, c4bs No. 7447, P WS 06102.5

Appendix 19.16 - Trans-Tasman Resources Mineral Permits

NEW ZEALAND PETROLEUM & MINERALS

Permit 55581 Report - 7/02/2025

Permit Number	55581
Permit Nonexclusive Y/N	N
Duration	20 years
Permit Area	24257 Hectares
Permit Offshore/Onshore	Offshore
Permit Status	Active
Permit Status Date	2/5/2014
Permit Location	Taranaki Region
Permit Commodity	Minerals
Permit Mineral Group	Metal
Permit Type Code	Mining Permit
Permit Type Description	Minerals Mining Permit
Permit Mineral Programme	Minerals Programme for Minerals 2013
Subsequent To Permit	50753
Permit Allocation Method	AWPO
Permit Commencement Date	2/5/2014
Permit Expiry Date	1/5/2034
Permit Grant Date	2/5/2014
Permit Operation Name	South Taranaki Bight
Owners	TRANS-TASMAN RESOURCES LIMITED
Operator	TRANS-TASMAN RESOURCES LIMITED
Minerals	Ironsand
B1_PER_ID1	13ATX
B1_PER_ID2	00000
B1_PER_ID3	00094



Permit 54068 Report - 7/02/2025

Permit Number	54068
Permit Nonexclusive Y/N	N
Duration	13 years
Permit Area	63503.647 Hectares
Permit Offshore/Onshore	Offshore
Permit Status	Active
Permit Status Date	19/12/2012
Permit Location	Taranaki Region
Permit Commodity	Minerals
Permit Mineral Group	Metal, Non-Metal
Permit Type Code	Exploration Permit
Permit Type Description	Minerals Exploration Permit
Permit Mineral Programme	Minerals Programme for Minerals 2013
Subsequent To Permit	50383
Permit Allocation Method	AWPO
Permit Commencement Date	19/12/2012
Permit Expiry Date	18/12/2025
Permit Grant Date	19/12/2012
Permit Operation Name	
Owners	TRANS-TASMAN RESOURCES LIMITED
Operator	TRANS-TASMAN RESOURCES LIMITED
Minerals	Aluminium, Antimony, Bismuth, Copper, Garnet, Gold, Ilmenite, Iron, Ironsand, Lead, Magnesium, Molybdenum, Nickel, Platinum Group Metals, Rare Earth Elements, Rutile, Silver, Tantalum, Tin, Titanium, Tungsten, Zinc, Zircon
B1_PER_ID1	11ATX
B1_PER_ID2	00000
B1_PER_ID3	00175

Appendix 19.16 - Trans-Tasman Resources 2023 Mineral Resource Statement

TARANAKI VTM IRON SAND PROJECT – SOUTH TARANAKI BIGHT NEW ZEALAND

MINERAL RESOURCE STATEMENT

COOK, KUPE AND TASMAN VTM DEPOSITS

1 MARCH 2023

Manuka Resources Limited's (ASX:MKR) wholly owned New Zealand subsidiary, Trans-Tasman Resources Limited (TTR), has calculated the mineral resource estimates for its Taranaki VTM[1] iron sand project located in the South Taranaki Bight off the west coast of the North Island, New Zealand (Figure 1) ([1] *Vanadiferous titanomagnetite* $Fe_{2.74}Ti_{0.24}V_{0.02}O_4$).

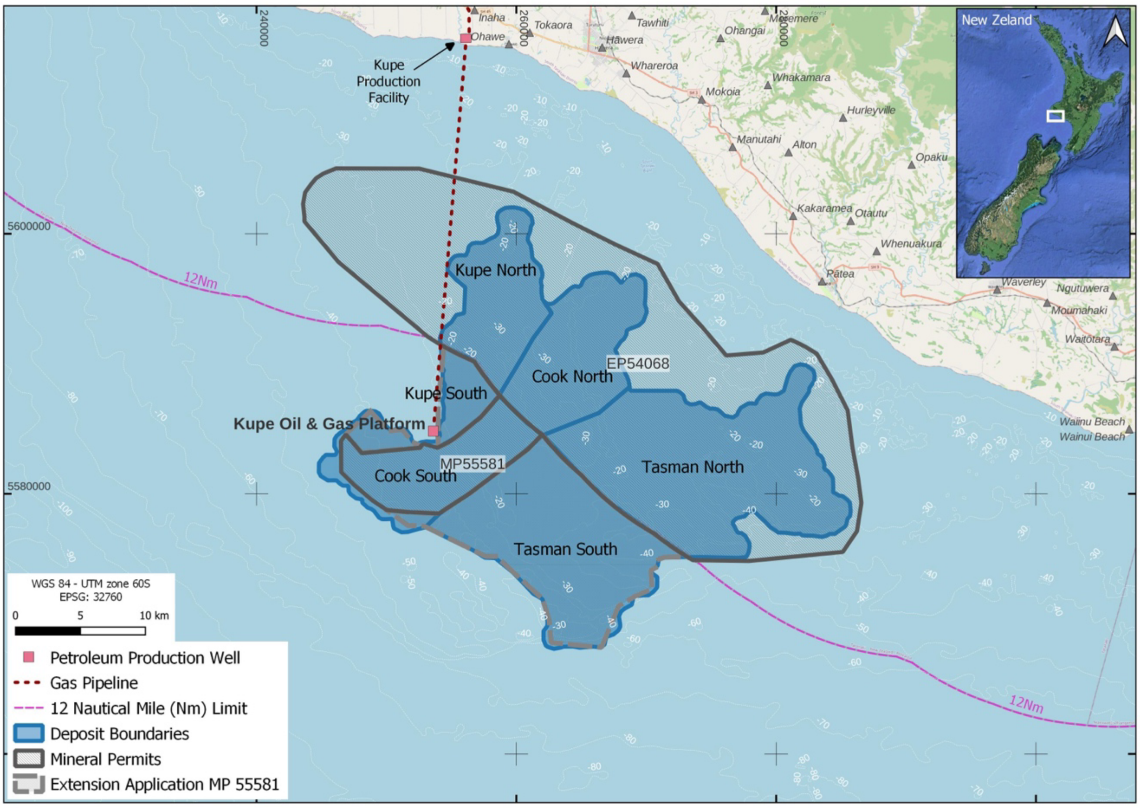


***Figure 1:** Location Plan of Taranaki VTM Deposits, South Taranaki Bight, New Zealand*

Three contiguous resource deposits, the Cook, Kupe and Tasman VTM deposits that make up the Taranaki VTM project, are separately reported. The mineral resource and Davis Tube Recovery (DTR) concentrate estimates reported, based on all available assay data as of 1 January 2015, include iron oxide and iron (Fe_2O_3 & Fe), titanium dioxide (TiO_2) and vanadium pentoxide (V_2O_5) mineral resource estimates.

The mineral resource estimates for Cook, Kupe and Tasman deposits, have been reported separately for each of the North Blocks inside the 12 nautical mile (Nm) limit within Mineral Exploration Permit EP54068 [Resource Management Act (RMA) approval area] and the South Blocks outside the 12Nm limit within Mineral Mining Permit MP55581 [Exclusive Economic Zone (EEZ) approval area].

The mineral resource estimates are prepared and classified in accordance with the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code 2012 Edition or JORC Code 2012).

Summary

The Taranaki VTM iron sand project has a total reported combined Indicated and Inferred mineral resource of 3,157Mt @ 10.17% Fe_2O_3, 1.03% TiO_2 and 0.05% V_2O_5 at a 7.5% Fe_2O_3 cut-off grade (Figure 1; Table 1).

The reported mineral resource estimate for the contiguous Cook, Kupe and Tasman deposit Blocks has an Indicated and Inferred mineral resource of 1,275Mt @ 10.44% Fe_2O_3, 1.05% TiO_2 and 0.05% V_2O_5 inside the 12Nm limit (within EP54068) and 1,881Mt @ 9.99% Fe_2O_3, 1.01% TiO_2 and 0.05% V_2O_5 for the initial mining area outside the 12Nm limit (within MP55581) (Figure 2; Table 1, detail Table 2, Table 4 and Table 6).

A DTR and Concentrate Grade estimation has been reported for the Cook North and South Blocks and the Kupe North and South Blocks using a 3.5% DTR cut-off grade (Table 1).

The mineral resource estimate for the Cook North and South Blocks reports a combined Indicated and Inferred recoverable mineral resource of 1,188.6Mt @ 11.17% Fe_2O_3, 1.14% TiO_2 and 0.05% V_2O_5 generating 84.0Mt concentrate at a grade of 56.18% Fe, 8.36% TiO_2 and 0.51% V_2O_5 at a 3.5% DTR cut-off grade (detail Table 2 and Table 3).

The mineral resource estimate for the Kupe North and South Blocks reports a combined Indicated and Inferred recoverable mineral resource of 688.5Mt @ 10.80% Fe_2O_3, 1.12% TiO_2 and 0.05% V_2O_5 generating 46.1Mt concentrate at a grade of 56.82% Fe, 8.38% TiO_2 and 0.51% V_2O_5 at a 3.5% DTR cut-off grade (detail Table 4 and Table 5).

Additional Taranaki VTM mineral resource estimates for the Tasman North and South Blocks have been reported using a 7.5% Fe_2O_3 (head) cut-off grade. At this cut-off grade the Tasman North and South Blocks have a combined Indicated and Inferred mineral resource of 1,279.6Mt @ 8.91% Fe_2O_3, 0.88% TiO_2 and 0.05% V_2O_5 at a 7.5% Fe_2O_3 cut-off grade (detail Table 6).

Table 1: *Taranaki VTM Project Reported Mineral Resource and Concentrate Tonnage and Grades*

Taranaki VTM Resource Estimates Summary									
	Indicated and Inferred Mineral Resources					DTR Concentrate			
Inside 12Nm (RMA)	**Cut-Off Grade**	**Mt**	**Fe_2O_3%**	**TiO_2%**	**V_2O_5%**	**Mt**	**Fe%**	**TiO_2%**	**V_2O_5%**
Cook North Block	3.5% DTR*	274	11.90	1.19	0.06	21	57.19	8.12	0.52
Kupe North Block	3.5% DTR*	417	11.48	1.21	0.06	31	57.07	8.35	0.51
Tasman North Block	7.5% Fe_2O_3	585	9.02	0.88	0.04				
Total VTM Resource RMA		**1,275**	**10.44**	**1.05**	**0.05**				
Outside 12Nm (EEZ)									
Cook South Block	3.5% DTR*	914	10.95	1.12	0.05	63	55.84	8.45	0.50
Kupe South Block	3.5% DTR*	272	9.76	0.98	0.05	16	56.33	8.43	0.50
Tasman South Block	7.5% Fe_2O_3	695	8.81	0.89	0.04				
Total VTM Resource EEZ		**1,881**	**9.99**	**1.01**	**0.05**				
Taranaki VTM Resource Total		**3,157**	**10.17**	**1.03**	**0.05**				

DTR is Davis Tube Recovery of the magnetic fraction of the sample

This Mineral Resource Estimate JORC Code 2012 replaces the historic 2015 (Revision 2018) JORC Mineral Resource Estimate for the South Taranaki Iron Sand Project previously released in 2022.

Assumptions and Methodology

The Taranaki VTM Mineral Resource estimate is based on a number of factors and assumptions:

- The VTM iron sand deposits are interpreted as being a blanket of sand overlying deeper geomorphologic features identified by geophysical surveys. The sands have been reworked by wave, current and tidal action but appear to reflect the underlying geomorphologic features as evidenced by the statistical differences noted across the area.
- The geomorphologic features have been categorised as fluvial, deltaic, dune, beach and slump domains.
- The Mineral Resource is constrained laterally by the geomorphologic domain boundaries and the extent of the 689 reverse circulation percussion (RCP) drill hole sample data available (Figures 3 and 4).
- The extent of Domain 6 has been adjusted to take into consideration step out drilling undertaken in 2014. Additional geostatistical evaluation shows that the area is still characteristic of the previous data.
- Modelling domains were extrapolated laterally 1,000m where unconfined by drilling or domain boundaries.
- Only reverse circulation drill samples have been used in the estimation of the resources. Only the -2mm part of each sample has been analysed with the physical recovery (REC) recorded in the database.
- A total of 4,237 samples have analyses for Fe_2O_3, SiO_2, Al_2O_3, TiO_2, CaO, K_2O, MgO, MnO, V_2O_5, P_2O_5, and LOI (head grades). 1,716 samples from the Cook and Kupe deposits have Davis Tube Recovery (DTR) results and 1,665 of these have analyses for the magnetic fraction.
- The Davis Tube Concentrate (DTC) samples have analyses for Fe, Al_2O_3, SiO_2, TiO_2, CaO, K_2O, MgO, Mn, P, V_2O_5, and LOI.
- Modelling domains (Figure 4) were used to flag the sample data for statistical analysis and estimation.
- Vertically, the Mineral Resources are constrained by a mineralisation envelope defined by a nominal 4% Fe_2O_3 edge cut-off grade (Figure 5).
- The survey control for collar positions is considered adequate for the purposes of this study.
- A review of the QAQC data was completed and the analytical data is considered satisfactory.
- A three dimensional block model was built using the geomorphologic domains and mineralisation envelope to constrain the resource estimate.
- Statistical analysis used the drill sample data weighted by physical recovery (REC) and Davis Tube recovery (DTR) as appropriate.
- The resource was estimated using an Ordinary Kriging algorithm. Head grades were estimated using samples weighted by recovery. Estimations for concentrate grades were weighted by physical recovery and DTR. The weighting is applied in order to appropriately reflect the relationship between the physical recovery and head assays for the head samples, and physical recovery, Davis Tube Recovery and the Davis Tube Concentrate assays for the magnetic concentrate samples. Weighting was completed by calculating the accumulation

(REC × Head Sample Assay, Rec × DTR × DTC assay) and subsequently back calculating the head and DTC grade estimates by dividing by the estimated REC and (REC × DTR) values.

- No high grade cutting or restraining of outlier samples was required.
- Head grades were estimated for Fe_2O_3, SiO_2, Al_2O_3, TiO_2, CaO, K_2O, MgO, MnO, V_2O_5, P_2O_5, LOI, Recovery and DTR. DTC grades were estimated for Fe, Al_2O_3, SiO_2, TiO_2, CaO, K_2O, MgO, Mn, P, V_2O_5, and LOI.
- The model was constructed and estimated using Micromine.
- Dry bulk density was assigned based on a regression against Fe. The regression was developed based on the theoretical density of the mineral sands supported by 46 laboratory density measurements.
- The resource model estimates have been classified as Indicated Resource where the drill spacing is on a 1,000m by 1,000m grid or closer, and Inferred Resource where the deposit is less systematically drilled but geological continuity can be interpreted.

Model Validation

This 2023 mineral resource model incorporates model validation from the previously reported 2015 model and the 2018 revision. These validation parameters include:

- Bathymetry – The bathymetric surface was updated to include more detailed data acquired from multi beam sonar surveys undertaken by NIWA in 2013.
- Database
  - Five additional deep drill holes had been added to the database after review of recovery and quality of the sampling
  - The 2015 "Area 2" resource estimation used 689 drill holes, including 58 drill holes completed in 2014.
- The base of mineralisation (BOM) was revised for the deep drill holes and new drilling.
- The model has been rotated clockwise to a bearing of 070° to optimise the blocks with the proposed mining direction.
- The model Parent Block size was created at 300m × 300m to reflect the expected Selective Mining Unit (SMU) size.
- Variography was reviewed and revised where necessary.

The most significant difference between the 2015 and 2018 reported models is the delineation and reporting of the Cook, Kupe and Tasman VTM deposits separately for each of the North Blocks inside the 12Nm limit within Mineral Exploration Permit EP54068 (RMA approval area) and the South Blocks outside the 12Nm limit within Mineral Mining Permit MP55581 (EEZ approval area).

Compliance with JORC Code 2012 Assessment Criteria

In addition, the resource estimates stated in this Mineral Resource Statement are based on the assessment criteria summarised in Table 7 and as disclosed in Appendix A JORC Code 2012 Table 1.

Mineral Resource Statement

The mineral resource estimates are classified in accordance with JORC Code 2012.

Grades and tonnages reported are for all material with the recovery of the resource shown on the tables. Reported Head Grades are the -2mm portion of the sample. Concentrate grades are for the magnetically recoverable portion of the sample. Concentrate tonnage is calculated from the head tonnage and DTR.

The mineral resources have been reported at 3.5% DTR cut-off grade where DTR analyses are available within the Cook and the Kupe deposit Blocks. The Tasman deposit has been reported at a cut-off grade of 7.5% Fe_2O_3 based on the statistical relationship between Fe_2O_3 and DTR.

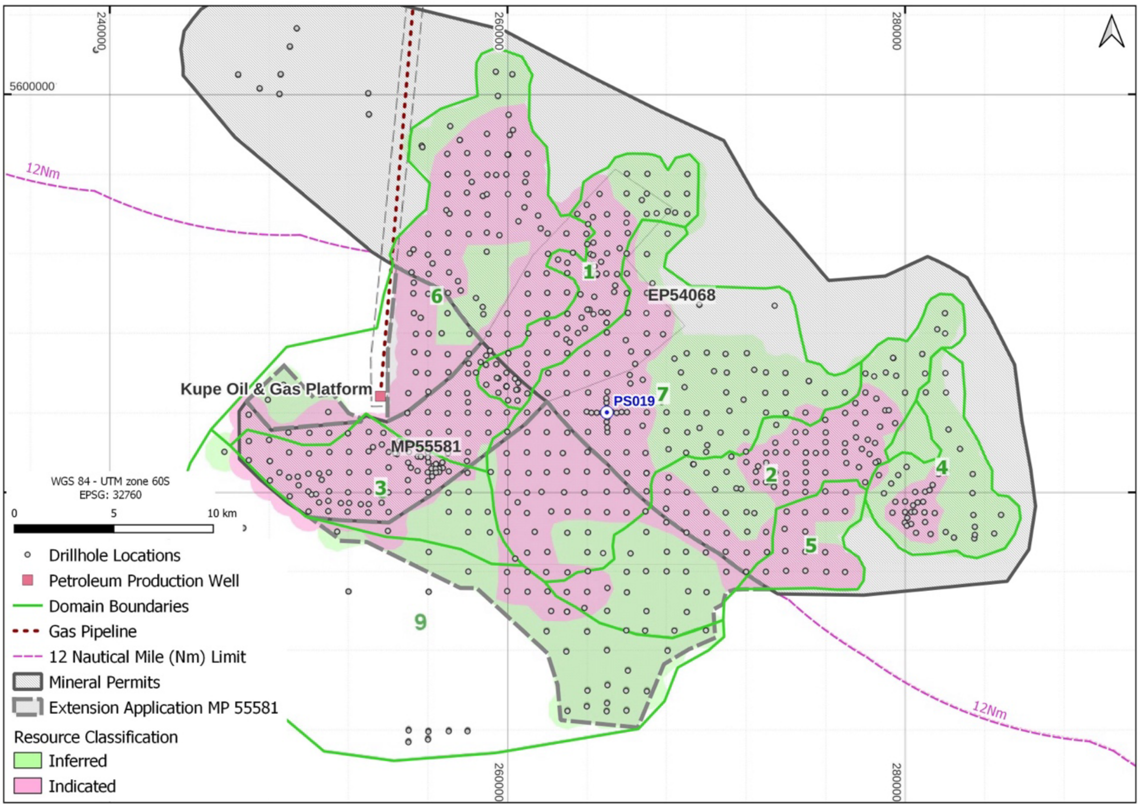


Figure 2: *Taranaki VTM deposit Indicated (Pink) and Inferred (Green) resource classification boundaries*

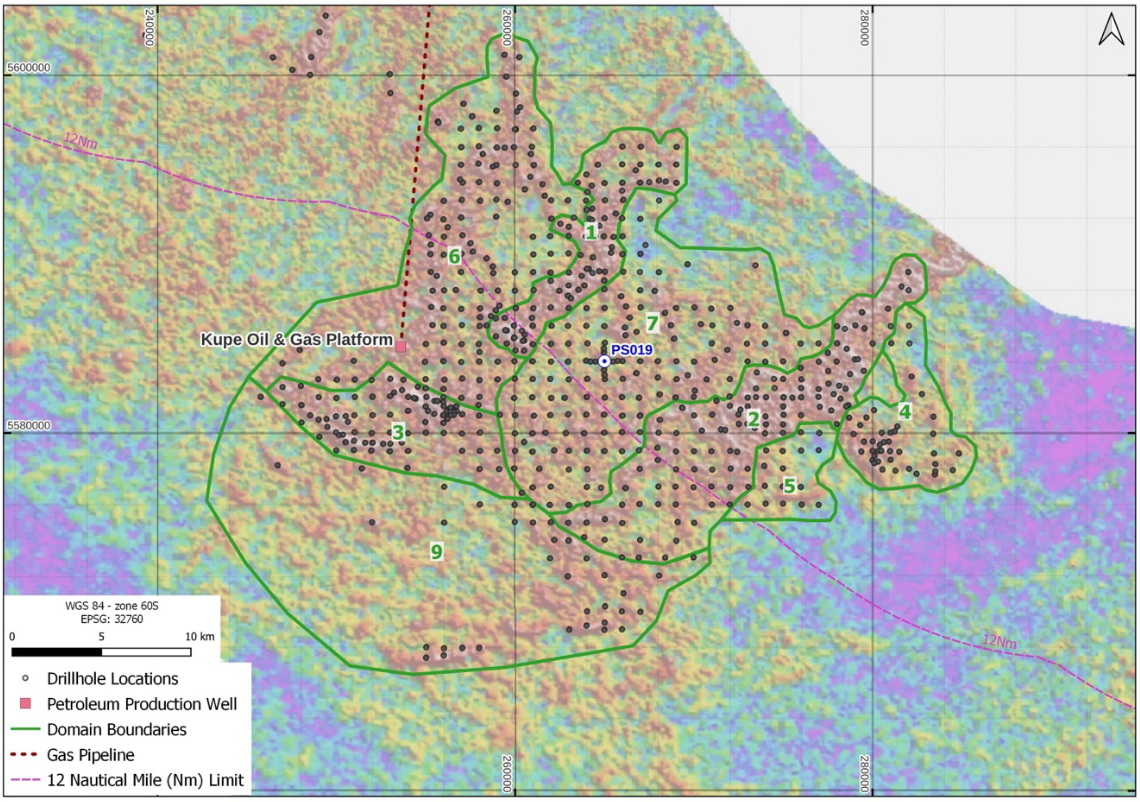


Figure 3: *Taranaki VTM deposit drill hole locations with aeromagnetic survey data*

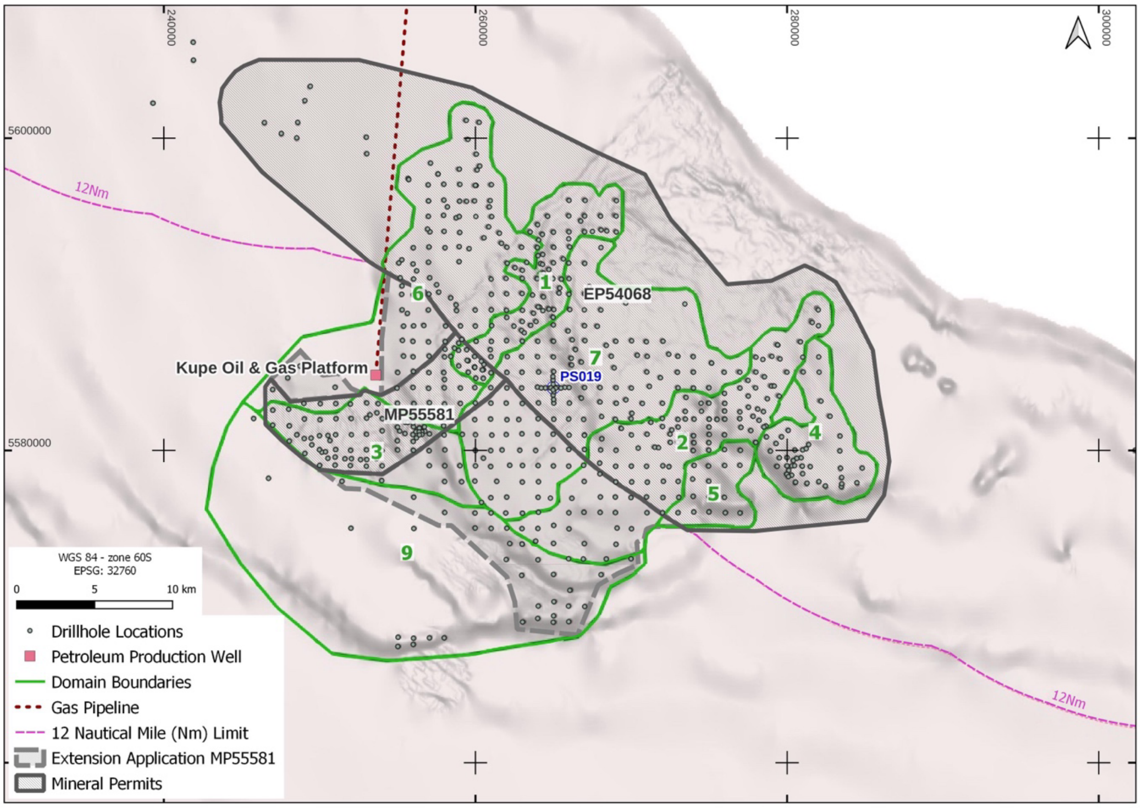


Figure 4: *Taranaki VTM deposit drill hole locations with Domain locations and greyscaled bathymetric data*

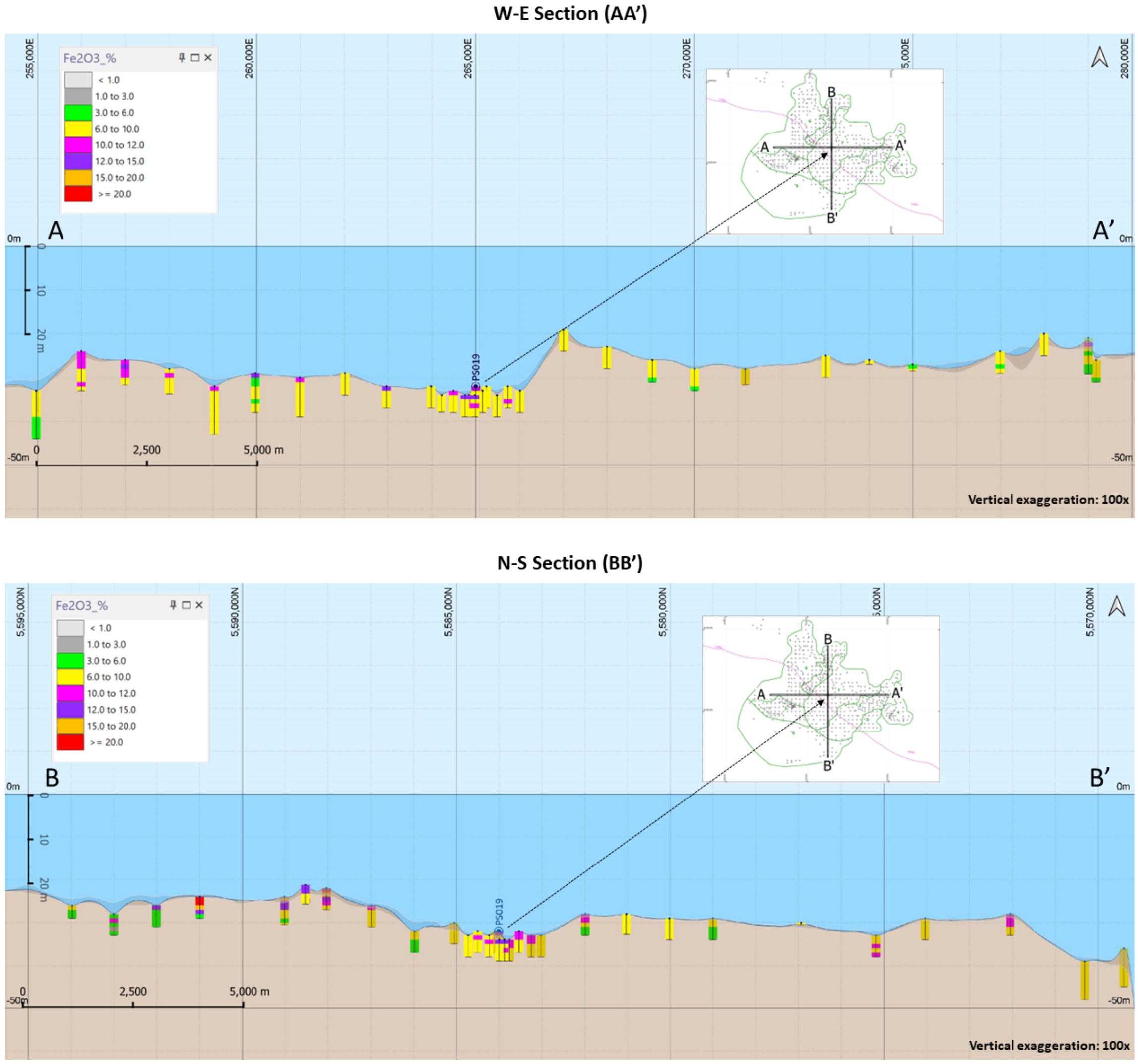


Figure 5: *Taranaki VTM deposit typical cross sections with down hole drill data for Fe_2O_3 – note 100 x vertical exaggeration and reference drill hole PS019*

***Table 2:** Tonnage and Head Grades (%) – Cook VTM Deposit – 3.5% DTR* Cut-Off Grade*

Cook VTM Resource Estimate																
2023 Tonnage and Head Grades (%) Cook North - 3.5% DTR Cut-Off Grade																
	Domain	Mt	Fe_2O_3	DTR	SiO_2	Al_2O_3	TiO_2	CaO	K_2O	MgO	MnO	V_2O_5	P_2O_5	LOI	REC(%)	Mt DTR Concentrate
Indicated	1	123.1	11.80	7.66	54.09	10.11	1.20	10.61	1.03	5.47	0.20	0.06	0.20	2.96	94.30	9.4
	6	42.6	11.50	7.48	55.29	9.94	1.17	10.16	1.05	4.91	0.19	0.06	0.19	3.12	95.00	3.2
	7	60.2	11.14	6.77	47.94	10.23	1.08	14.83	0.90	6.29	0.22	0.05	0.23	4.60	86.60	4.1
Indicated Total		**225.9**	**11.57**	**7.39**	**52.68**	**10.11**	**1.16**	**11.65**	**1.00**	**5.58**	**0.20**	**0.06**	0.20	**3.43**	**92.40**	**16.7**
Inferred	1	37.2	14.53	10.11	49.01	8.34	1.47	12.73	0.85	5.42	0.21	0.07	0.20	4.99	91.30	3.8
	7	11.0	9.84	5.59	42.34	8.68	0.95	18.99	0.69	6.45	0.19	0.05	0.19	8.98	77.76	0.6
Inferred Total		**48.3**	**13.46**	**9.08**	**47.49**	**8.42**	**1.35**	**14.16**	**0.81**	**5.66**	**0.20**	**0.07**	**0.20**	**5.90**	**88.20**	**4.4**
Cook North Resource Total		**274.2**	**11.90**	**7.69**	**51.76**	**9.81**	**1.19**	**12.09**	**0.96**	**5.60**	**0.20**	**0.06**	**0.20**	**3.86**	**91.66**	**21.1**
2023 Tonnage and Head Grades (%) Cook South - 3.5% DTR Cut-Off Grade																
	Domain	Mt	Fe_2O_3	DTR	SiO_2	Al_2O_3	TiO_2	CaO	K_2O	MgO	MnO	V_2O_5	P_2O_5	LOI	REC(%)	Mt DTR Concentrate
Indicated	1	51.1	13.89	9.55	49.48	11.63	1.40	11.05	1.13	6.21	0.23	0.07	0.29	1.90	95.50	4.9
	3	485.6	11.77	7.63	51.29	12.68	1.20	10.94	1.16	5.40	0.21	0.06	0.26	2.18	97.90	37.0
	6	314.3	9.69	5.70	52.44	13.58	0.99	11.25	1.17	4.80	0.18	0.05	0.25	2.59	96.30	17.9
	7	10.0	8.88	4.89	53.74	14.59	0.92	10.25	1.39	4.67	0.18	0.04	0.26	1.70	91.40	0.5
	9	3.9	8.26	4.66	53.64	14.16	0.82	11.04	1.23	4.48	0.17	0.05	0.25	2.59	98.38	0.2
Indicated Total		**864.9**	**11.09**	**7.00**	**51.46**	**13.15**	**1.13**	**11.05**	**1.16**	**5.22**	**0.20**	**0.05**	**0.26**	**2.31**	**97.10**	**60.5**
Inferred	3	1.4	9.46	5.01	52.58	13.49	0.97	11.32	1.24	5.30	0.19	0.04	0.26	2.30	98.02	0.1
	6	47.7	8.51	4.88	54.39	14.11	0.91	10.20	1.28	3.81	0.16	0.04	0.22	2.96	97.50	2.3
	7	0.5	9.37	5.78	53.71	13.88	1.01	10.85	1.25	4.92	0.19	0.04	0.24	1.92	94.18	0.0
Inferred Total		**49.6**	**8.55**	**4.89**	54.33	**14.09**	**0.91**	**10.23**	**1.28**	**3.86**	**0.16**	**0.04**	**0.22**	**2.93**	**97.48**	**2.4**
Cook South Resource Total		**914.4**	**10.95**	**6.88**	**51.62**	**13.20**	**1.12**	**11.01**	**1.17**	**5.14**	**0.20**	**0.05**	**0.25**	**2.34**	**97.12**	**62.9**
Cook VTM Resource Total		**1,188.6**	**11.17**	**7.07**	**51.65**	**12.42**	**1.14**	**11.26**	**1.12**	**5.25**	**0.20**	**0.05**	**0.24**	**2.69**	**95.86**	**84.0**

***Table 3:** Tonnage and Concentrate Grades (%) – Cook VTM Deposit – 3.5% DTR* Cut-Off Grade*

Cook VTM Concentrate Estimate													
2023 Tonnage and Head Grades (%) Cook North - 3.5% DTR Cut-Off Grade													
	Domain	Mt	Fe	Al_2O_3	SiO_2	TiO_2	CaO	K_2O	MgO	Mn	P	V_2O_5	LOI
Indicated	1	9.4	57.97	3.59	3.12	8.29	0.89	0.08	3.16	0.52	0.09	0.52	-3.27
	6	3.2	58.17	3.55	2.78	8.40	0.86	0.06	3.15	0.53	0.10	0.52	-3.26
	7	4.1	57.64	3.75	3.48	8.05	0.98	0.08	3.28	0.51	0.09	0.53	-3.38
Indicated Total		**16.7**	**57.92**	**3.63**	**3.15**	**8.25**	**0.91**	**0.07**	**3.19**	**0.52**	**0.09**	**0.52**	**-3.30**
Inferred	1	3.8	53.36	3.11	1.79	7.50	0.68	0.03	2.83	0.47	0.08	0.54	-3.04
	7	0.6	58.01	3.67	3.03	8.00	1.01	0.05	3.34	0.50	0.07	0.53	-3.30
Inferred Total		**4.4**	**54.42**	**3.24**	**2.07**	**7.61**	**0.76**	**0.04**	**2.94**	**0.48**	**0.08**	**0.54**	**-3.10**
Cook North Concentrate Total		**21.1**	**57.19**	**3.54**	**2.93**	**8.12**	**0.88**	**0.07**	**3.14**	**0.51**	**0.09**	**0.52**	**-3.26**
2023 Tonnage and Head Grades (%) Cook South - 3.5% DTR Cut-Off Grade													
	Domain	Mt	Fe	Al_2O_3	SiO_2	TiO_2	CaO	K_2O	MgO	Mn	P	V_2O_5	LOI
Indicated	1	4.9	55.50	3.88	5.51	8.32	1.26	0.17	3.34	0.51	0.11	0.49	-2.98
	3	37.0	55.92	3.73	5.01	8.47	1.18	0.16	3.27	0.51	0.12	0.50	-2.99
	6	17.9	55.82	3.74	5.19	8.43	1.23	0.16	3.27	0.52	0.12	0.50	-3.00
	7	0.5	54.33	4.01	6.72	8.28	1.47	0.21	3.41	0.51	0.12	0.49	-2.86
	9	0.2	55.26	3.75	5.71	8.39	1.32	0.17	3.38	0.50	0.12	0.50	-2.93
Indicated Total		**60.5**	**55.84**	**3.75**	**5.12**	**8.45**	**1.20**	**0.16**	**3.28**	**0.51**	**0.12**	**0.50**	**-2.99**
Inferred	3	0.1	54.36	3.83	6.43	8.44	1.32	0.20	3.34	0.51	0.12	0.49	-2.86
	6	2.3	55.83	3.64	5.14	8.48	1.18	0.17	3.17	0.52	0.12	0.49	-2.97
	7	0.0	55.71	3.76	5.45	8.44	1.36	0.16	3.39	0.52	0.11	0.51	-3.00
Inferred Total		**2.4**	**55.79**	**3.65**	**5.18**	**8.48**	**1.18**	**0.17**	**3.18**	**0.52**	**0.12**	**0.49**	**-2.97**
Cook South Concentrate Total		**63.0**	**55.84**	**3.74**	**5.12**	**8.45**	**1.20**	**0.16**	**3.28**	**0.51**	**0.12**	**0.50**	**-2.99**
Cook VTM Concentrate Total		**84.0**	**56.18**	**3.69**	**4.57**	**8.36**	**1.12**	**0.14**	**3.24**	**0.51**	**0.11**	**0.51**	**-3.06**

***Table 4:** Tonnage and Head Grades (%) – Kupe VTM Deposit – 3.5% DTR* Cut-Off Grade*

Kupe VTM Resource Estimate																
2023 Tonnage and Head Grades (%) Kupe North Block - 3.5% DTR Cut-Off																
	Domain	Mt	Fe_2O_3	DTR	SiO_2	Al_2O_3	TiO_2	CaO	K_2O	MgO	MnO	V_2O_5	P_2O_5	LOI	REC(%)	Mt DTR Concentrate
Indicated	6	134.4	12.01	8.09	50.97	12.67	1.26	10.54	1.16	4.59	0.20	0.06	0.23	3.24	94.00	10.9
Inferred	6	282.3	11.22	6.96	52.61	12.25	1.18	10.54	1.14	5.08	0.19	0.05	0.21	2.82	92.91	19.7
Kupe North Resource Total		**416.7**	**11.48**	**7.33**	**52.08**	**12.38**	**1.21**	**10.54**	**1.15**	**4.92**	**0.19**	**0.06**	**0.22**	**2.96**	**93.26**	**30.5**
2023 Tonnage and Head Grades (%) Kupe South Block - 3.5% DTR Cut-Off																
	Domain	Mt	Fe_2O_3	DTR	SiO_2	Al_2O_3	TiO_2	CaO	K_2O	MgO	MnO	V_2O_5	P_2O_5	LOI	REC(%)	Mt DTR Concentrate
Indicated	6	238.2	9.70	5.67	50.89	12.80	0.97	12.52	1.05	4.91	0.18	0.05	0.25	3.65	97.40	13.5
Inferred	6	33.6	10.16	6.26	50.44	12.65	1.03	12.66	1.07	4.92	0.19	0.05	0.25	3.67	96.25	2.1
Kupe South Resource Total		**271.8**	**9.76**	**5.74**	**50.84**	**12.78**	**0.98**	**12.54**	**1.06**	**4.91**	**0.18**	**0.05**	**0.25**	**3.65**	**97.26**	**15.6**
Kupe VTM Resource Total		**688.5**	**10.80**	**6.70**	**51.59**	**12.54**	**1.12**	**11.33**	**1.11**	**4.92**	**0.19**	**0.05**	**0.23**	**3.23**	**94.84**	**46.1**

***Table 5:** Tonnage and Concentrate Grades (%) – Kupe VTM Deposit – 3.5% DTR* Cut-Off Grade*

Kupe VTM Concentrate Estimate													
2023 Tonnage and Head Grades (%) Kupe North - 3.5% DTR Cut-Off Grade													
	Domain	Mt	Fe	Al_2O_3	SiO_2	TiO_2	CaO	K_2O	MgO	Mn	P	V_2O_5	LOI
Indicated	6	10.9	56.97	3.61	4.02	8.48	0.99	0.13	3.11	0.52	0.11	0.51	-3.03
Inferred	6	19.7	57.13	3.67	4.08	8.28	0.99	0.12	3.15	0.51	0.10	0.51	-3.05
Kupe North Concentrate Total		**30.5**	**57.07**	**3.65**	**4.06**	**8.35**	**0.99**	**0.12**	**3.14**	**0.51**	**0.10**	**0.51**	**-3.04**
2023 Tonnage and Head Grades (%) Kupe South - 3.5% DTR Cut-Off Grade													
	Domain	Mt	Fe	Al_2O_3	SiO_2	TiO_2	CaO	K_2O	MgO	Mn	P	V_2O_5	LOI
Indicated	6	13.5	56.32	3.62	4.57	8.43	1.16	0.13	3.23	0.52	0.11	0.50	-3.03
Inferred	6	2.1	56.42	3.63	4.47	8.43	1.12	0.13	3.20	0.52	0.11	0.50	-3.04
Kupe South Concentrate Total		**15.6**	**56.33**	**3.62**	**4.55**	**8.43**	**1.15**	**0.13**	**3.22**	**0.52**	**0.11**	**0.50**	**-3.03**
Kupe VTM Concentrate Total		**46.1**	**56.82**	**3.64**	**4.22**	**8.38**	**1.05**	**0.13**	**3.17**	**0.51**	**0.11**	**0.51**	**-3.04**

***Table 6:** Tonnage and Head Grades (%) – Tasman VTM Deposit – 7.5% Fe_2O_3 Cut-Off Grade*

Tasman VTM Resource Estimate														
2023 Tonnage and Head Grades (%) Tasman North - 7.5% Fe_2O_3 Cut-Off Grade														
	Domain	Mt	Fe_2O_3	SiO_2	Al_2O_3	TiO_2	CaO	K_2O	MgO	MnO	V_2O_5	P_2O_5	LOI	REC(%)
Indicated	2	98.2	8.77	48.01	11.99	0.87	15.20	1.06	5.38	0.19	0.04	0.25	5.37	83.40
	4	70.2	9.88	46.25	11.79	0.95	16.17	0.90	6.15	0.21	0.05	0.26	5.00	89.30
	5	39.2	9.37	50.31	14.11	0.92	12.73	1.20	5.83	0.20	0.04	0.27	2.12	83.10
	7	87.3	9.20	50.07	12.49	0.92	13.51	1.14	5.51	0.19	0.04	0.24	3.75	88.80
Indicated Total		**294.9**	**9.24**	**48.51**	**12.37**	**0.91**	**14.60**	**1.06**	**5.66**	**0.20**	**0.04**	**0.25**	**4.37**	**86.40**
Inferred	2	98.2	8.80	47.42	12.75	0.86	15.45	1.03	5.76	0.20	0.04	0.24	4.67	81.00
	4	67.2	8.91	45.70	11.18	0.85	17.29	0.90	6.10	0.20	0.04	0.23	6.10	82.28
	5	2.0	8.05	51.87	13.55	0.78	12.23	1.21	5.58	0.18	0.04	0.26	2.13	92.30
	7	122.2	8.76	44.68	10.80	0.85	18.21	0.88	6.10	0.20	0.04	0.24	7.02	81.84
Inferred Total		**289.6**	**8.80**	**45.90**	**11.57**	**0.85**	**17.02**	**0.94**	**5.98**	**0.20**	**0.04**	**0.24**	**5.97**	**81.65**
Tasman North Resource Total		**584.5**	**9.02**	**47.21**	**11.98**	**0.88**	**15.80**	**1.00**	**5.82**	**0.20**	**0.04**	**0.24**	**5.16**	**84.05**
2023 Tonnage and Head Grades (%) Tasman South - 7.5% Fe_2O_3 Cut-Off Grade														
	Domain	Mt	Fe_2O_3	SiO_2	Al_2O_3	TiO_2	CaO	K_2O	MgO	MnO	V_2O_5	P_2O_5	LOI	REC(%)
Indicated	2	31.6	9.13	51.92	15.06	0.94	11.35	1.37	5.04	0.21	0.04	0.24	1.73	85.10
	3	29.1	8.87	50.53	14.46	0.88	12.66	1.18	5.19	0.19	0.04	0.27	2.75	89.10
	6	1.3	8.91	49.22	13.60	0.86	14.10	1.02	5.87	0.20	0.04	0.28	3.28	94.80
	7	172.7	8.79	51.84	14.62	0.88	11.83	1.27	5.14	0.20	0.04	0.25	1.96	84.70
	9	80.3	9.13	50.34	14.37	0.90	12.86	1.18	5.63	0.21	0.04	0.26	2.20	89.00
Indicated Total		**315.0**	**8.92**	**51.34**	**14.58**	**0.89**	**12.13**	**1.25**	**5.26**	**0.20**	**0.04**	**0.25**	**2.08**	**86.30**
Inferred	2	67.9	8.26	53.29	16.50	0.89	9.49	1.58	3.78	0.17	0.04	0.24	1.93	93.60
	3	96.1	8.67	51.87	14.80	0.88	11.45	1.29	4.70	0.18	0.04	0.26	2.51	93.10
	6	3.4	9.15	49.35	13.52	0.88	13.62	1.03	5.91	0.20	0.04	0.28	2.92	93.30
	7	24.2	8.77	51.64	14.61	0.87	11.98	1.26	5.19	0.19	0.04	0.26	2.04	81.40
	9	188.4	8.92	51.48	14.53	0.89	12.17	1.23	5.51	0.20	0.04	0.27	1.85	91.30
Inferred Total		**380.06**	**8.73**	**51.89**	**14.95**	**0.89**	**11.51**	**1.31**	**4.98**	**0.19**	**0.04**	**0.26**	**2.05**	**91.50**
Tasman South Resource Total		**695.1**	**8.81**	**51.64**	**14.78**	**0.89**	**11.79**	**1.28**	**5.11**	**0.19**	**0.04**	**0.26**	**2.06**	**89.14**
Tasman VTM Resource Total		**1,279.6**	**8.91**	**49.62**	**13.50**	**0.88**	**13.62**	**1.15**	**5.43**	**0.19**	**0.04**	**0.25**	**3.48**	**86.82**

Table 7: *Disclosure Table to Comply with Listing Rule 5.8.1*

Criteria	Commentary
Geology	• The Taranaki VTM deposits are submarine aeolian/alluvial/marine accumulation of iron sand in palaeochannels, beaches and dunes. • The main mineral of interest is vanadium bearing titanomagnetite.
Geological interpretation	• Preliminary drilling showed the deposits to be relatively consistent in the top 6m with most material being mineralised. • The infill drilling is now showing better qualitative correlation with the airborne magnetic surveys with higher grade mineralisation in general being coincident with magnetic highs. The correlation is not always consistent and the impact on exploration and the resource is still being assessed. • Confidence in the geological interpretation is medium to high.
Sampling techniques	• The material being sampled is subsea sand originally deposited in marine and terrestrial environments. • Samples used in the resource estimation are from drill holes only. • Grab samples have only been used as qualitative indicators of the presence of magnetic heavy minerals during early exploration. • The majority of the drilling used a passive triple tube reverse circulation system. Deep drilling used tri cone roller bit with deep drilling limited to an operating water depth of approximately 30m. The full sample for each metre was collected and a sub-sample split, with the >2mm material screened which is then analysed by XRF. • Drill samples from the proposed mine area and the Kupe Blocks have been subject to Davis Tube Recovery to determine the magnetically recoverable portion of the sample. The concentrate recovered has been analysed by XRF
Sub-sampling techniques and sample preparation	• 1 metre samples were taken from the sample cyclone. The sample is then dried and split using a rotary splitter. Sample sizes are appropriate for the sandy material being collected. • Duplicate samples are routinely submitted to monitor the sample preparation process. • All procedures are well documented and understood by the operational personnel.
Drilling techniques	• The drill sampling uses a proprietary passive triple tube reverse circulation technique drilling a 75.75mm diameter hole to a maximum depth of 11m. • Thirteen 5-inch diameter RC drill holes were drilled in 2012 and 2013 to a maximum depth of 30 m.
Data spacing and distribution	• Much of the resource area is now drilled on a nominal 1,000m by 1,000m grid. Analysis to date suggests that this is an adequate sample spacing to define an Indicated Mineral Resource. • Deeper drilling may start to introduce more variability and lead to a requirement for infill drilling. • Samples are not composited for analysis.
Quality of assay data and laboratory tests	• The analytical techniques, particularly the Davis Tube Recovery analysis, are appropriate for this type of deposit. • Regular reference standards (IRM), blanks and duplicate samples are submitted to the laboratory to monitor the accuracy and precision of the analysis process and results. • Analysis of the QAQC sample results to date indicate that the accuracy and precision of the assay data is adequate for the mineral resource estimation

Criteria	Commentary
Verification of sampling and assaying	• Independent verification of sampling has not been undertaken due to the logistics involved. • At Golders request a series of samples from the 2010 drilling campaign were resubmitted to an alternative laboratory. These referee samples returned analyses results consistent with the original analyses. • Drilling and sampling of several holes has been observed by Golder Associates consultants. Referee sampling has been used to validate the accuracy and precision of historical samples. Twin holes have been drilled but the results from twin holes are inconclusive. • All sampling and data management procedures are documented. • Data management is considered adequate. • Rotary Reverse circulation sampling has been trialled. Golder observed the drilling of two of these holes and considers the samples to be non-representative due to sample loss. Data from these holes has not been used.
Estimation and modelling techniques	• The available sampling data is sufficient to allow variogram models and kriging parameters to be defined. The models were estimated using Ordinary Kriging. The estimation has a maximum extrapolation of 1,000m from any data point. • The models were estimated and constructed using Micromine software. • The estimate has been made into 300m × 300m × 1m parent blocks oriented at 070°. These blocks represent the mining SMU as defined in the PFS, and are approximately one third of the average drill spacing. • Head Fe_2O_3 and DTR show a positive correlation. This correlation has been used to estimate DTR outside the reported VTM deposits where DTR has been measured. • The sample population showed no significant outlier samples so no grade cutting or grade restraint was applied. • The estimation was unfolded to the bathymetric surface. • The models have estimated the major and deleterious elements for the -2mm fraction for the full model. In addition, Davis Tube Recovery and Concentrate grades have been estimated for the Cook and Kupe VTM deposits. • The models were validated against the drill holes visually and statistically. The estimations for both models are considered to have a medium to high level of confidence.
Cut-off parameters	• The Fe_2O_3 cut-off used to define the mineralisation was based on the population statistics for Fe_2O_3. The DTR cut-off of 3.5% applied to reporting is based on preliminary economic estimates of mining cut-off grade. Based on the good correlation between head Fe (or Fe_2O_3) and DTR 3.5% DTR is equivalent to 7.5% Fe_2O_3.
Mining factors or assumptions	• The current assumption is that this will be a dredging operation using subsea crawler technology. It will be a bulk mining scenario with any subgrade overburden incorporated into the mineralised zone where practicable. • Consequently, only a base of mineralisation is defined in the geological model with minor amounts of subgrade overburden and interburden incorporated into the model. • The base of mineralisation was defined at 4% Head Fe_2O_3.based on the population statistics of the analyses. DTR analyses are incomplete for the entire model area and could not be used to define the cut off, however there is a strong positive correlation between Fe_2O_3 and DTR.

Criteria	Commentary
Metallurgical factors or assumptions	• No metallurgical recovery factors have been applied. Samples are screened to -2mm before analysis. The screened recovery is used to weight the head grade estimation. Davis Tube Recovery (DTR) analyses have been performed on samples from drill holes in the Cook and Kupe VTM deposits.

JORC Code 2012 Mineral Resource Statement Dated 1 March 2023 Prepared By:

Matthew Brown

Principal
Siecap (NZ) Limited

Alan J Eggers

Director
Trans-Tasman Resources Limited

APPENDIX A JORC Code 2012 Edition Table 1

Compliance with JORC Code 2012 Assessment Criteria

The JORC Code 2012 describes a number of criteria, which must be addressed in the documentation of Mineral Resource estimates, prior to public release of the information. These criteria provide a means of assessing whether or not parts of or the entire data inventory used in the estimate are adequate for that purpose. The resource estimates stated in this document are based on the criteria set out in Table 1 of the JORC Code 2012.

Section 1 Sampling Techniques and Data
(Criteria in this section apply to all succeeding sections)

Criteria	JORC Code Explanation	Commentary
Sampling techniques	• *Nature and quality of sampling (eg: cut channels, random chips, or specific specialised industry standard measurement tools appropriate to the minerals under investigation, such as down hole gamma sondes, or handheld XRF instruments, etc). These examples should not be taken as limiting the broad meaning of sampling.* • *Include reference to measures taken to ensure sample representivity and the appropriate calibration of any measurement tools or systems used.* • *Aspects of the determination of mineralisation that are Material to the Public Report.* • *In cases where 'industry standard' work has been done this would be relatively simple (eg: 'reverse circulation drilling was used to obtain 1 m samples from which 3 kg was pulverised to produce a 30g charge for fire assay'). In other cases, more explanation may be required, such as where there is coarse gold that has inherent sampling problems. Unusual commodities or mineralisation types (eg: submarine nodules) may warrant disclosure of detailed information.*	• The material being sampled is subsea sand originally deposited in marine and terrestrial environments. • Samples used in the resource estimation are from drill holes only. • Grab samples have only been used as qualitative indicators of the presence of magnetic heavy minerals during early exploration. • The majority of the drilling used a passive triple tube reverse circulation system. Deep drilling used tri cone roller bit with deep drilling limited to an operating water depth of approximately 30m. The full sample for each metre was collected and a sub-sample split, with the >2mm material screened which is then analysed by XRF. • Drill samples from the proposed mine area and the Kupe Blocks have been subject to Davis Tube Recovery to determine the magnetically recoverable portion of the sample. The concentrate recovered has been analysed by XRF
Drilling techniques	• *Drill type (eg: core, reverse circulation, open-hole hammer, rotary air blast, auger, Bangka, sonic, etc) and details (eg: core diameter, triple or standard tube, depth of diamond tails, face-sampling bit or other type, whether core is oriented and if so, by what method, etc).*	• The drill sampling uses a proprietary passive triple tube reverse circulation technique drilling a 75.75mm diameter hole to a maximum depth of 11m. • Thirteen 5-inch diameter RC drill holes were drilled in 2012 and

Criteria	JORC Code Explanation	Commentary
		2013 to a maximum depth of 30 m.
Drill sample recovery	• *Method of recording and assessing core and chip sample recoveries and results assessed.* • *Measures taken to maximise sample recovery and ensure representative nature of the samples.* • *Whether a relationship exists between sample recovery and grade and whether sample bias may have occurred due to preferential loss/gain of fine/coarse material.*	• Golder Associates have previously reviewed the drilling and sampling and consider that a representative sample is being collected. Sample weights are recorded. • Oversized samples due to hole 'blow outs' are excluded from the resource estimation. • Recovery analysis has been undertaken to ensure representative samples are used in the model.
Logging	• *Whether core and chip samples have been geologically and geotechnically logged to a level of detail to support appropriate Mineral Resource estimation, mining studies and metallurgical studies.* • *Whether logging is qualitative or quantitative in nature. Core (or costean, channel, etc) photography.* • *The total length and percentage of the relevant intersections logged.*	• The qualitative logging of samples is of sufficient detail to support the current mineral resource.
Sub-sampling techniques and sample preparation	• *If core, whether cut or sawn and whether quarter, half or all core taken.* • *If non-core, whether riffled, tube sampled, rotary split, etc and whether sampled wet or dry.* • *For all sample types, the nature, quality and appropriateness of the sample preparation technique.* • *Quality control procedures adopted for all sub-sampling stages to maximise representivity of samples.* • *Measures taken to ensure that the sampling is representative of the in-situ material collected, including for instance results for field duplicate/second-half sampling.* • *Whether sample sizes are appropriate to the grain size of the material being sampled.*	• 1 metre samples were taken from the sample cyclone. The sample is then dried and split using a rotary splitter. Sample sizes are appropriate for the sandy material being collected. • Duplicate samples are routinely submitted to monitor the sample preparation process. • All procedures are well documented and understood by the operational personnel.
Quality of assay data and laboratory tests	• *The nature, quality and appropriateness of the assaying and laboratory procedures used and whether the technique is considered partial or total.* • *For geophysical tools, spectrometers, handheld XRF instruments, etc, the parameters used in determining the analysis including instrument*	• The analytical techniques, particularly the Davis Tube Recovery analysis, are appropriate for this type of deposit. • Regular reference standards (IRM), blanks and duplicate samples are submitted to the laboratory to monitor the accuracy and precision of the analysis process and results.

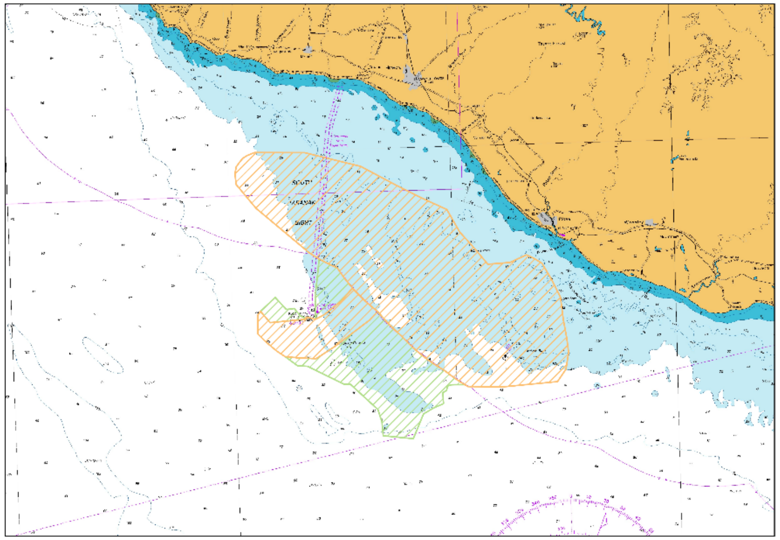
Criteria	JORC Code Explanation	Commentary
	make and model, reading times, calibrations factors applied and their derivation, etc. • *Nature of quality control procedures adopted (eg: standards, blanks, duplicates, external laboratory checks) and whether acceptable levels of accuracy (ie: lack of bias) and precision have been established.*	• Analysis of the QAQC sample results to date indicate that the accuracy and precision of the assay data is adequate for the mineral resource estimation
Verification of sampling and assaying	• *The verification of significant intersections by either independent or alternative company personnel.* • *The use of twinned holes.* • *Documentation of primary data, data entry procedures, data verification, data storage (physical and electronic) protocols.* • *Discuss any adjustment to assay data.*	• Independent verification of sampling has not been undertaken due to the logistics involved. • At Golders request a series of samples from the 2010 drilling campaign were resubmitted to an alternative laboratory. These referee samples returned analyses results consistent with the original analyses. • Drilling and sampling of several holes has been observed by Golder Associates consultants. Referee sampling has been used to validate the accuracy and precision of historical samples. Twin holes have been drilled but the results from twin holes are inconclusive. • All sampling and data management procedures are documented. • Data management is considered adequate. • Rotary Reverse circulation sampling has been trialled. Golder observed the drilling of two of these holes and considers the samples to be non-representative due to sample loss. Data from these holes has not been used.
Location of data points	• *Accuracy and quality of surveys used to locate drill holes (collar and down-hole surveys), trenches, mine workings and other locations used in Mineral Resource estimation.* • *Specification of the grid system used.* • *Quality and adequacy of topographic control.*	• For the scale of the Taranaki VTM deposit the location of samples by hand held GPS is considered adequate. • GPS data is in latitude and longitude. • Modelling data is in UTM – WGS 84 Zone 60 • Commercial/Public domain bathymetric data is considered adequate over most of the tenements and good in the mine area where the data has been supplemented with NIWA multibeam sonar data.

Criteria	JORC Code Explanation	Commentary
Data spacing and distribution	• *Data spacing for reporting of Exploration Results.* • *Whether the data spacing and distribution is sufficient to establish the degree of geological and grade continuity appropriate for the Mineral Resource and Ore Reserve estimation procedure(s) and classifications applied.* • *Whether sample compositing has been applied.*	• Much of the resource area is now drilled on a nominal 1,000m by 1,000m grid. Analysis to date suggests that this is an adequate sample spacing to define an Indicated Mineral Resource. • Deeper drilling may start to introduce more variability and lead to a requirement for infill drilling. • Samples are not composited for analysis.
Orientation of data in relation to geological structure	• *Whether the orientation of sampling achieves unbiased sampling of possible structures and the extent to which this is known, considering the deposit type.* • *If the relationship between the drilling orientation and the orientation of key mineralised structures is considered to have introduced a sampling bias, this should be assessed and reported if material.*	• All drill holes are vertical providing the optimum orientation for sampling these bedded sand deposits.
Sample security	• *The measures taken to ensure sample security.*	• Sample security is good with all samples being under TTR supervision up until submission at the laboratory. • Laboratory chain of custody and security have been reviewed by Golders Associates previously and are considered fit for purpose.
Audits or reviews	• *The results of any audits or reviews of sampling techniques and data.*	• In 2010 Golder undertook a detailed audit of the drill hole database. Minor anomalies in the database were found and corrected. • In 2012 QG (Perth) undertook a due diligence of the resource data and estimation. • To address issues raised by Golder in their QAQC data analysis, Jeremy Batchelor of Chem Tek Consulting undertook an independent lab audit and QAQC data analysis in 2013 finding the laboratory procedures and results satisfactory. There have been no procedural changes with sampling, sample preparation or testing since this audit was undertaken. • Mr Stephen Godfrey (then Resource Evaluation Services) and Matthew Brown (then TTR GM Exploration) reviewed and the database for the 2015 resource model and 2018 revision.

Section 2 Reporting of Exploration Results
(Criteria listed in the preceding section also apply to this section)

Criteria	JORC Code Explanation	Commentary

Mineral tenement and land tenure status	• *Type, reference name/number, location and ownership including agreements or material issues with third parties such as joint ventures, partnerships, overriding royalties, native title interests, historical sites, wilderness or national park and environmental settings.*
	• *The security of the tenure held at the time of reporting along with any known impediments to obtaining a licence to operate in the area.*
		• TTR hold granted Mineral Exploration Permit EP54068 which expires in December 2021 and is subject to an extension of time application. See mineral tenement map below.
		• TTR hold granted Mineral Mining Permit MP55581 which expires in May 2034. An extension of area application has been lodged for MP55581 on 1 July 2022. See mineral tenement map below.
		• These tenements allow exploration activities to be undertaken.
		• All tenements are owned 100% by TTR.
		• Royalty commitment for MP 55581 is 1% of net sales revenue when net sales revenues exceed NZD$100,000; and be the greater of 1% of net sales revenue or a 5% accounting profits royalty when net sales revenues exceed NZD$1,000,000.
		• Under the Crown Minerals Act (1991) mining permits are subject environmental approvals under the following legislation:
		  ○ Marine consents under the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (EEZ Act) for activities beyond the 12Nm limit.
		  ○ Resource consents under the Resource Management Act 1991 (RMA) for activities (including discharges) within the 12Nm limit.
		  ○ Marine discharge consents are required under the EEZ Act or Discharge Management Plans under the Maritime Transport Act 1994 (MTA) for discharges beyond the 12Nm limit.

Criteria	JORC Code Explanation	Commentary
		
Exploration done by other parties	• *Acknowledgment and appraisal of exploration by other parties.*	• Some petroleum bore logs record near surface iron sands. • Geophysical surveys were largely reconnaissance in nature providing limited offshore detail. • Limited, historical sampling of shallow offshore deposits has been undertaken providing indicative results only.
Geology	• *Deposit type, geological setting and style of mineralisation.*	• The Taranaki VTM deposits are submarine aeolian/alluvial/marine accumulation of iron sand in palaeochannels, beaches and dunes. • The main mineral of interest is vanadium bearing titanomagnetite.
Drill hole Information	• *A summary of all information material to the understanding of the exploration results including a tabulation of the following information for all Material drill holes:*	• 726 vertical seafloor drill holes have been drilled. • The current resource model uses 689 of these drill holes, drilled

Criteria	JORC Code Explanation	Commentary
	○ *easting and northing of the drill hole collar* ○ *elevation or RL (Reduced Level – elevation above sea level in metres) of the drill hole collar* ○ *dip and azimuth of the hole* ○ *down hole length and interception depth* ○ *hole length.* • *If the exclusion of this information is justified on the basis that the information is not Material and this exclusion does not detract from the understanding of the report, the Competent Person should clearly explain why this is the case.*	and sampled, averaging 6.024m in depth for a total of 4,150.6m. • The remaining holes are reconnaissance, bulk sampling and trial holes.
Data aggregation methods	• *In reporting Exploration Results, weighting averaging techniques, maximum and/or minimum grade truncations (eg: cutting of high grades) and cut-off grades are usually Material and should be stated.* • *Where aggregate intercepts incorporate short lengths of high grade results and longer lengths of low grade results, the procedure used for such aggregation should be stated and some typical examples of such aggregations should be shown in detail.* • *The assumptions used for any reporting of metal equivalent values should be clearly stated.*	• Exploration drilling results are not reported here.
Relationship between mineralisation widths and intercept lengths	• *These relationships are particularly important in the reporting of Exploration Results.* • *If the geometry of the mineralisation with respect to the drill hole angle is known, its nature should be reported.* • *If it is not known and only the down hole lengths are reported, there should be a clear statement to this effect (eg: 'down hole length, true width not known').*	• The iron sands are bedded sand deposits. Drilling to date has only defined the true thickness of the deposits in ten drill holes.
Diagrams	• *Appropriate maps and sections (with scales) and tabulations of intercepts should be included for any significant discovery being reported These should include, but not be limited to a plan view of drill hole collar locations and appropriate sectional views.*	• See Figures 1 to 5, in the Mineral Resource Statement.
Balanced reporting	• *Where comprehensive reporting of all Exploration Results is not practicable, representative reporting of both low and high grades and/or widths should be practiced to avoid misleading reporting of Exploration Results.*	• Exploration Results are not reported here.

Criteria	JORC Code Explanation	Commentary
Other substantive exploration data	• *Other exploration data, if meaningful and material, should be reported including (but not limited to): geological observations; geophysical survey results; geochemical survey results; bulk samples – size and method of treatment; metallurgical test results; bulk density, groundwater, geotechnical and rock characteristics; potential deleterious or contaminating substances.*	• Exploration data to date includes geophysical surveys, grab samples, bulk samples and drilling. Metallurgical test work has been done on the magnetic recovery, physical separation and communition testing of bulk samples with the TTR pilot plant. • Enough data is available to make a reasonably confident estimate of the dry bulk density.
Further work	• *The nature and scale of planned further work (eg: tests for lateral extensions or depth extensions or large-scale step-out drilling).* • *Diagrams clearly highlighting the areas of possible extensions, including the main geological interpretations and future drilling areas, provided this information is not commercially sensitive.*	• Potential for further infill drilling to extend the available recoverable resources in the Cook and Kupe Deposits resource areas. • Pending budget approval, a detailed vessel based geophysical survey over the mine area is planned.

Section 3 Estimation and Reporting of Mineral Resources
(Criteria listed in section 1, and where relevant in section 2, also apply to this section)

Criteria	JORC Code Explanation	Commentary
Database integrity	• *Measures taken to ensure that data has not been corrupted by, for example, transcription or keying errors, between its initial collection and its use for Mineral Resource estimation purposes.* • *Data validation procedures used.*	• Golder Associates have previously undertaken a detailed audit of the drill hole database validating the data and ensuring that adequate security and backup procedures are in place. • Drill data is routinely checked for internal consistency, anomalies and omissions prior to each resource estimation.

Site visits	• *Comment on any site visits undertaken by the Competent Person and the outcome of those visits.*
	• *If no site visits have been undertaken indicate why this is the case.*
		• The site has been visited by a competent person, Stephen Godfrey, on four occasions.
		  ○ January, 2010 – reviewed drilling and sampling. Recommendations for improved procedures made and implemented.
		  ○ July 2012 – reviewed pilot plant, project in general
		  ○ February 2013 – reviewed rotary RC drilling. Identified sampling issues.
		  ○ March 2015 – review of database and development of

Criteria	JORC Code Explanation	Commentary
		the model using Micromine software.
Geological interpretation	• *Confidence in (or conversely, the uncertainty of) the geological interpretation of the mineral Deposit.* • *Nature of the data used and of any assumptions made.* • *The effect, if any, of alternative interpretations on Mineral Resource estimation.* • *The use of geology in guiding and controlling Mineral Resource estimation.* • *The factors affecting continuity both of grade and geology.*	• Preliminary drilling showed the deposits to be relatively consistent in the top 6m with most material being mineralised. • The infill drilling is now showing better qualitative correlation with the airborne magnetic surveys with higher grade mineralisation in general being coincident with magnetic highs. The correlation is not always consistent and the impact on exploration and the resource is still being assessed. • Confidence in the geological interpretation is medium to high.
Dimensions	• *The extent and variability of the Mineral Resource expressed as length (along strike or otherwise), plan width, and depth below surface to the upper and lower limits of the Mineral Resource.*	• The Taranaki VTM deposits have been drilled over a strike length of 100km and a width of 6 to 12km.
Estimation and modelling techniques	• *The nature and appropriateness of the estimation technique(s) applied and key assumptions, including treatment of extreme grade values, domaining, interpolation parameters and maximum distance of extrapolation from data points. If a computer assisted estimation method was chosen include a description of computer software and parameters used.* • *The availability of check estimates, previous estimates and/or mine production records and whether the Mineral Resource estimate takes appropriate account of such data.* • *The assumptions made regarding recovery of by-products.* • *Estimation of deleterious elements or other non-grade variables of economic significance (eg: sulphur for acid mine drainage characterisation).* • *In the case of block model interpolation, the block size in relation to the average sample spacing and the search employed.* • *Any assumptions behind modelling of selective mining units.* • *Any assumptions about correlation between variables.* • *Description of how the geological interpretation was used to control the resource estimates.* • *Discussion of basis for using or not using grade cutting or capping.* • *The process of validation, the checking process used, the comparison*	• The available sampling data is sufficient to allow variogram models and kriging parameters to be defined. The models were estimated using Ordinary Kriging. The estimation has a maximum extrapolation of 1,000m from any data point. • The models were estimated and constructed using Micromine software. • The estimate has been made into 300m × 300m × 1m parent blocks oriented at 070°. These blocks represent the mining SMU as defined in the PFS, and are approximately one third of the average drill spacing. • Head Fe_2O_3 and DTR show a positive correlation. This correlation has been used to estimate DTR outside the reported VTM deposits where DTR has been measured. • The sample population showed no significant outlier samples so no grade cutting or grade restraint was applied. • The estimation was unfolded to the bathymetric surface. • The models have estimated the major and deleterious elements for the -2mm fraction for the full model. In addition, Davis Tube Recovery and Concentrate grades have been estimated for the

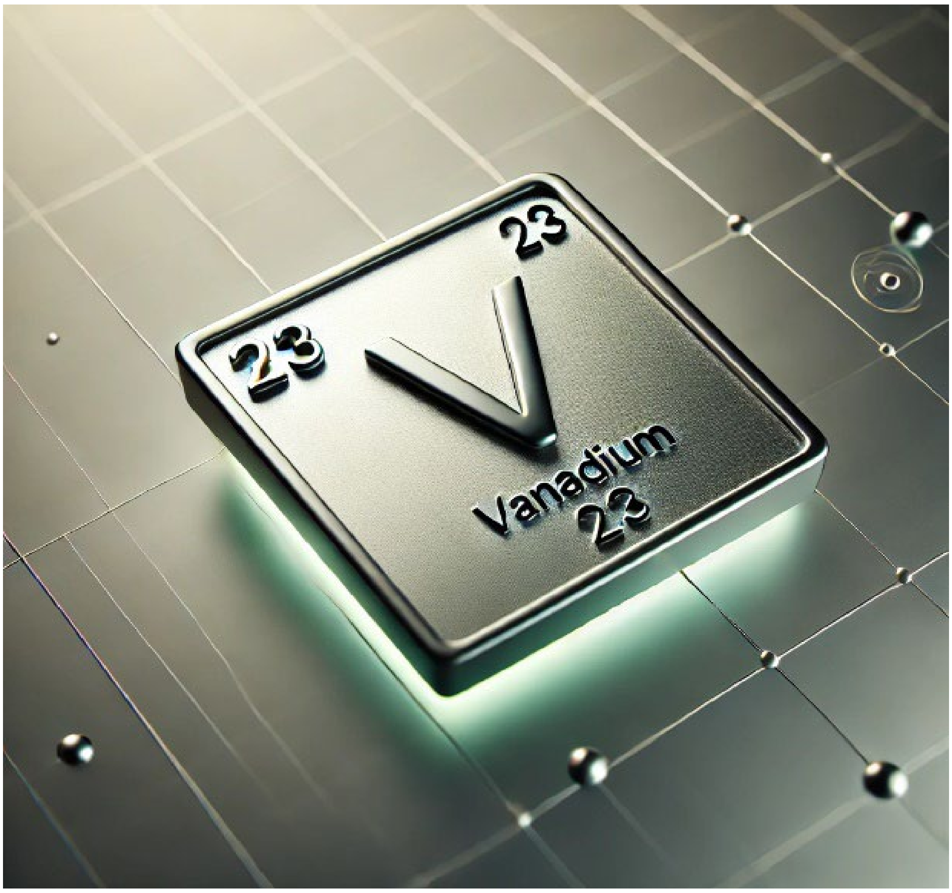
Criteria	JORC Code Explanation	Commentary
	of model data to drill hole data, and use of reconciliation data if available.	Cook and Kupe VTM deposits. • The models were validated against the drill holes visually and statistically. The estimations for both models are considered to have a medium to high level of confidence.
Moisture	• *Whether the tonnages are estimated on a dry basis or with natural moisture, and the method of determination of the moisture content.*	• All tonnages are estimated on dry basis consistent with the sample analysis which is reported as a dry mass percent.
Cut-off parameters	• *The basis of the adopted cut-off grade(s) or quality parameters applied.*	• The Fe_2O_3 cut-off used to define the mineralisation was based on the population statistics for Fe_2O_3. The DTR cut-off of 3.5% applied to reporting is based on preliminary economic estimates of mining cut-off grade. Based on the good correlation between head Fe (or Fe_2O_3) and DTR 3.5% DTR is equivalent to 7.5% Fe_2O_3.
Mining factors or assumptions	• *Assumptions made regarding possible mining methods, minimum mining dimensions and internal (or, if applicable, external) mining dilution. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider potential mining methods, but the assumptions made regarding mining methods and parameters when estimating Mineral Resources may not always be rigorous. Where this is the case, this should be reported with an explanation of the basis of the mining assumptions made.*	• The current assumption is that this will be a dredging operation using subsea crawler technology. It will be a bulk mining scenario with any subgrade overburden incorporated into the mineralised zone where practicable. • Consequently, only a base of mineralisation is defined in the geological model with minor amounts of subgrade overburden and interburden incorporated into the model. • The base of mineralisation was defined at 4% Head Fe_2O_3.based on the population statistics of the analyses. DTR analyses are incomplete for the entire model area and could not be used to define the cut off, however there is a strong positive correlation between Fe_2O_3 and DTR.
Metallurgical factors or assumptions	• *The basis for assumptions or predictions regarding metallurgical amenability. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider potential metallurgical methods, but the assumptions regarding metallurgical treatment processes and parameters made when reporting Mineral Resources may not always be rigorous. Where this is the case, this should be reported with an explanation of*	• No metallurgical recovery factors have been applied. Samples are screened to -2mm before analysis. The screened recovery is used to weight the head grade estimation. Davis Tube Recovery (DTR) analyses have been performed on samples from drill holes in the Cook and Kupe VTM deposits.

Criteria	JORC Code Explanation	Commentary
	the basis of the metallurgical assumptions made.	
Environmental factors or assumptions	• *Assumptions made regarding possible waste and process residue disposal options. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider the potential environmental impacts of the mining and processing operation. While at this stage the determination of potential environmental impacts, particularly for a greenfields project, may not always be well advanced, the status of early consideration of these potential environmental impacts should be reported. Where these aspects have not been considered this should be reported with an explanation of the environmental assumptions made.*	• Tailings from the mining operation are to be returned to the seafloor in mined out areas. • Baseline environmental studies have been undertaken and have determined that any environmental impact can be avoided, remedied or mitigated.
Bulk density	• *Whether assumed or determined. If assumed, the basis for the assumptions. If determined, the method used, whether wet or dry, the frequency of the measurements, the nature, size and representativeness of the samples.* • *The bulk density for bulk material must have been measured by methods that adequately account for void spaces (vugs, porosity, etc), moisture and differences between rock and alteration zones within the Deposit.* • *Discuss assumptions for bulk density estimates used in the evaluation process of the different materials.*	• Dry bulk density was determined by laboratory analysis and verified by comparison to the theoretical bulk density. Bulk density is sensitive to the heavy mineral content. A regression formula was used to estimate bulk density based on the Fe content. • A small number of samples (3) suggest decreasing porosity with Fe grade. If the samples prove valid, they have the potential to increase the tonnage of the deposit by several percent.
Classification	• *The basis for the classification of the Mineral Resources into varying confidence categories.* • *Whether appropriate account has been taken of all relevant factors (ie: relative confidence in tonnage/grade estimations, reliability of input data, confidence in continuity of geology and metal values, quality, quantity and distribution of the data).* • *Whether the result appropriately reflects the Competent Person's view of the Deposit.*	• Those parts of the resource classified as Indicated have been sampled at density considered adequate to support the classification. No adverse quality or geological uncertainty parameters affect this classification. The Inferred classification of the deposit reflects the assumed geological and geostatistical continuity in parts of the current model where the drill spacing exceeds 1,000m by 1,000m. • Classification of the Taranaki VTM deposit was undertaken by the competent person.
Audits or reviews	• *The results of any audits or reviews of Mineral Resource estimates.*	• The current mineral resource estimate has not been externally audited. In 2012 QG (Perth) undertook a due diligence of the resource data and estimation.

Criteria	JORC Code Explanation	Commentary
Discussion of relative accuracy/ confidence	• *Where appropriate a statement of the relative accuracy and confidence level in the Mineral Resource estimate using an approach or procedure deemed appropriate by the Competent Person. For example, the application of statistical or geostatistical procedures to quantify the relative accuracy of the resource within stated confidence limits, or, if such an approach is not deemed appropriate, a qualitative discussion of the factors that could affect the relative accuracy and confidence of the estimate.* • *The statement should specify whether it relates to global or local estimates, and, if local, state the relevant tonnages, which should be relevant to technical and economic evaluation. Documentation should include assumptions made and the procedures used.* • *These statements of relative accuracy and confidence of the estimate should be compared with production data, where available.*	• The current resource estimates for each of the Cook, Kupe and Tasman deposits are global estimates. The relatively sparse data does not allow a high confidence local estimate. • The model is considered adequate to use in a mine planning study for a bulk dredging style operation.

Appendix 19.17 - Metallurgical Review- Recovery of vanadium from the Taranaki VTM Project

WELLINGTON | BRISBANE | MELBOURNE | PORT MORESBY



Brisbane Office

Level 7, 300 Adelaide Street, Brisbane QLD 4000

Tel: +61 7 3157 4400

Email: brisbane@siecap.com.au

Sydney Office

Level 57, 19-29 Martin Place, Sydney NSW 2000

Melbourne Office

Level 2, Southbank Blvd, Southbank VIC 3006

New Zealand Office

Level 4 Suite 404, 2 Te Tahi Bay Rd, Porirua,

Wellington, 5022

Trans-Tasman Resources Limited

Metallurgical Review:

Recovery of Vanadium from Taranaki VTM Project

New Zealand

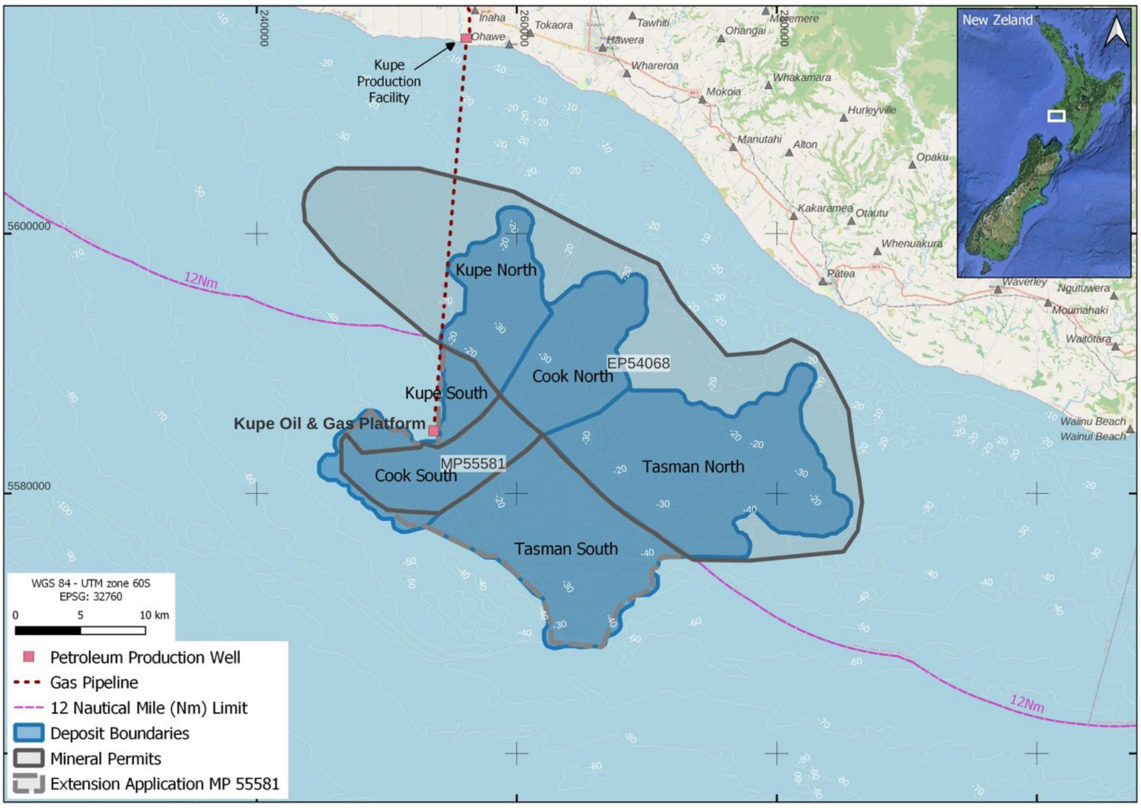
4 February 2025

Executive Summary

Objective and Scope

This metallurgical review for Trans-Tasman Resources (TTR) focuses on optimising the recovery of vanadium from its Taranaki VTM Project titanomagnetite iron sands.

TTR has reported JORC mineral resource estimates for its VTM (a vanadiferous titanomagnetite iron sand) “VTM” project located in the South Taranaki Bight off the west coast of the North Island, New Zealand (Figure 1) of combined Indicated and Inferred mineral resource of 3,157Mt @ 10.17% Fe_2O_3, 1.03% TiO_2 and 0.05% V_2O_5 at a 7.5% Fe_2O_3 cut-off grade containing 1.6Mt of vanadium pentoxide (V_2O_5)[1].



Location Plan of Taranaki VTM Deposits, South Taranaki Bight, New Zealand

Vanadium is present as a co-product in the TTR resource and would be a substantial source of the metal or its compound from future processing. The study encompasses laboratory-scale testing, highlighting process flow sheet development for further process optimisation followed by a one (1)-tonne-per-hour (tph) pilot plant, and a preliminary economic and environmental assessment to evaluate scalability, efficiency, and sustainability. The test work completed since 2018 has been very encouraging and demonstrates pathways to capturing this critical metal as a separate product stream using conventional technology.

[1] Manuka Resources Limited ASX Announcement 1 March 2023

Key Findings

- *Vanadium as a Critical Mineral:* Vanadium is a strategic mineral vital for construction, aerospace, and renewable energy technologies, particularly vanadium redox[2] flow batteries (VRFBs) used for large-scale energy storage. Global demand continues to outpace supply, emphasizing vanadium's critical role in decarbonisation and energy resilience resulting in its inclusion on several country and state government critical metals lists.
- *Extraction Method:* The recent test work and the subsequent study concluded that the Salt Roasting and Water Leaching process holds significant promise for extracting vanadium from New Zealand's ironsands, especially when operating conditions were carefully optimised. Achieving a 79% vanadium recovery rate under laboratory conditions underscored the process's viability.

Laboratory Testing: Summary and Analysis

- Laboratory testing was conducted by the University of Canterbury and Callaghan Innovation to validate the sodium salt roasting-water leaching process, optimise key parameters, and highlight areas for further testing and analysis associated with recovery from titanomagnetite.

Findings of the Laboratory Testing

- *Optimised Conditions:* Recovery rates peaked at 79% under conditions including:
  - Pre-roasting at 800°C.
  - Sodium carbonate roasting at 1000°C.
  - Acid leaching for 2 hours.
- These results of the testing and the testing conditions are encouraging and point to a viable full-scale process
- *Complexities Identified:* Formation of silicon and aluminium compounds during roasting, high-salinity wastewater, and gas emissions were aspects of the process flow route requiring mitigation strategies.
- *Feedstock Variability:* Consistency in feedstock composition was critical to achieving optimal recovery rates and typical of efficient ore flow sheets.

Recommended Bench Scale Testing

Further Bench Scale Testing is recommended to refine process parameters, validate initial findings, and ensure optimal performance before scaling up to pilot or full-scale operations.

Development of a One (1) tph Pilot Plant to confirm the Process Flow Sheet

- *Objective:* Translate laboratory-scale and bench scale testing findings into a scalable, efficient, and sustainable industrial process.
- *Key Components:*
  - Milling and Magnetic Separation
  - Air Roasting
  - Salt Roasting
  - Water Leaching
  - De-Silication
  - Ammonium Metavanadate (AMV) Precipitation
  - Calcination

[2] Redox batteries are fire safe and present minimal safety risks compared with solid state batteries

Economic and Environmental Considerations

- *CAPEX and OPEX:* Preliminary estimates for a Pilot plant set capital costs at USD 1.92 million and identify labour and reagent costs as the cost most impacting the operating economics, again typical of a process flow sheet regardless of scale.
- *Environmental Considerations:* Key factors include wastewater salinity, CO_2 emissions, and solid waste. Implementing mitigation strategies, such as advanced scrubbing systems and renewable energy integration, can help manage these impacts effectively.

Next Steps

- *Bench Scale Testing:* This is to refine, optimise and confirm the process flow sheet.
- *Pilot Plant Implementation*: This will validate the proposed flow sheet under pilot-scale conditions and provide data essentially for the scalability of the design.
- *Optimisation Trials*: Refine roasting and leaching parameters to further enhance efficiency to capture the maximum amount of vanadium in the most economical manner – trade-off studies.
- *Sustainability Initiatives:* Develop waste reduction and energy optimisation strategies.
- *Stakeholder Collaboration:* Further the company's existing multiyear engagement with industry, government, and academia to secure continued support and partnerships.

Conclusion

Laboratory tests conducted by the University of Canterbury and Callaghan Innovation confirm the viability of sodium salt roasting-water leaching process for the sustainable recovery of vanadium from the TTR VTM concentrate.

The TTR test work not only achieved high recovery rates of Vanadium (79%) but also exemplifies a model that balances economic viability with environmental stewardship. This dual focus ensures that resource extraction aligns with sustainable development goals.

The additional bench scale testing and development of the proposed pilot plant will confirm and derisk the process further, providing empirical data to feed into the bankable feasibility study to allow a full evaluation of vanadium pentoxide as a separate product stream as compared to just selling a vanadium rich iron concentrate.

Contents

Executive Summary 2
Introduction 7
Vanadium Extraction Methods Review 9
Laboratory Testing in Collaboration with University of Canterbury and Callaghan Innovation 12
Contributing New Zealand Based Research 15
Recommended Bench Scale Test Program 18
Updated Flow Sheet Development – One tph Pilot Plant 20
Preliminary Economic Evaluation: Pilot Plant 27
Environmental Considerations 30
Next Steps 31
References 32

List of Figures

Figure 1: General approaches to Vanadium Extraction(Gao, 2022) , with the Proposed TTR process shown in the red box 10

Figure 2: Mass balance of the PC sand through the University of Canterbury laboratory testing process 13

Figure 3 : Final extraction values at 2 hr as a function of HCl concentration........ 15

Figure 4 – Comparison of Non-Roasted vs Roasted Leached Samples 16

Figure 6: Process Flow Diagram, referencing the UC/Callaghan Innovation Laboratory Test work Against Pilot Scale Flow Sheet 20

Figure 7: Effect of PSD on the vanadium extraction from titanomagnetite roast. Taken from (Goso, 2016) 21

Figure 8: University of Canterbury Vanadium Recovery from the pre-heating of the TTR concentrate 22

Figure 9: University of Canterbury salt roast additive test results 22

Figure 10 - @Risk CAPEX Report 28

List of Tables

Table 1: Comparison of vanadium extraction from vanadium-bearing ore/concentrate and slag based on research. Reference (Amirreza Nasimifar, 2022) (Feng Gao, 2021) 11

Table 2: Sample Major Oxide Compositions 12

Table 3 – Major Oxide Composition Comparison with UC/Callaghan Innovation Laboratory Tests 15

Table 4: The dry mass balance of the University of Canterbury laboratory testing taken from a representative sand sample with water leaching. 25

Introduction

This updated metallurgical review has been prepared for Trans-Tasman Resources, expanding on its test work into advanced mineral processing techniques to optimise the extraction and separation of vanadium from New Zealand sourced vanadiferous -titano-magnetite iron sands concentrate. The scope of this study is to provide an analysis of available processing methods, detailed analysis of TTR commissioned and completed metallurgical testing, the identification of a preferred extraction methodology and the estimated capital and operating costs of a process aimed at maximising the yield and quality of vanadium.

Vanadium, a transition metal with unique properties, is gaining recognition for its strategic importance in the decarbonisation of heavy industry and the emergence of renewable energy technologies. Known for its ability to enhance the strength, durability, and corrosion resistance of steel and other alloys, vanadium is essential in industries such as construction, aerospace, and renewable energy.

Of particular interest is its role in vanadium redox flow batteries (VRFBs), a leading technology for large-scale energy storage critical to the global transition toward low-carbon energy systems. With the significant recent development of vanadium redox flow batteries (VRFB) (Olabi et al., 2023), they have gained significant popularity in large-scale applications, particularly in renewable energy storage. One of the critical advantages of VRFBs is their capability to safely store large amounts of energy for extended durations, making them ideal for grid-scale energy storage.

The largest battery built to date is the 500MW/2000MWh Hybrid Energy Storage Project located in Wushi, China in 2024, of which 50% of the storage is VRFM[3]. Closer to home, Western Australia, whose main grid is the biggest isolated network in the world is building a number of big batteries, some among the world's largest. The Western Australia state government has committed to build a 50 MW, 10 hour vanadium flow battery to support the grid around the mining town of Kalgoorlie[4].

Studies suggest that coupled to a wind source, a 1 MW, 8.3 MWh installation would save up to 0.058 MT of CO_2 over its lifetime (20-years) due to a reduction in renewable energy curtailment, which is equivalent to ca. 29,000 MT of coal burned (Santos et al.,2021).

Globally, vanadium demand is projected to grow significantly, driven by its critical applications. According to Vanitec[5], approximately 90% of vanadium produced is used in the steel industry, where it improves strength and durability in construction-grade steels. The remaining 10% is increasingly utilised in energy storage and high-tech industries, with the VRFB market expected to grow at a compound annual growth rate of over 20% by 2030.

Current global vanadium production is concentrated in countries with complex geopolitical characteristics such as China, Russia, and South Africa, with secondary recovery from steel slags contributing to supply. Despite this, demand is anticipated to outpace supply, underscoring the need for new, stable suppliers, particularly in the southern hemisphere which make use of innovative processing and sustainable sourcing.

Critical Minerals

A critical mineral is defined as a mineral that is indispensable to the functioning of modern economies and technologies but faces supply risks due to factors such as geopolitical tensions, limited production sources, or technical challenges in extraction and processing. These minerals are vital across various sectors, including energy, manufacturing, and technology, and any disruption in their availability could have far-reaching economic and national security consequences. Furthermore, critical minerals play a pivotal role in addressing technologies to counter climate

[3] China Electric Equipment Group Supports Successful Grid Connection of Largest Hybrid Energy Storage Project | Vanitec
[4] Biggest vanadium flow battery in Australia promised for ailing Kalgoorlie grid. https://reneweconomy.com.au/
[5] Vanitec represents the mining, processing, manufacture, research and use of vanadium and vanadium-containing products. https://vanitec.org/

change and advancing renewable energy production. They are essential for the development of low-carbon technologies such as wind turbines, solar panels, and battery storage systems, enabling the transition to cleaner energy systems and supporting global sustainability goals.

In New Zealand, the Ministry of Business, Innovation, and Employment (MBIE) has identified vanadium as a critical mineral in its Critical Minerals List for New Zealand[6] , highlighting its significance to both domestic and international supply chains. This designation reflects vanadium's growing demand, its applications in emerging technologies, and its limited global production, which is currently concentrated in only a few countries. It is important to note that Vanadium is regarded as having an elevated supply risk due to the sourcing of most current global production and global shortages will continue to impact on the ability of New Zealand and our international partners to secure Vanadium.

Vanadium is considered a critical mineral for several important reasons, which relate to both its unique properties and its role in key industries:

1. Enhancement of Steel Strength and Durability: Vanadium is primarily used in the production of high-strength steel alloys, which are essential for the construction, automotive, and energy sectors. These alloys are vital in manufacturing infrastructure, transportation vehicles, and energy infrastructure, making vanadium indispensable for modern economies.
2. Advancements in Energy Storage: Beyond its role in steel production, vanadium is increasingly critical in the field of energy storage. Vanadium redox flow batteries (VRFBs), which use vanadium to store and release energy, are being developed as an alternative to traditional battery technologies. VRFBs offer benefits like long cycle life and scalability, which make them ideal for grid-scale energy storage solutions. As renewable energy sources (such as wind and solar) increase, there is a growing need for efficient and reliable energy storage systems, driving up the demand for vanadium.
3. Geopolitical and Economic Considerations: The global production of vanadium is highly concentrated in a few countries, such as China, Russia, and South Africa, which leads to supply risks and geopolitical concerns. Countries like the United States have recognized vanadium's importance by listing it as a critical mineral, signifying its essential role in national security and economic stability.
4. Strategic Importance: The strategic importance of vanadium is further underscored by its role in aerospace, and energy sectors. Its ability to enhance the properties of metals and energy storage systems makes it essential for industries that are vital to a nation's security, infrastructure, and energy independence.

In January 2025, the New Zealand Government released its Minerals Strategy to 2040 [40], in which it outlines the guiding principles and outcomes for the development of critical minerals. As a critical mineral, TTR's development of the vanadiferous -titano-magnetite iron sands concentrate supports the current New Zealand Government Minerals Strategy, ensuring a stable and secure supply of vanadium is crucial for supporting infrastructure development and advancing energy storage technologies, particularly as countries transition to cleaner, more sustainable energy sources.

The key objectives of this metallurgical review are:

- To evaluate the findings from the research already completed.
- To incorporate additional experimental test work and advances within the industry.
- To address challenges related to emissions, reagent behaviour, and the recovery of by-product fractions such as titanium and iron.
- To recommend next steps for pilot-scale testing and industrial application.

[6] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/minerals-and-petroleum/critical-minerals-list

Vanadium Extraction Methods Review

Vanadium extraction methods are broadly classified into two principal categories: pyrometallurgical and hydrometallurgical processes. These methods cater to a range of feedstocks, including naturally occurring vanadiferous titanomagnetites and secondary sources like industrial by-products, each with unique chemical and physical characteristics. Pyrometallurgical processes rely on high-temperature operations to achieve the thermal separation and concentration of vanadium , in contrast, hydrometallurgical processes utilise chemical reactions in aqueous solutions to selectively dissolve and recover vanadium, emphasising precision and purity.

Pyrometallurgy Process Overview

The pyrometallurgical extraction of vanadium from vanadiferous titanomagnetites (VTM) involves high-temperature processing to recover vanadium as a valuable byproduct. The process typically begins with smelting VTM in a blast furnace or electric arc furnace to separate the molten iron-rich phase from the slag. Vanadium primarily concentrates in the slag as vanadium oxides. The vanadium-rich slag is then treated through oxidation and roasting to produce vanadium pentoxide (V_2O_5), which is subsequently purified and converted into various vanadium products. The method is widely used due to its efficiency in handling large-scale deposits, though it requires careful management of energy consumption and environmental emissions (Amirreza Nasimifar, 2022).

New Zealand Steel utilises the pyrometallurgical process to extract vanadium as a byproduct from titanomagnetite ironsand mined in the Waikato region. The ironsand is smelted in electric arc furnaces at the Glenbrook steel plant, where molten iron and a vanadium-rich slag are separated. Along with coal and limestone, the primary concentrate (ironsand) is heated and dried in one of four multi-hearth furnaces. It is then fed into the four reduction kilns, where it is converted to 80% metallic iron. Two melters then convert this into molten iron. The iron, at around 1480°C, is transferred to the Vanadium Recovery Unit (VRU), where vanadium-rich slag is recovered for export and further processing.

In the 2000s, an estimated 12,000 tonnes per year were exported to China. However, heightened environmental regulations and stricter enforcement of waste management standards led to a ban on slag imports. Concerns over the environmental impact of processing slag, including emissions, waste disposal, and contamination risks, were key drivers of this decision. As a result, countries like New Zealand, which generate vanadium-rich slag as a byproduct of steel production, had to seek alternative markets. The United States has since become a significant importer of this slag, leveraging its own industrial infrastructure and regulatory frameworks to process and recover vanadium in an environmentally controlled manner. This shift underscores the impact of environmental policies on global supply chains and trade dynamics for industrial byproducts.

Hydrometallurgy Process Overview

Hydrometallurgical extraction of vanadium from vanadiferous titanomagnetites (VTM) utilises advanced chemical processes to recover valuable metals through aqueous chemistry techniques. Hydrometallurgy broadly involves the use of leaching, solution concentration, and purification steps to extract and separate metals from ores, concentrates, or recycled materials, often offering a more environmentally friendly and energy-efficient alternative to traditional pyrometallurgical methods. A number of hydrometallurgical processes are in use globally.

The TIVAN® process, developed by TNG Limited, employs a unique acid leach and solvent extraction method to achieve high recovery rates of vanadium, titanium, and iron with minimal environmental impact. Similarly, Neomet's proprietary process uses chloride-based leaching and recycling to efficiently separate and purify metals, emphasising sustainability and cost-effectiveness. The ARGEX process focuses on producing high-purity titanium dioxide but also extracts vanadium as a byproduct, utilising low-temperature leaching and innovative separation techniques.

Together, these methods demonstrate the growing potential of hydrometallurgical technologies to sustainably and economically recover critical metals from complex ores like VTM.

Preferred Vanadium Extraction Method

The sodium salt roasting - water leaching process, a subset of the hydrometallurgical process is an established and robust technology employed to extract Vanadium from the VTM and with a high vanadium recovery rate has been widely utilised in the vanadium production plants in South Africa and Brazil, accounting for20–30% of the world's total vanadium production annually (Gao et al. 2022).

TTR chose the Salt Roasting and Water Leaching process for extracting vanadium from New Zealand ironsands due to its proven performance, technological maturity, environmental benefits, and compatibility with this unique resource. This softer environmental process reduces reliance on harsh chemicals by using a straightforward roasting step with readily available salts, such as sodium carbonate or chloride, to transform vanadium into water-soluble compounds, which are then efficiently extracted through water leaching.

The Salt Roasting and Water Leaching process comes with challenges that must be addressed to optimise extraction. One key issue is the reaction of sodium salts with elements like silicon (Si) and aluminium (Al) in the ore, forming stable solid compounds that can reduce vanadium recovery. Additionally, the use of ammonium salts during vanadium precipitation generates significant volumes of high-salinity, ammonium-rich wastewater, increasing treatment costs and environmental management requirements.

But compared to more complex and energy-intensive alternatives described in the preceding sections, this process generates fewer hazardous byproducts and greenhouse gas emissions and allows for easier management of waste streams. These environmental benefits, combined with its adaptability to the composition of New Zealand ironsands, make Salt Roasting and Water Leaching the ideal choice for sustainable vanadium recovery and TTR's preferred route.

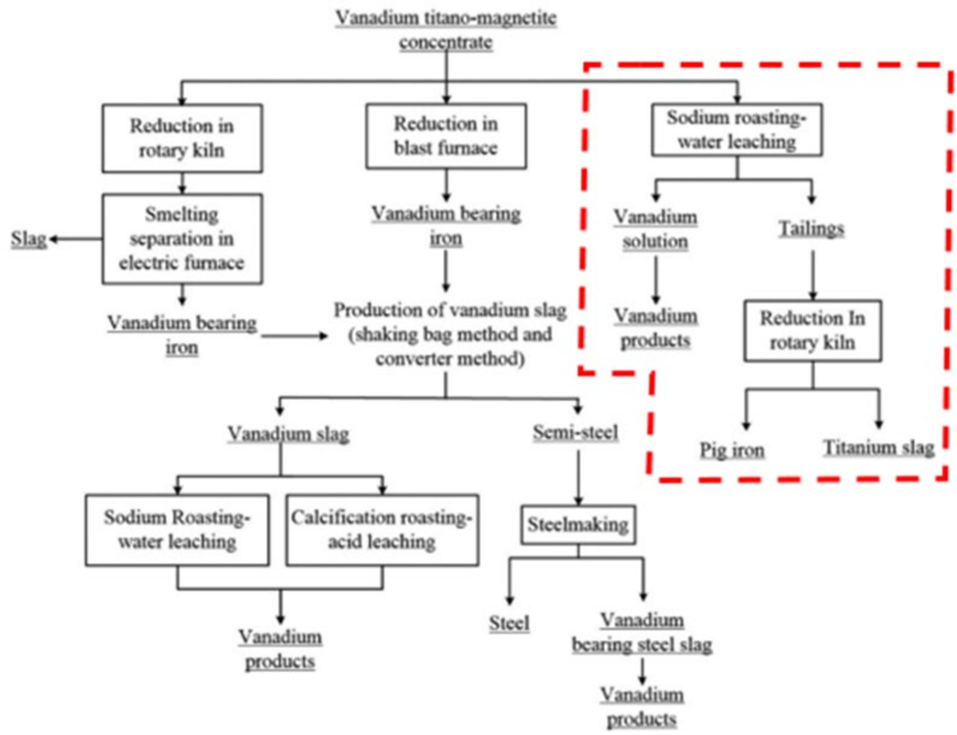


Figure 1: General approaches to Vanadium Extraction(Gao, 2022) , with the Proposed TTR process shown in the red box

Vanadium resource	Vanadium concentration (V)	Method	Optimum Conditions								Vanadium recovery
			Roasting			Leaching					
			Temp	Time	Salt content	Reagent	Acid/base	Time	Temp	Liquid to solid ratio	
Vanadium-bearing	0.8%	Sodium roasting-	1100 °C	3 hours	13 wt.%	Water	-	3 hours	90 °C	-	>80%
Vanadium- bearing	0.35%	Sodium roasting-	1010 °C	2.1 hours	41 wt.%	Sulfuric	4.25 mol/L	4.7 hours	85 °C	12.4	>83%
Vanadium-bearing titanomagnetite	0.48%	Sodium roasting-water leaching	1100 °C	2 hours	16 wt.% Na_2CO_3	Water	-	1 hour	90 °C	4	>80%
Cr-V slag	-	Sodium roasting-	800 °C	2 hours	-	Water	-	1 hour	25 °C	3	>87%
Steel converter slag	0.95%	Sodium roasting-	1000 °C	45 min	10 wt.%	$Na_2CO_3$and	Na2CO3: 40-50	60 min	80 °C	15	>80%
Cr-V slag	5.16%	Sodium roasting-	850 °C	90 min	15 wt.% NaOH, 35	Water	-	30min	90 °C	3	>95%
Steel converter slag	1.2%	Sodium roasting-	1000 °C	2 hours	20 wt.%	Sulfuric	2.05 mol/L	60 min	70 °C	19.99	>96%
Vanadium slag	4.73%	Sodium roasting-	850 °C	60 min	10 wt.%	Sodium	160 g/L	150 min	95 °C	10	>90%
Steel converter slag	3.5%	Sodium roasting-	850 °C	60 min	50 wt.%	Water	-	-	-	-	>85%
Cr-V slag	-	Calcium roasting two-step acid	800 °C	1 hour	12.3 wt.% Na_2CO_3	Sulfuric acid	-	Step 1: 20 min Step 2: 20 min	Step 1: 50 °C Step 2: 50°C	Step 1: 10 Step 2: 5	>87%
Titanomagnetite concentrate	-	Sodium roasting-water leaching	1150 °C	-	6-8 wt.% sodium salt	Water	-	-	90 °C	-	>75%

Table 1: Comparison of vanadium extraction from vanadium-bearing ore/concentrate and slag based on research. Reference (Amirreza Nasimifar, 2022) (Feng Gao, 2021)

Laboratory Testing in Collaboration with University of Canterbury and Callaghan Innovation

University of Canterbury – Department of Chemical and Process Engineering

In 2021, the University of Canterbury (UC) and Callaghan Innovation (CI) conducted lab-scale testing on titanomagnetite concentrate sourced from three New Zealand locations, including TTR concentrate. The TTR sample and a second sample (Labelled as "PC" to maintain confidentiality, as its identification is restricted due to commercial sensitivity) shared nearly identical major oxide compositions, leading to comparable performance during testing. In contrast, the third sample exhibited a significantly different composition and performed notably worse in the testing program, highlighting the impact of ore variability on extraction efficiency.

The TTR and PC samples are ironsand concentrates while the VRC sample (Labelled as "VRC" to maintain confidentiality, as its identification is restricted due to commercial sensitivity) was a pyrometallurgical product i.e. vanadium enriched slag which understandably performed differently.

Sample	Name	Fe_2O_3	MnO	TiO_2	CaO	K_2O	P_2O_5	SiO_2	Al_2O_3	MgO	Na_2O	V_2O_5
1	TTR	82.90	0.68	8.60	0.74	0.09	0.29	2.42	3.79	3.09	0.11	0.57
2	PC	84.30	0.63	7.96	0.51	0.05	0.09	2.16	3.79	2.84	0.07	0.60
3	VRC	32.11	10.39	13.84	2.86	0.01	0.09	17.56	1.55	1.13	0.13	13.72

Table 2: Sample Major Oxide Compositions

The testing program explored the potential of the Salt Roasting and Water Leaching process, described in the previous section, the method favoured for its simplicity, established performance, and adaptability to local resources. The laboratory-scale testing evaluated and optimised the process for vanadium recovery from New Zealand ironsands.

The study evaluated roasting conditions, leaching solvents, and pre-treatment steps, and aimed to identify optimum operational parameters while addressing challenges such as byproduct management and environmental impacts.

The study concluded that the Salt Roasting and Water Leaching process holds significant promise for extracting vanadium from New Zealand's ironsands, especially when operating conditions were carefully optimised. Achieving a remarkable 77% vanadium recovery rate under laboratory conditions underscored the process's viability. However, challenges such as managing byproducts, addressing environmental impacts, and accommodating variations in sand composition were identified as hurdles to industrial-scale implementation. To advance this work, the study recommended future efforts focus on reducing wastewater and gas emissions, further enhancing the process's environmental sustainability, and conducting pilot-scale tests to confirm its commercial feasibility.

Experimental Procedure:

The experimental procedure detailed in the report outlines the steps taken to evaluate the Salt Roasting and Water Leaching process for vanadium extraction from the ironsand samples. Key steps included:

Sample Preparation:

- The samples were homogeneously mixed with sodium salts (e.g., sodium carbonate or chloride) using a ball mill for 60 minutes to ensure even distribution.

Roasting:

- The prepared mixtures were roasted in a furnace equipped with temperature control to explore various roasting conditions, including temperature and duration.
- After roasting, the samples were cooled to room temperature and ground to ensure uniformity.

Leaching:

- The roasted materials were leached using distilled water or acidic solvents under controlled conditions.
- Residual solids were separated using centrifugation and washed three times with distilled water to remove any remaining salts or impurities.

Analysis:

- The composition of the roasted and leached samples was analysed using X-ray fluorescence (XRF) to determine metal content.
- The leachate was further analysed using inductively coupled plasma mass spectrometry (ICP-MS) to quantify the vanadium and other elements extracted.

Process Optimization:

- Experiments were conducted to optimise pre-treatment, roasting, and leaching parameters. These included varying temperatures, roasting times, sodium salt compositions, and leaching solvents.

This methodical approach provided critical insights into the conditions that would maximise vanadium recovery, laying the foundation for further refinement and scalability of the process.

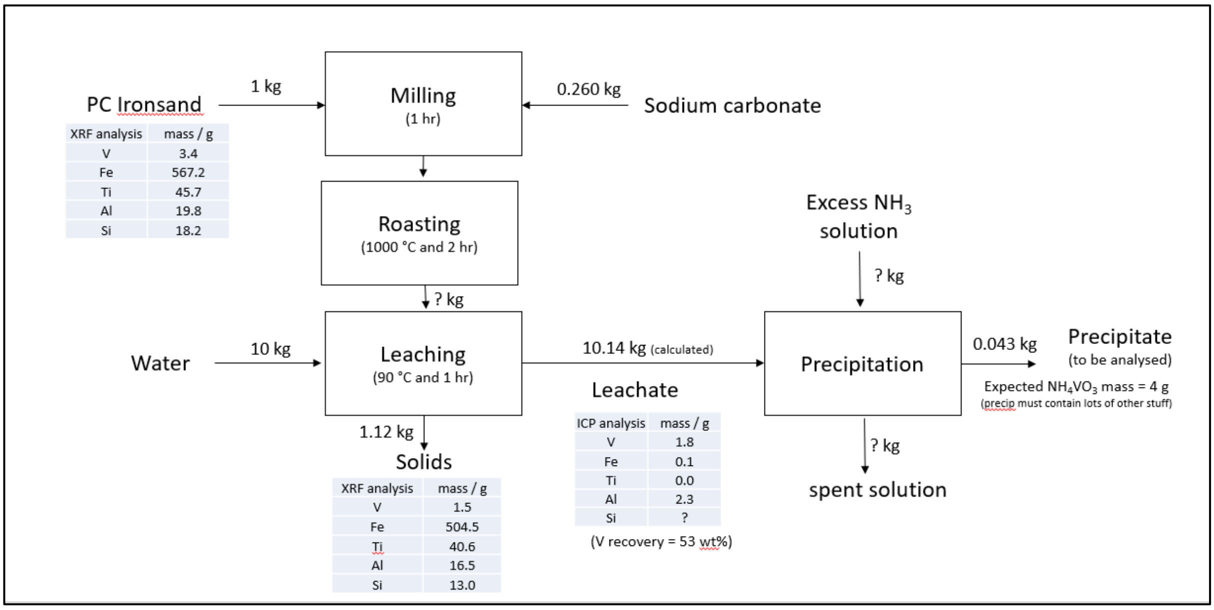


Figure 2: Mass balance of the PC sand through the University of Canterbury laboratory testing process

Analysis of the Results

The third sample (VRC) was excluded from the Siecap conducted analysis due to its differing composition compared to the TTR and the second (PC) sample. While the TTR and PC samples shared similar major oxide compositions and demonstrated comparable performance, the VRC sample's distinct chemical makeup resulted in a vanadium recovery rate of only 9% under the baseline processing condition. As such, this analysis study focused on the two representative samples to provide meaningful insights into optimising vanadium extraction.

Average Vanadium Extraction Across Samples (Baseline Test)

The study evaluated vanadium recovery from the representative samples under identical baseline roasting and leaching conditions (roasting a 20g sample with 5 g of sodium carbonate at 1000 °C for 2 hours, followed by leaching at 90ºC with distilled water for 1 hour). Under these baseline conditions, the results revealed varying levels of vanadium recovery.

On average, the baseline testing yielded a vanadium recovery rate of approximately 55% across the two representative sand samples.

1. Optimisation of Vanadium Extraction

The study then systematically investigated the effect of various parameters on vanadium extraction:

- Whilst the UC/Callaghan Innovation test work references a coarse leach it does not elaborate on what defined the coarse leach. However, Goso et.al. 2016 [11] detailed the impact of a coarse leach on vanadium recovery and clearly defined the effect of the particle size distribution (PSD) i.e. D100 of 1000 µm and D90 of 25 µm, in which case the pulp density and pH were kept constant at 65 m/m% and 7.8, respectively. The results show that the best vanadium extraction was generally achieved when the coarser material (D100 of 1000 µm) was used as feed.
- Pre-treatment: Air roasting the sand prior to sodium salt roasting improved vanadium recovery from 55% to 65%.
- Roasting Conditions:
    - Temperature: Vanadium recovery increased with roasting temperature, peaking at 1000 °C.
    - Duration: Recovery improved with time, reaching a maximum of 56% after 4 hours. However, the difference in recovery between 2 and 4 hours was minimal, suggesting diminishing returns with extended roasting times.
    - Sodium Salts: Sodium carbonate and a mixture of 50 wt.% sodium chloride and 50 wt.% sodium carbonate both achieved comparable recovery rates.
- Leaching Conditions:
    - Time: The leaching duration had a marginal effect, with vanadium recovery stabilizing at 57% after 2 hours.
    - Solvent: Acidic solvents demonstrated superior performance compared to distilled water, achieving up to 65% vanadium extraction. However, the use of acidic solvents presents several adverse environmental impacts that must be carefully managed. Acidic solvents are inherently more reactive and, if not handled properly, can pose risks to soil and water quality through potential leakage or improper disposal. These solvents may produce hazardous by-products or residues, requiring robust waste management systems to prevent contamination of ecosystems.

2. Vanadium Extraction under Optimum Conditions

The detailed composition analysis showed efficient recovery of vanadium alongside other elements such as iron (Fe) and titanium (Ti). This demonstrates the effectiveness of an optimised process.

Combining optimal parameters (air roasting at 800 °C for 2 hours, sodium carbonate roasting at 1000 °C for 2 hours, and water leaching for 2 hours), on a coarse leached representative sample the test work achieved an average vanadium recovery of 77%.

A slight increase in the vanadium recovery i.e. 79% was achieved using an acidic leach. The additional handling and storage protocols that are demanded by the use of acidic solvents would preclude its use in a full-size plant.

3. Challenges Identified

The process identified the following challenges:

- Formation of stable solid compounds during roasting, particularly with silicon (Si) and aluminium (Al), reducing vanadium availability.
- Generation of high-salinity ammonium-rich wastewater during vanadium precipitation, increasing treatment costs.
- Emission of harmful kiln gases, requiring advanced gas scrubbing systems to minimise environmental impacts.

Contributing New Zealand Based Research

Extraction of Vanadium from New Zealand Titanomagnetite Sand and Vanadium Recovery Concentrate University of Victoria – Lachlan Gaudin MSc Thesis

This thesis was undertaken to explore the potential methods of selectively extracting vanadium first from vanadium recovery concentrate (VRC) and then from iron sand (IS) sample materials. The research undertaken as part of this thesis showed that Vanadium can be selectively leached from both the New Zealand Iron Sands and Vanadium Recovery Concentrate (Vanadium Rich Slag).

The results of this research pertaining specifically to the roasting and leaching of the Ironsand sample was used for the analysis of this review.

Name	Fe_2O_3	MnO	TiO_2	CaO	K_2O	P_2O_5	SiO_2	Al_2O_3	MgO	Na_2O	V_2O_5
TTR	82.90	0.68	8.60	0.74	0.09	0.29	2.42	3.79	3.09	0.11	0.57
PC	84.30	0.63	7.96	0.51	0.05	0.09	2.16	3.79	2.84	0.07	0.60
IS	84.7	0.73	7.8	0.4	-	0.1	1.61	3.89	2.68	0.1	0.58

Table 3 – Major Oxide Composition Comparison with UC/Callaghan Innovation Laboratory Tests

The first stage of experiments conducted on the ironsand concentrate entailed the HCl leaching of a non-roasted sample and determining the percentage of each targeted element that could be extracted during a 2hr leaching period using hydrochloric acid (HCl) at specific concentrations.

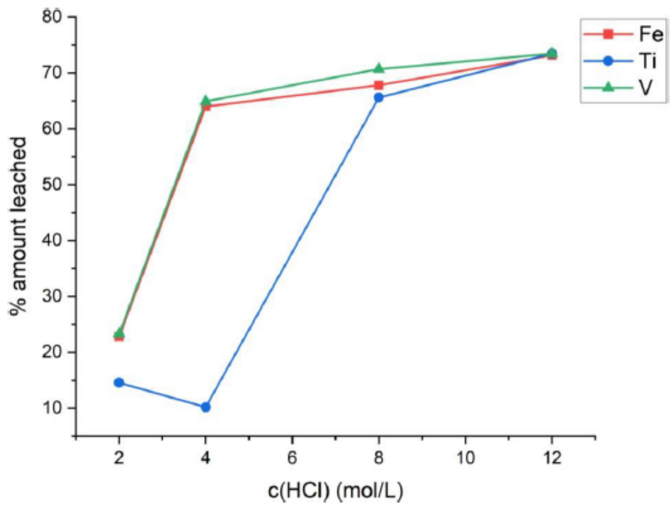


Figure 3 : Final extraction values at 2 hr as a function of HCl concentration

The second stage of experiments conducted on the ironsand concentrate entailed first roasting of the sample at 900 C for 3 hours in air. and then determining the percentage of each targeted element that could be extracted during a 2hr leaching period using hydrochloric acid at specific concentrations.

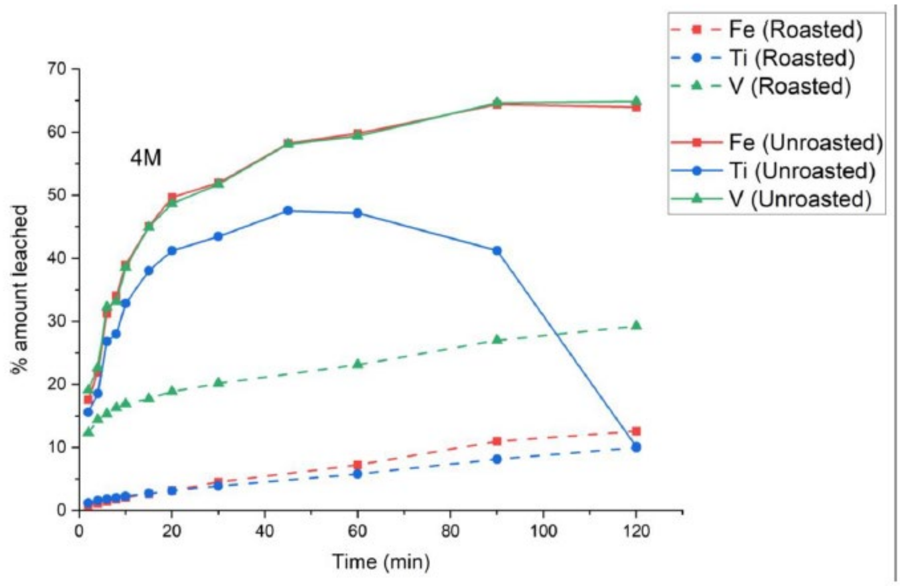


Figure 4 – Comparison of Non-Roasted vs Roasted Leached Samples

Generally, the leaching rate of each element (Fe, Ti, and V) decreased after the roasting procedure. This was because the roasting of the ironsand sample formed HCl-resistant phases.

The total % amount leached during the unroasted experiment was approximately 65 %, and this dropped to approximately 30 % for Vanadium after roasting. Also importantly, in the unroasted leaching experiment, the Vanadium curve closely followed the Fe curve indicating that the Vanadium was locked up in the ferrous mineral. After roasting while the Vanadium curve did not follow the Fe curve, it did take on the same slope after the first few minutes. This observation seems to indicate that the Vanadium leached over the first few minutes is not bound in the Fe mineral phase whilst the Vanadium leached thereafter seems to indicate that this portion of Vanadium is found in the ferrous mineral phase.

Insights

The findings from the thesis contribute to and reinforce the knowledge gained in the UC/Callaghan Innovation laboratory tests by providing additional insights into the behaviour of Vanadium during the extraction process. Specifically:

- Comparison of Compositions: The thesis highlights the similarities in major oxide compositions across ironsand samples (TTR, PC, and IS), validating the comparison across the samples used in the UC/Callaghan Innovation tests. This alignment strengthens the reliability of findings about the impact of roasting and leaching on vanadium extraction.
- Selective Leaching: The thesis demonstrates that vanadium can be selectively leached from ironsand concentrates, providing evidence for the efficacy of hydrometallurgical techniques. This aligns with the UC/Callaghan Innovation findings where roasting and leaching processes were optimised for better vanadium recovery.
- Roasting Impacts: The thesis identified that roasting forms HCl-resistant phases, thereby reducing vanadium leaching rates from approximately 65% (unroasted) to 30% (roasted). This supports the selection of water based leaching methods.
- Behaviour of Vanadium: The thesis reveals how vanadium's leaching behaviour differs between roasted and unroasted samples. In roasted samples, vanadium appears to partially decouple from the ferrous mineral phase, a nuance not uncovered in the UC/Callaghan Innovation tests but which provides deeper context for the importance of pre-treatment and phase changes during roasting.

- The thesis's focus on HCl leaching expands the understanding of solvent efficacy, providing a comparison with the distilled water and acid leaching investigated by UC/Callaghan Innovation. This broader solvent exploration can guide future optimisation efforts.
- Whilst the thesis generally supports a water leach, tests conducted by UC Callaghan on a "BC" (Best Case) sample, sourced from a representative sample indicates that using a salt roast process then leaching with a HCL formulation could result in a Vanadium recovery of 79%. One issue that will have to be resolved if an HCL Leach is pursued, is the effect of the increased presence of AL_2O_3 in the leachate and its effect on the efficiency of the precipitation process.

Overall, the thesis deepens the understanding of vanadium extraction mechanisms, validating the methodologies used by UC/Callaghan Innovation while introducing additional perspectives on phase behaviour, leaching efficiency, and sample variability. These insights can inform process refinement and scalability for industrial applications.

Recommended Bench Scale Test Program

The transition from laboratory-scale research to a scalable, efficient, and sustainable industrial process has identified key areas that require further investigation. These areas must be thoroughly examined through an additional, well-structured bench-scale testing program to provide critical data supporting the development of a Pilot Plant.

To advance the evaluation of vanadium recovery from the TTR titanomagnetite concentrate, it is recommended that the next phase of testing involve an expanded bench-scale program. This program should be designed to systematically assess and optimise the conditions for each stage of the industrial process, ensuring maximum vanadium recovery while addressing technical and economic feasibility for commercial-scale implementation.

To facilitate a comprehensive evaluation, it is proposed that the bench-scale tests be conducted on a representative 20 kg sample of titanomagnetite concentrate. This larger sample size will allow for detailed testing of key parameters, including but not limited to:

- *Leaching Efficiency:* Identifying optimal reagent concentrations, temperature, and retention times to maximise vanadium dissolution.
- *Precipitation and Purification:* Refining methods to selectively recover vanadium while minimising impurity co-extraction.
- *Solid-Liquid Separation*: Assessing filtration and settling characteristics to optimise process efficiency.
- *Residue Management:* Evaluating tailings characteristics and potential reuse or disposal strategies.
- *Process Scalability*: Simulating continuous processing conditions to validate operational feasibility.
- *Economic Viability:* Identifying cost drivers and potential optimisations for pilot- and full-scale operations.

By conducting this expanded bench-scale testing program with a 20 kg concentrate sample, the study will generate robust data necessary for refining process parameters, de-risking scale-up challenges, and further informing Pilot Plant design. Siecap regards this step as critical to establishing a commercially viable and technically sound vanadium recovery process.

Recommended Approach

The test work should involve a systematic evaluation of processing steps to determine the repeatable optimal conditions that will achieve the most efficient recovery of vanadium from the TTR sample. From these results, TTR will be able to refine the proposed pilot plant setup, recommended within this report. In addition, it is recommended that TTR review the byproduct streams with the proposed process flow and the development of pig iron and titanium credits.

The key focus areas should include:

Material Assessment and Preparation

- Conduct preliminary analysis to understand the TTR concentrate composition (i.e. particle size density, pulp density) and the effects it may have on vanadium extraction.
- Air roasting of ore pre-reactant and optimisation with water leaching

Processing Evaluation

- Assess the impact of roasting on vanadium extraction efficiency and impurity removal.
- Investigate different reagent applications for optimising the roasting and leaching processes.
- Identify potential operational challenges such as material handling, reagent consumption, and by-product formation.
- Investigate the areas provided in this report under the section Next Steps.

- The Siecap Phase 1 report provided a high-level metallurgical flow chart (Figure 5), which provides the basis for testing of bench scale samples, with agreed testing parameters to be identified with TTR and the metallurgical consultant / laboratory.

Technical and Environmental Considerations

- Review the formation of silicate compounds and other impurities that could impact vanadium recovery.
- Evaluate the waste streams and the impact of roasting and leaching, including wastewater salinity and gas emissions.
- Develop mitigation strategies for process waste and emissions control.

Financial and Economic Considerations

- Estimate costs associated with reagent usage, energy consumption, and waste management.
- Evaluate the overall economic feasibility of implementing the extraction process.

Bench Scale Testing - Recommendations and Next Steps

A flexible approach to the bench-scale testing is recommended, allowing for iterative refinements based on initial findings.

The study should focus on identifying the most efficient and cost-effective methods before proceeding to the pilot-scale validation. Ensuring technical viability alongside environmental and financial sustainability will be key to sustainable vanadium extraction from the TTR concentrate.

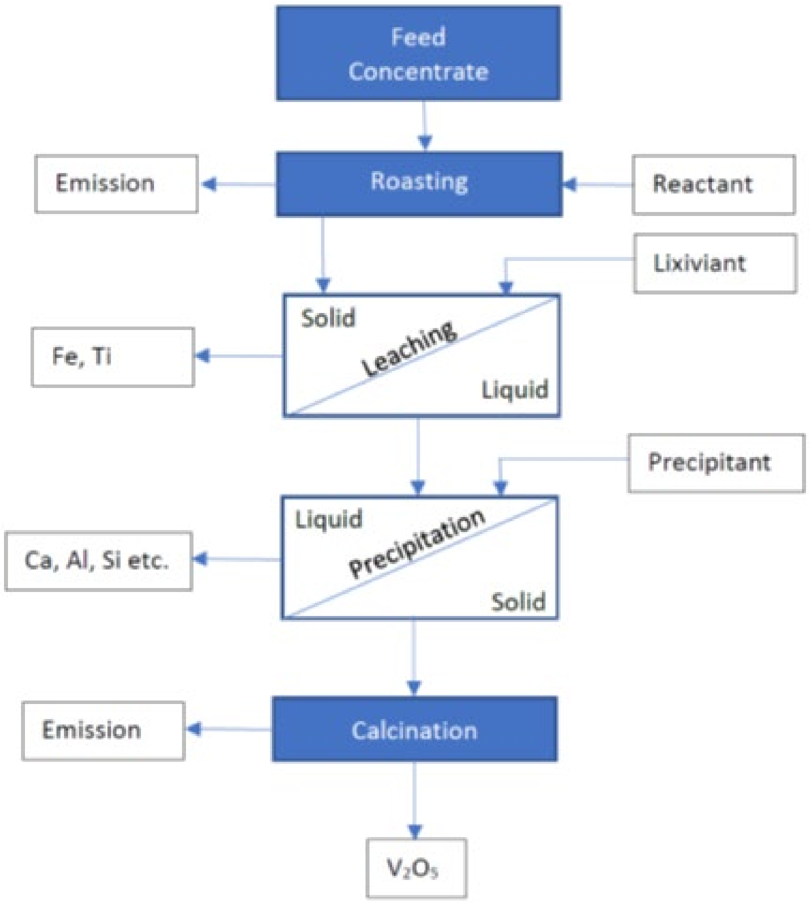


Figure 5: Outline of the Process Flow Sheet for the basis of the bench scale testing

Updated Flow Sheet Development – One tph Pilot Plant

Introduction to Process Flow Sheet Development

The development of a pilot plant process flow sheet is a critical step in translating the laboratory-scale research and the proposed additional bench scale testing program into a scalable, efficient, and sustainable industrial process.

The laboratory-scale research has allowed the designing of a logical sequence of unit operations to achieve the desired product quality, maximise recovery rates, and minimise environmental impacts and has also highlighted areas that need to be studied further in the additional proposed bench scale testing program.

For vanadium extraction from ironsand, flow sheet development integrates key steps such as pre-treatment, roasting, leaching, and purification, each optimised based on experimental findings. This process ensures that the chosen methods, including roasting conditions, leaching solvents, and byproduct management strategies, are not only technically feasible but also economically viable. By aligning laboratory results with practical operational requirements, the process flow sheet serves as a roadmap for transitioning to pilot-scale and eventually full-scale production.

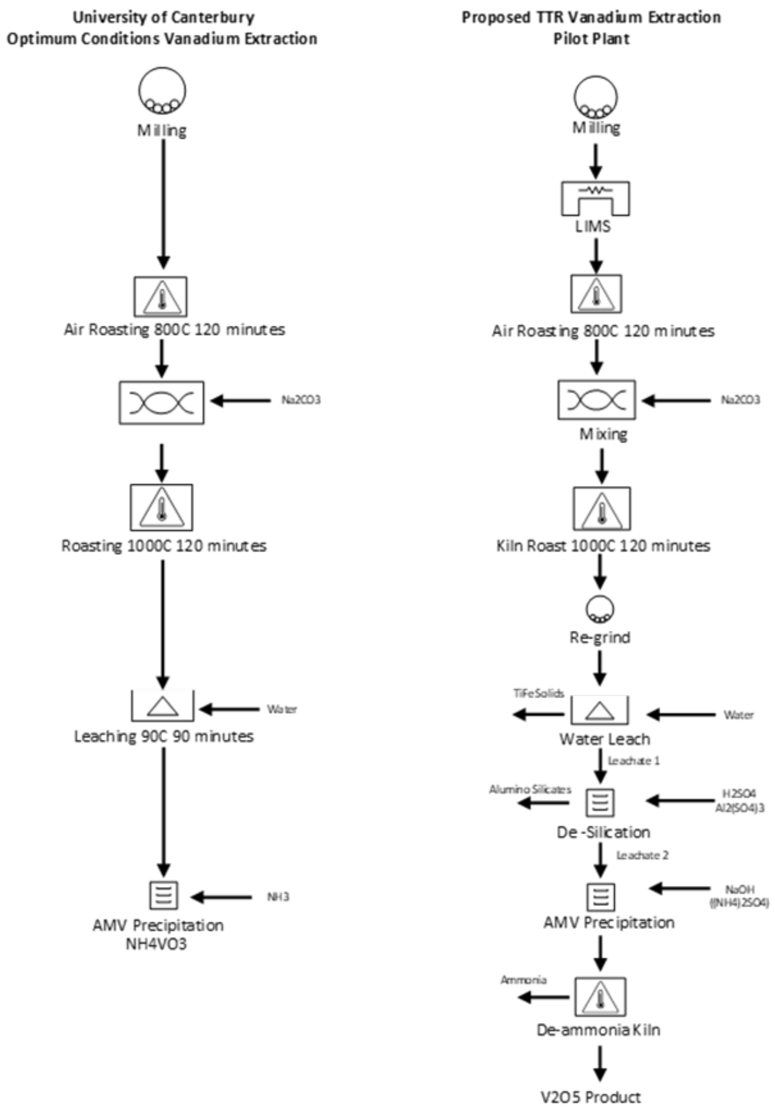


Figure 5: Process Flow Diagram, referencing the UC/Callaghan Innovation Laboratory Test work Against Pilot Scale Flow Sheet

Sizing the pilot plant at a 1 ton per hour (tph) feed rate allows TTR to mitigate technical, financial, and operational risks associated with scaling up from laboratory or bench-scale processes.

A 1 tph capacity will allow for comprehensive testing of the process under conditions closely resembling full-scale operations while maintaining manageable capital and operating costs. This scale is large enough to generate reliable data on process efficiency, recovery rates, and waste management, yet small enough to enable flexibility in modifying equipment or processes in response to unexpected challenges.

Additionally, the 1 tph capacity reduces potential environmental impacts during the pilot phase, ensuring compliance with regulatory requirements and easing community acceptance. By optimising at this intermediate scale, the project can build a robust foundation for a successful transition to commercial-scale production.

Development of the TTR Process Flow Sheet

Milling

The impact of particle size distribution (PSD) on vanadium extraction was evaluated by Goso et.al. (2016), and the results of the UC/Callaghan Innovation test work highlighted that the highest vanadium extraction was generally achieved using coarser material (D100 of 1000 µm) as feed.

The reduced vanadium extraction observed with the finer grind size was attributed to potential oxidation during milling, which may have led to the formation of insoluble phases. (Goso, 2016)

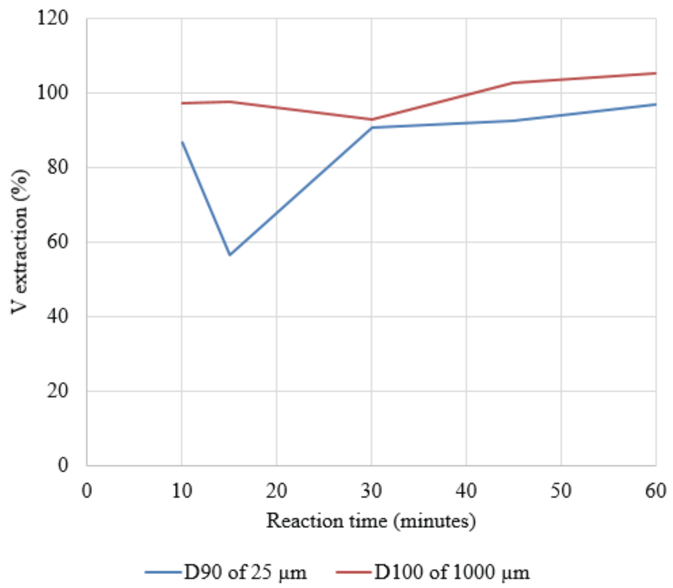


Figure 6: Effect of PSD on the vanadium extraction from titanomagnetite roast. Taken from (Goso, 2016)

As part of any ongoing testing, it is recommended that the particle size distribution be subjected to further testing to confirm the optimum range that will provide maximum vanadium extraction.

Low-Intensity Magnetic Separation

The inclusion of a LIMS circuit will remove any further non-magnetic material from the concentrate, post milling, thereby removing any liberated silicates. This would enable the process to further advance quality consistency and provide a slight uplift in the vanadium percentage in the roasting feed.

Air Roasting

The UC/Callaghan Innovation test work (Montecillo, 2021) clearly showed that air roasting the concentrate prior to a blending and roasting process increased the vanadium extraction.

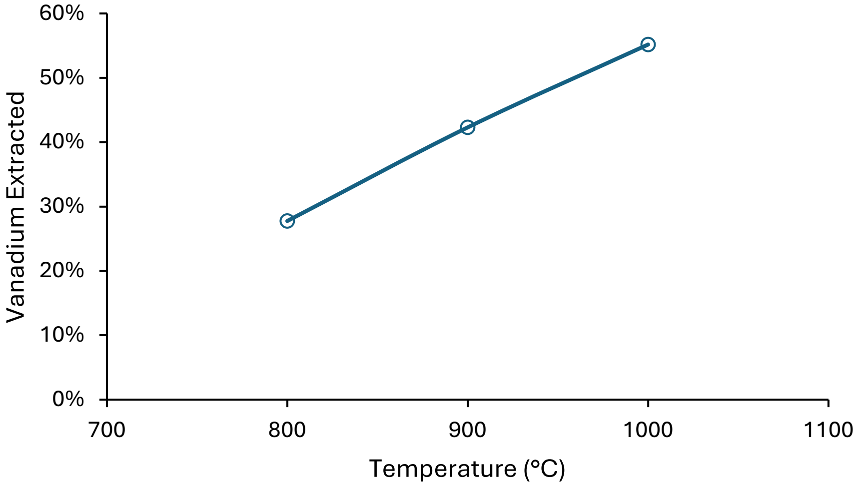


Figure 7: University of Canterbury Vanadium Recovery from the pre-heating of the TTR concentrate

Salt Roasting

The quality of the roasting process significantly influences vanadium recovery, and roasting additives are typically used to enhance its effectiveness. However, traditional additives such as sodium and calcium salts present several challenges. Sodium salt additives require large quantities to achieve high vanadium leaching efficiency, leading to the generation of polluting gases and challenges in their treatment. In the case of the TTR titanomagnetite concentrate the salt addition could be as high as 25% of the feed material. Similarly, calcium salt additives pose issues like high additive consumption, selective compatibility with roasting materials, and potentially high costs associated with vanadium extraction. (Li, 2018).

The UC/Callaghan Innovation test work (Montecillo, 2021) undertook analysis of different sodium salt additive to determine if there was an improvement in the vanadium extraction. The results showed there was a slight advantage with the use of sodium carbonate, however this was minimal. In comparison, the roasting conditions (time and temperature) play a critical part in the extraction of vanadium. This is supported by a number of the technical references.

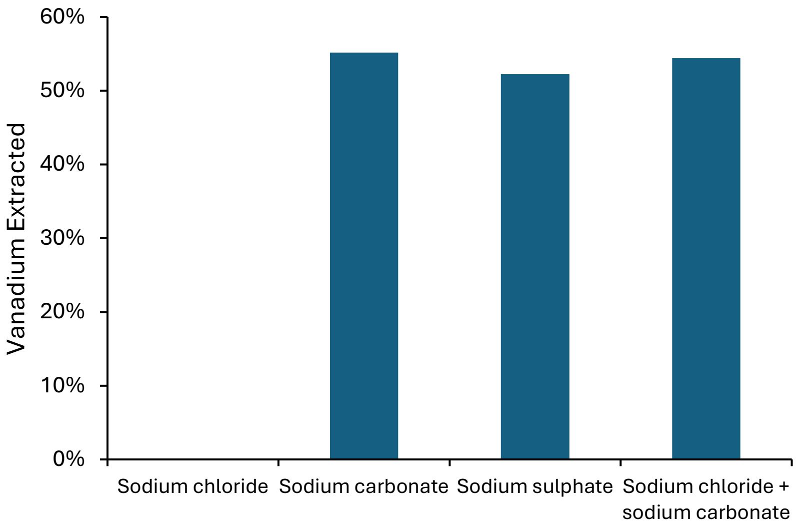


Figure 8: University of Canterbury salt roast additive test results

Sodium Carbonate (Na_2CO_3):

- Chemical Interaction: Sodium carbonate reacts with vanadium oxides in the feed to form water-soluble sodium vanadates during roasting. This enhances vanadium recovery in the subsequent leaching process.
- Temperature Stability: Sodium carbonate is stable at high temperatures and facilitates effective roasting at elevated conditions (e.g., ~1000 °C).
- Byproducts: The reaction typically produces CO_2 as a gas, which is less challenging to scrub compared to some other gaseous emissions.
- Effectiveness: It is often more effective for vanadium recovery due to its strong reactivity with vanadium-containing compounds.
- Environmental Impact: Produces relatively manageable gaseous byproducts, primarily CO_2, but requires attention to carbon emissions.

Sodium Chloride (NaCl):

- Chemical Interaction: Sodium chloride can enhance the mobility of certain metal ions during roasting by creating volatile metal chlorides. However, its reactivity with vanadium oxides may not be as strong as sodium carbonate.
- Chlorination Effects: NaCl may volatilize and form chlorides during roasting, which can lead to the loss of valuable metals or cause operational challenges.
- Byproducts: Roasting with NaCl can produce harmful chlorine or hydrochloric acid gases, necessitating advanced scrubbing systems to mitigate environmental and safety risks.
- Effectiveness: While NaCl can aid in the extraction of other elements, its efficiency for vanadium recovery may be lower compared to sodium carbonate unless used in specific combinations (e.g., with Na_2CO_3).
- Environmental Impact: The release of chlorine-containing gases poses a higher environmental and health risk compared to sodium carbonate.

Key Differences:

- Reactivity: Sodium carbonate is more directly reactive with vanadium oxides, forming soluble compounds, while sodium chloride primarily influences mobility and may have limited direct reactivity with vanadium.
- Byproducts: Sodium carbonate produces CO_2, whereas sodium chloride can release more hazardous chlorine-based gases.
- Efficiency: Sodium carbonate is typically more effective for vanadium recovery under standard roasting conditions.

Re-Grinding

Due to the salt roasting and cooling process, the material sinters into a crusty slag-like texture. The post salt roast material will require to be ground to facilitate an efficient leaching process.

Water Leaching

Salt roasting followed by water leaching is an efficient process for enhanced vanadium recovery, converting vanadium in titano-magnetite into water-soluble vanadates such as sodium or potassium vanadate. Water leaching effectively dissolves these compounds, ensuring high recovery rates while selectively separating vanadium from insoluble materials like iron and titanium oxides. This enhances the purity of the extracted solution, simplifying downstream processing. Environmentally, the process eliminates the need for strong acids or harsh chemicals, reducing both environmental impact and operational hazards. Operating under mild conditions at ambient or slightly elevated temperatures, water leaching consumes less energy than more aggressive hydrometallurgical methods. It is also cost-effective, requiring simple equipment and minimising material losses through efficient resource utilisation. Scalable for industrial applications, this method is well-suited for large-scale vanadium extraction and enables the recovery of valuable byproducts like titanium, improving economic viability. Additionally, its selective nature reduces impurities in the vanadium solution, leading to high-quality final products with improved metallurgical performance

In review the research and industry papers, the effect of not only the particle size distribution, leaching time affect the vanadium extraction, but also the pulp density of the feed into the leaching process can improve the vanadium recovery, (Goso, 2017 and Muthukumar, 2020). It is recommended further testing of these variables is undertaken to optimise the leaching process of the TTR concentrate.

De-Silication Precipitation

The precipitation of silicates from a water-based leachate within a stirred precipitation tank will be a critical step in the TTR process. During leaching, silicate minerals will dissolve alongside the vanadium. Precipitating the silicates serves to purify the solution, preventing interference in subsequent processing steps such as metal recovery or precipitation. This process will involve adjusting the pH, temperature, and introducing a specific reagent to promote selective silicate precipitation while minimising the loss of Vanadium.

Silicate Removal

After silicates are precipitated through controlled pH adjustment and reagent addition, the resulting solid precipitates will be separated from the liquid using a filter press. This equipment works by forcing the slurry through a series of filter plates, which trap the solid precipitates while allowing the clarified leachate to pass through. The filter press provides a reliable and efficient method for handling large volumes of slurry, producing a clear filtrate and compact filter cake that can be easily removed and disposed of or further processed. By effectively removing silicates, the filter press prevents contamination, scaling, or clogging in subsequent processing stages, ensuring the vanadium-rich solution remains suitable for precipitation or extraction steps. This approach is particularly advantageous for its operational simplicity, scalability, and ability to handle high-solids content.

Ammonium Metavanadate (AMV) Precipitation

The formation of AMV begins with the treatment of the vanadium-rich leachate solution within a stirred precipitation tank. The addition of ammonium salts, commonly ammonium sulphate or ammonium chloride will induce a chemical reaction that results in the precipitation of ammonium metavanadate.

This process is highly selective and efficient, enabling the separation of vanadium from other impurities in the leachate. The precipitated AMV is then collected, filtered, and subjected to further processing steps, such as calcination, to produce high-purity vanadium pentoxide or other specialized vanadium compounds. AMV's significance extends beyond its role in the production chain; its controlled precipitation also ensures high recovery rates and contributes to the economic viability of vanadium extraction and refinement operations.

AMV Removal

The AMV precipitate will be separated from the leachate using a filter belt, which continuously processes the slurry by feeding it onto a moving porous belt. As the slurry moves along the belt, vacuum or pressure filtration removes the liquid, leaving behind a filter cake of AMV. The filter belt system is particularly advantageous for its ability to handle high-throughput operations and maintain continuous processing. The collected AMV filter cake will be washed to remove residual impurities. This efficient and scalable approach ensures high recovery rates, minimises losses, and supports the production of high-purity vanadium compounds.

De-ammonia kiln calcination

During this thermal decomposition, the recovered and cleaned AMV is subjected to precisely controlled kiln conditions, including optimal temperatures and residence times, to ensure complete breakdown of ammonium compounds while preserving the purity and desired crystalline structure of the resulting V_2O_5.

A key feature of the calcination process is the recovery of ammonia gas released during decomposition. The installed system will capture and recycle this ammonia, minimising emissions and reducing the environmental footprint of the operation. This closed-loop approach not only aligns with sustainability goals but also enhances overall process efficiency by converting what would otherwise be a waste product into a reusable input. By combining precision control, product quality, and environmental stewardship, de-ammonia kiln calcination ensures the production of high-grade vanadium pentoxide while supporting a more sustainable industrial process.

The direct extraction method of vanadium from vanadium-titanium magnetite (VTM) is typically performed using a sodium salt roasting-water leaching process. In this method, VTM is roasted in a rotary kiln under oxidizing conditions with sodium salts, followed by wet grinding and water leaching of the roasted calcine. The vanadium-bearing solution is purified by adding ammonium sulphate ($(NH_4)_2SO_4$) or ammonium chloride (NH_4Cl) to precipitate ammonium metavanadate (AMV) and ammonium polyvanadate (APV). This method has been successfully applied in countries like South Africa and Brazil, enabling economic extraction of vanadium from VTM concentrate. Based on typical industry indicators, vanadium pentoxide can be obtained with a purity of 99.5% to 99.8% by sodium roasting-water leaching, with the proposed process the vanadium leaching efficiency and the total recovery process are 97% and 71.41% to 78% respectively. (Nasimifar, 2022)

In review of the industrial vanadium extraction processes, sodium salt roasting followed by water leaching remains the dominant process for extracting vanadium from VTM, owing to its high efficiency, low operational cost, and simplicity. With increasingly stringent environmental regulations, the focus must shift toward innovative processes that emphasize comprehensive resource utilization and pollution reduction at the source. These advancements represent the future of the industry and warrant ongoing research and development. (Li, 2018).

Process Flow Sheet - Dry Basis Mass Balance

The following is a table showing the high-level dry mass balance of the titanomagnetite, based on a 1000 tph pilot plant. The basis of this mass flow sheet is taken from the UC/Callaghan Innovation test results for the recovery of a representative titanomagnetite sand sample. This has the following assumptions

- There is a 99% LIMS recovery rate
- Roasting feed of Sodium Carbonate of 20%
- Roasting produces approximately 12% mass emissions (based on Trinh, 2021- Efficient Recovery of Vanadium and Titanium from Domestic Titanomagnetite Concentrate Using Molten Salt Roasting and Water Leaching)
- High recovery of solids - 95% (based on UC/Callaghan Innovation testing)

Process Stage	Mass (Kg)	Fe	Mn	Ti	Ca	K	P	Si	Al	Mg	Na	V
Ball Mill Feed	1000.0	589.59	4.84	47.68	3.63	0.43	0.20	10.08	20.08	17.13	0.51	3.35
LIMS Feed	990.00	589.59	4.84	47.68	3.63	0.43	0.20	10.08	20.08	17.13	0.51	3.35
Roasting Feed	1188.00	278.16	4.60	47.68	3.63	0.43	0.20	10.08	20.08	17.13	103.46	3.35
Leach Tanks Feed	1045.44	278.16	4.60	47.68	3.63	0.43	0.20	10.08	20.08	17.13	103.46	3.35
TiFe Solids	982.71	476.86	3.86	33.40	4.57	3.86	0.09	19.54	14.56	12.38	47.22	1.39
Leachate	58.96	0.43	0.01	0.10	0.00	0.00	1.86	0.00	17.47	0.26	49.49	2.63
Vanadium Recovery												78%

Table 4: The dry mass balance of the University of Canterbury laboratory testing taken from a representative sand sample with water leaching.

The dry mass balance conducted during the UC/Callaghan Innovation testing provides an initial overview of the material flow and vanadium recovery potential and does not include the de-silication (removal of the alumino-silicates) and AMV processes which uplift the purification of the vanadium recovered. Further testing and analysis will be required to refine these results. Additional work is needed to validate the distribution of vanadium across the individual process streams, assess losses more accurately, and determine the impact of process variables on recovery efficiency. This will ensure a more comprehensive understanding of the system and support the optimisation of processing parameters for scalable production. Future testing should also address any discrepancies observed and incorporate a broader range of input materials to enhance the reliability of the mass balance findings.

Preliminary Economic Evaluation: Pilot Plant

The estimation of capital expenses (CAPEX) for the Pilot Plant is a conceptual high-order assessment aimed at providing a preliminary understanding of potential costs. This includes the initial capital investment for infrastructure such as roasting kilns, leaching tanks, separation units, and essential support systems like waste and water management facilities. While a full operating expenses (OPEX) assessment is not included, a high-level evaluation highlights cost-sensitive elements of operating the pilot plant, specifically the costs of labour and chemical reagents such as sodium salts for roasting. These estimates are based on generalised assumptions about process parameters, feed grade, and scale of operations, offering a foundational economic perspective to guide further detailed feasibility studies.

It is recommended that the pilot plant be constructed in New Zealand.

Building the plant locally will support the retention of intellectual property (IP) by maintaining close control over innovative processes and technologies developed during the demonstration phase. Additionally, operating the plant in New Zealand allows for the collection of critical data and insights that will inform key decisions about the final location of the full-scale operational plant.

Factors such as logistical challenges, supply chain considerations, and environmental impacts can be evaluated more effectively, enabling the identification of an optimal site for the commercial facility while ensuring the pilot plant phase contributes maximum value to the project's overall success. The Pilot plant would be housed within a regular large-scale steel shed/warehouse and should not prove problematic to locate.

Capital Expenditure (CAPEX)

The capital cost assessment for this project has been prepared on a factorial basis and has been estimated to an accuracy of -25% to +50% in accordance with a typical Class 5 estimate as defined by the AACE standards. Basic flow sheets have been prepared and equipment sized. The equipment pieces have been priced and specialised factors have been used to account for the rest of the costs associated with construction of the plant.

The CAPEX estimate is a Monte Carlo-based capital expenditure (CAPEX) estimate and provides a probabilistic estimate, enabling the robust evaluation of uncertainties. In this case, the P80 value—representing the cost level that is expected to be exceeded only 20% of the time—has been adopted as the base price. This level reflects a reasonably confident yet realistic cost expectation. To account for contingencies, an allowance of 15% has been included. This methodology balances risk tolerance and financial planning, supporting informed decision-making .

CAPEX Assumptions

- New equipment (used equipment items will be considered if readily available)
- No government taxes or charges
- No owners cost
- No future currency variation, a fixed price has been assumed on the selected currency reference date.

Estimation Criteria

- Concentrate feed is delivered to the Pilot Plant at a cost of USD 25/tonne
- Concentrate feed throughput of 1 tonne per hour (tph)
- Project contingency set at 15%
- Estimated equipment pricing based on budget pricing from various sources.

Currency Basis (24/01/2025)

- 1.75 NZD: 1 USD
- 1.58 AUD: 1 USD
- 0.96 EUR: 1 USD

CAPEX

P80 USD 1,667,121.00 (NZD 2,917,462.00)

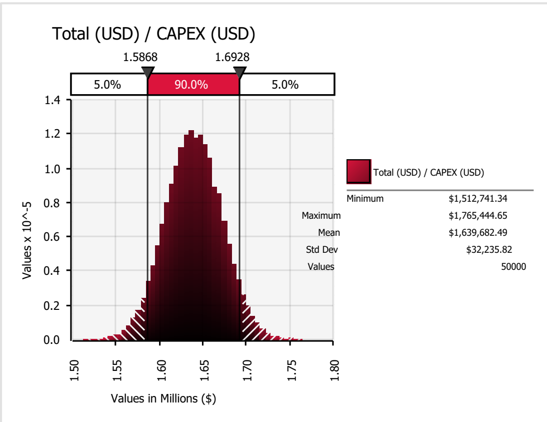
Contingency USD 250,070.00 (NZD 437,500.00)

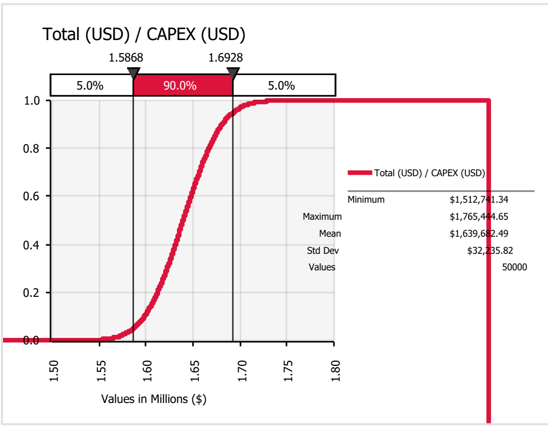
Total CAPEX Estimate USD 1,917,191.00 (NZD 3,355,085.00)

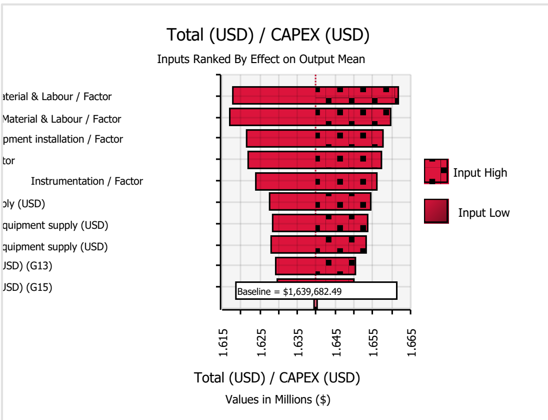
@RISK Output Report for Total (USD) / CAPEX (USD)

Performed By: Siecap NZ

Date: 24 January 2025 10:41:12







Simulation Summary Information	
Workbook Name	TTR 1 tph Pilot Plant
Number of Simulations	1
Number of Iterations	50000
Number of Inputs	22
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	23/01/2025 11:37
Simulation Duration	00:01:03
Random # Generator	Mersenne Twister
Random Seed	682966582

Summary Statistics for Total (USD) / CAPEX (USD)				
Statistics			**Percentile**	
Minimum	$	1,512,741.34	**5%**	$ 1,586,798.07
Maximum	$	1,765,444.65	**10%**	$ 1,598,205.07
Mean	$	1,639,682.49	**15%**	$ 1,605,957.71
Std Dev	$	32,235.82	**20%**	$ 1,612,219.25
Variance		1039148337	**25%**	$ 1,617,625.31
Skewness		0.014868746	**30%**	$ 1,622,576.80
Kurtosis		2.933770451	**35%**	$ 1,627,080.11
Median	$	1,639,574.73	**40%**	$ 1,631,378.29
Mode	$	1,633,415.72	**45%**	$ 1,635,461.97
Left X	$	1,586,798.07	**50%**	$ 1,639,574.73
Left P		5%	**55%**	$ 1,643,838.14
Right X	$	1,692,785.63	**60%**	$ 1,647,986.88
Right P		95%	**65%**	$ 1,652,286.87
Diff X	$	105,987.56	**70%**	$ 1,656,651.56
Diff P		90%	**75%**	$ 1,661,520.11
#Errors		0	**80%**	$ 1,667,120.64
Filter Min		Off	**85%**	$ 1,673,326.57
Filter Max		Off	**90%**	$ 1,681,103.56
#Filtered		0	**95%**	$ 1,692,785.63

Change in Output Statistic for Total (USD) / CAPEX (USD)				
Rank	**Name**	**Lower**		**Upper**
1	Electrical Material & Labo	$	1,618,029.44	$ 1,661,681.52
2	Piping Material & Labour	$	1,616,959.94	$ 1,659,631.98
3	Equipment installation /	$	1,621,417.26	$ 1,657,565.74
4	Process building	$	1,622,105.72	$ 1,657,373.53
5	Instrumentation / Factor	$	1,624,043.79	$ 1,655,946.21
6	Rotary kiln / Equipment s	$	1,627,655.24	$ 1,654,420.83
7	1000C 90 Minutes / Equ	$	1,628,302.30	$ 1,653,667.04
8	500C 120 Minutes / Equ	$	1,627,961.90	$ 1,653,263.39
9	Equipment supply (USD	$	1,629,177.91	$ 1,650,400.31
10	Equipment supply (USD	$	1,629,800.66	$ 1,649,826.57

Figure 9 - @Risk CAPEX Report

Operational Expenses (OPEX)

A high-level evaluation underscores the critical cost-sensitive elements of operating the pilot plant, focusing on labour and chemical reagents as primary operational expenses.

Labour costs are anticipated to be a significant component, reflecting the need for skilled personnel to oversee process monitoring, operate complex equipment, and perform routine and preventive maintenance. The availability, training, and retention of such personnel will directly impact operational efficiency and overall costs.

Chemical reagents, particularly sodium salts used in the roasting process, represent another key expense[7]. These consumables are fundamental to the plant's operations, and their cost sensitivity arises from variations in market prices, supply chain logistics, and the specific quantities required for achieving desired process outcomes.

Understanding and managing these cost drivers will be essential for optimising operational efficiency and ensuring the financial viability of the pilot plant.

The Challenge of OPEX Estimation for a Pilot Plant

Developing a full operating expense (OPEX) estimate for a pilot plant is impractical as they are designed to test process feasibility and scalability rather than achieve optimised, steady-state operations.

Variability in process parameters, feed grades, scale of operations, and equipment performance introduces significant unpredictability in operating costs. Furthermore, the plant's purpose—to validate, and refine processes—means operational conditions will change frequently, making it challenging to establish reliable cost baselines. As a result, high-level evaluations focusing on key cost drivers, like labour and chemical reagents, will provide a more meaningful and actionable framework for decision-making and planning at this early stage.

Enabling Improved OPEX Through the Pilot Plant

The pilot plant will serve as a pivotal step toward reducing long-term operational expenses (OPEX) by providing a controlled environment to test and refine processes.

By simulating full-scale operations, it will allow for the identification and mitigation of inefficiencies in labour allocation, reagent consumption, and energy usage. Key insights gained from the pilot plant phase—such as optimising chemical dosing rates, improving equipment uptime, and streamlining operational workflows—will directly translate into reduced costs at commercial scale.

Additionally, the data collected during the pilot plant phase will support informed decision-making for process adjustments and technology upgrades, ensuring a smoother transition to full-scale operations with lower OPEX.

---

[7] Soda Ash - Price - Chart - Historical Data - News states January 2025 sodium carbonate at NZ$366 / tonne
https://businessanalytiq.com/procurementanalytics/index/sodium-chloride-price-index/#google_vignette

Environmental Considerations

The salt roasting and water leaching process for vanadium extraction involves several steps that may impact the environment. To ensure sustainable and responsible operations, it is critical to identify, assess, and mitigate potential environmental challenges. Below are key considerations:

Emissions from Salt Roasting

- Carbon Dioxide (CO_2) Emissions: The high-temperature roasting process will release CO_2.
- Volatile Organic Compounds (VOCs): The roasting process will release minor quantities of VOCs depending on feedstock impurities.
- Particulate Matter (PM): Dust and fine particles generated during processing

Sodium Salt Usage and Residue Management

- Sodium Carbonate Residues: The roasting process generates residues containing unreacted sodium salts and other by-products.
- Effluent Control: Sodium-rich effluents from water leaching can contribute to salinity issues.

Wastewater and Solid Waste

- Water Leaching Effluents: Wastewater from the leaching stage may contain dissolved salts, trace metals, and other impurities.
- Solid Waste from Residue: Post-leach residues must be safely managed.

Energy Intensity

- Energy Consumption: The roasting process is energy-intensive due to the high temperatures required. To reduce environmental impact, options such as waste heat recovery, process optimisation, or shifting to lower-carbon energy sources (e.g., biomass or solar thermal energy) should be explored.

Resource Efficiency

- Water Usage: Water demand for leaching must be managed. Recycling and reuse systems can help reduce freshwater dependency.
- Material Recycling: Reagents used in the process can potentially be recovered and reused, reducing raw material consumption and associated environmental impacts.

Mitigation Strategies

To address these considerations, an integrated environmental management approach is recommended:

1. Implement advanced emissions control systems to minimise air pollution.
2. Adopt closed-loop water management systems to reduce water usage and effluent discharge.
3. Recover and reuse reagents to enhance resource efficiency.
4. Optimise energy use through process innovations and renewable energy integration.
5. Develop comprehensive waste management plans to safely handle solid and liquid residues.

By proactively addressing these environmental considerations, the salt roasting and water leaching process can be developed into a more sustainable and environmentally responsible method for vanadium extraction.

Next Steps

To achieve the full potential of Vanadium recovery from TTR sand, Siecap recommends that the next steps focus on refining key processes and confirming the process flow diagram. These efforts will aim to improve efficiency, enhance recovery rates, and align operations with sustainability goals. By optimising roasting parameters, advancing leaching techniques, and validating processes at scale, TTR can pave the way for a more economically and environmentally viable recovery pathway.

Optimisation of Roasting Parameters for TTR Sand:

- Investigate adjustments to key roasting variables, such as temperature, duration, and sodium carbonate concentration, to improve efficiency.
- Conduct experimental trials to determine the ideal conditions for maximising vanadium recovery from TTR sand.

Enhanced Leaching Techniques:

- Explore varying concentrations, liquid-to-solid ratios (pulp densities), and leaching times to identify conditions that enhance vanadium extraction.
- Explore the particle size distribution effect on vanadium extraction, with water leaching.

Precipitation Testing:

- Undertake precipitation testing to optimise the TTR titanomagnetite V_2O_5 purity.
- To achieve a product of acceptable purity and physical properties, further testing and optimisation of batch and continuous precipitation processes will be essential. Testing should also ensure a vanadium precipitation efficiency of 98% and evaluate the efficacy of recycling residual vanadium in the filtrate. Comprehensive analysis of these parameters will provide valuable insights into refining operational efficiency and maintaining product quality.

Characterisation of TTR Sand:

- Perform detailed mineralogical and physical analyses to better understand the factors limiting vanadium recovery.
- Use the findings to inform targeted modifications to the roasting and leaching processes.

Scalability and Process Validation:

- Validate the PFD processes under pilot-scale conditions to ensure feasibility and effectiveness for industrial applications.
- Assess the economic implications of process improvements to balance recovery efficiency with cost-effectiveness.

Sustainability Considerations:

- Evaluate the environmental impact of sodium carbonate roasting and leaching processes, including emissions, recycling and waste management.
- Identify potential process modifications that align with sustainability goals, such as reducing energy consumption or waste production.

References

1. Liu, Z., et al. (2022). Fusion separation of vanadium-titanium magnetite and enrichment. *Journal of Alloys and Compounds*.
2. Xiong, W., et al. (2024). The changing technology trends in processing titaniferous magnetite. *Canadian Metallurgical Quarterly*.
3. Feng, G., Du, H., Wang, S., Chen, B., Li, J., Zhang, Y., Li, M., Liu, B., & Olayiwola, A. U. (2023). A comparative study of extracting vanadium from vanadium titano-magnetite: Calcium salt roasting vs. sodium salt roasting. *Mineral Processing and Extractive Metallurgy Review, 44*(5), 352-364.
4. Chen, X., et al. (2019). Upgrading of raw vanadium titanomagnetite concentrate. *Journal of the Southern African Institute of Mining and Metallurgy*.
5. Publication of CN105112689A. (2015). Method for extracting titanium from vanadium titano-magnetite: A patented process involving sodium or potassium salt additives during reduction smelting to obtain molten iron and titanium-containing slag.
6. Gaulin, L. (2022) Extraction of vanadium from New Zealand titanomagnetite sand and vanadium recovery concentrate. (Master's thesis), Victoria University of Wellington.
7. Gilligan, R., & Nikoloski, A. (2020). The extraction of vanadium from titanomagnetites and other sources. *Minerals Engineering, 146*.
8. Smith, R., et al. (2021). Technical challenges in the extraction of vanadium. *Metallurgical Reviews*.
9. Zhou, H., et al. (2023). Improving the recovery of vanadium from vanadium-titanium magnetite. *Journal of Metallurgy*.
10. Chen, D., Zhao, H., Hu, G., Qi, T., Yu, H., & Zhang, G., et al. (2015). An extraction process to recover vanadium from low-grade vanadium-bearing titanomagnetite. *Journal of the Less-Common Metals*, 437-442.
11. Goso, X., Lagendijk, H., Erwee, M., & Khosa, G. (2016). Indicative vanadium deportment in the processing of titaniferous magnetite by the roast-leach and electric furnace smelting process. In *Hydrometallurgy Conference 2016: Sustainable Hydrometallurgical Extraction of Metals* (pp. 69-80). Southern African Institute of Mining and Metallurgy.
12. Grzmil, B., Grela, D., Kic, B., & Podsiadly, M. (2008). The influence on the course of hydrolysis of titanyl sulfate. *Polish Journal of Chemical Technology*, 4-12.
13. Hitching, K., & Kelly, E. (1982). Extraction of vanadium from N.Z. steel slags using a salt roast/leach process. *The Australasian Institute of Mining and Metallurgy*.
14. Howard, R., Richards, S., Welch, B., & Moore, J. (1992). Pyrometallurgical processing of vanadiferous slag using plasma/induction heating. *6th International Ferroalloys Congress* (pp. 225-231).
15. Howard, R., Richards, S., Welch, B., & Moore, J. (1994). Vanadium distribution in melts intermediate to ferroalloy production from vanadiferous slag. *Metallurgical Transactions, 25*.
16. Hukkanen, E., & Walden, H. (1985). The production of vanadium and steel from titanomagnetites. *International Journal of Mineral Processing* (pp. 89-102). Elsevier.
17. Li, R., Liu, T., Zhang, Y., Huang, J., & Xu, C. (2018). Efficient extraction of vanadium from vanadium-titanium magnetite concentrate by potassium salt roasting additives. *Minerals*.
18. Nkosi, S., Dire, P., Nyambeni, N., & Goso, X. (2017). A comparative study of vanadium recovery from titaniferous magnetite using salt, sulfate, and soda ash roast-leach processes. In *3rd Young Professionals Conference* (pp. 191-200). Southern African Institute of Mining and Metallurgy.

19. Roschin, A., & Roschin, V. (2007). Pyrometallurgical treatment of titanomagnetite ore from the Ural region. *INFACON XI* (p. 814). New Delhi.

20. Sachkov, V., Nefedov, R., Orlov, V., Medvedev, R., & Sachkova, A. (2017). Hydrometallurgical processing technology of titanomagnetite ores. *Minerals*.

21. Steinberg, W., Geyser, W., & Nell, J. (2011). The history and development of the pyrometallurgical processes at Evraz Highveld Steel & Vanadium. *Southern African Institute of Mining and Metallurgy*.

22. Taylor, P., Shuey, E., Vidal, E., & Gomez, J. (2006). Extractive metallurgy of vanadium containing titaniferous magnetite ores: A review. *Minerals & Metallurgical Processing*.

23. Takahashi, K., Nakayama, K., Matsumoto, N., Morita, S., & Hashimoto, K. (2010). Vanadium resource of the iron sand deposits of Japan. *The Society of Resource Geology*.

24. Tavakolikhaledi, M. (2014). Vanadium: Leaching and solvent extraction [Doctoral dissertation, The University of British Columbia].

25. Rohrmann, B. (1985). Vanadium in South Africa. *Journal of the Southern African Institute of Mining and Metallurgy*.

26. Silitinga, B. E. (1974). Recovery of vanadium from slags [Master's thesis, The University of New South Wales].

27. Ghoddocy Nejad, D., Taghizadeh, M., & Khanchi, A. R. (2019). Vanadium extraction from a magnetite ore using alkaline roasting and acid leaching processes: Optimization of parameters by response surface methodology. *Journal of Mining and Environment, 10*, 241-255.

28. Chen, S. Y., & Chu, M. S. (2014). A new process for the recovery of iron, vanadium, and titanium from vanadium titanomagnetite. *Journal of the Southern African Institute of Mining and Metallurgy, 114*.

29. Connnelly, D. (2019). Titaniferous magnetites as a source of vanadium, titanium, and iron. *AusIMM Conference Proceedings - Iron Ore 2019*.

30. Connnelly, D., Reed, C., & Palmer, R. (2008). Trends with titaniferous magnetite processing for vanadium extraction. *AusIMM Metallurgical Plant Design and Operating Strategies (MetPlant 2008)*.

31. Gao, F., Olayiwola, A. U., Liu, B., Wang, S., Du, H., Li, J., Wang, X., Chen, D., & Zhang, Y. (2021). Review of vanadium production Part 1: Primary resources. *Mineral Processing and Extractive Metallurgy Review, 43*(4), 466–488.

32. Goso, X. C., Lagendijk, H., Erwee, M., & Khosa, G. (2016). Indicative vanadium deportment in the processing of titaniferous magnetite by the roast–leach and electric furnace smelting processes. In *Hydrometallurgy Conference 2016: Sustainable Hydrometallurgical Extraction of Metals* (Cape Town, 1–3 August 2016). Southern African Institute of Mining and Metallurgy.

33. Gustafsson, S., & Wang, W. Z. (1985). Recovery of vanadium from hot metal. *International Journal of Mineral Processing*.

34. Muthukumar, K., Patel, K., Mohapatra, D., Padh, B., & Reddy, B. R. (2020). Selective recovery of vanadium as AMV from calcium vanadate sludge by direct AS leaching process: An industrial approach. *Waste Management, 102*, 815–822.

35. Nasimifar, A., & Mehrabani, J. V. (2021). Comparison of different processes for the production of vanadium pentoxide from vanadium-containing sources. In *Proceedings of the First International Conference on Metallurgical, Mechanical and Mining Engineering*.

36. Nasimifar, A., & Mehrabani, J. V. (2022). A review on the extraction of vanadium pentoxide from primary, secondary, and co-product sources. *International Journal of Mining and Geo-Engineering*.

37. New Zealand Ministry of Business, Innovation, and Employment (MBIE). (2024). Draft critical mineral list. *Public Consultation Document*. Wood Mackenzie.

38. New Zealand Ministry of Business, Innovation, and Employment (MBIE). (2024). Draft critical mineral list. *Public Consultation Document*. Wood Mackenzie.

39. New Zealand Ministry of Business, Innovation, and Employment (MBIE). (2025). A Critical Minerals List for New Zealand: ISBN (print) 978-1-991316-73-8

40. New Zealand Ministry of Business, Innovation, and Employment (MBIE). (2025). A Minerals Strategy for New Zealand to 2040: ISBN (print): 978-1-991316-29-5.

41. Olabi, A. G., Allam, M. A., Abdelkareem, M. A., Deepa, T. D., Alami, A. H., Abbas, Q., Alkhalidi, A., & Sayed, E. T. (2023). Redox flow batteries: Recent developments in main components, emerging technologies, diagnostic techniques, large-scale applications, and challenges and barriers. *Batteries, 9*(8), 409.

42. Santos, D. A., Dixit, M. K., Kumar, P. P., & Banerjee, S. (2021). Assessing the role of vanadium technologies in decarbonizing hard-to-abate sectors and enabling the energy transition. *Science, 24*(11), 103277.

43. Soderkvist, C. (2013). Vanadium for flow batteries. (Master's thesis). Mälardalen University in Västerås.

44. Summerfield, D. (2018). Australian resource reviews: Vanadium 2018. *Australian Government - Geoscience Australia*.

45. Sweatman, W. L., Wake, G. C., Fullard, L., & Bruna, M. (2012). Recovering vanadium during the production of steel from iron sand. *ANZIAM Journal, 53*.

46. Thompson, S. (2020). Recovery of vanadium and titanium from NZ titanomagnetite iron sands Phase 1. *Siecap NZ Ltd - Internal Report*.

47. Trinh, H. B., & Kim, S. (2021). Efficient recovery of vanadium and titanium from domestic titanomagnetite concentrate using molten salt roasting and water leaching. *Minerals Journal*.

48. University of Canterbury. (2021). Vanadium extraction - Roast leach process. Department of Chemical and Process Engineering. Athena Montecillo.

Appendix 19.18 - MTI Breach Testing Report

MTI Holland B.V.

P.O. Box 8, 2960 AA Kinderdijk
6, Smitweg, 2961 AW Kinderdijk

T +31 78 691 03 22
F +31 78 691 03 31
info@mtiholland.com
www.mtiholland.com

Report breaching tests, New Zealand

GR 067

Date	Reference	Status
1st of November 2013	51973 – GR 067	Draft

Summary

Client : IHC Mining

Order number : 51973

Report date : 1/11/2013

Keywords : Breaching, iron sand, TTRL

Classification :

Status : Draft

Prepared by : Vincent van Dijk, Roland Higler

Date	Reference	Status
1st of November 2013	51973 GR 067	**Error! Reference source not found.**

Quality Control

Prepared:	Vincent van Dijk Signed	Date
Prepared:	Roland Higler Signed	Date
Reviewed:	Mario Alvarez Grima Signed	Date
Approved:	Taco de Boer Signed	Date

Disclaimer

This document is dated 1-11-2013

Date
1st of November 2013

Reference
51973 GR 067

Status
Error! Reference source not found.

Content

1 INTRODUCTION 4

2 BREACHING PRODUCTION THEORY 5

3 TEST PROCEDURE 8

4 TEST RESULTS 12

4.1 Porosity 12

4.2 Permeability 12

4.3 Angle of internal friction 14

4.4 Head wall velocity 14

4.5 Suction pipe velocity 16

4.6 The effect of erosion on the v_w 17

5 BREACHING PRODUCTION CALCULATION 18

5.1 Sensitivity analysis of the breach production 20

5.2 Spillage 21

6 CONCLUSIONS 23

7 RECOMMENDATIONS 24

8 REFERENCES 24

9 APPENDIXES (DATA) 25

1 Introduction

This is the report with the results of the breaching tests done from 3rd till the 12th of October in Porirua, New Zealand. The main objective of the breaching tests is, as mentioned in M10002-0002, to assess the breaching behaviour of iron sand for different soil conditions and for the different soil types as found in the mining site. The breaching behaviour of the sand is researched to progress the development of a crawler system mining iron sands.

To be more specific, the head wall velocity v_w has been measured and compared with the theoretical calculation. Furthermore a sensitivity analysis has been performed to determine the pit production at different production speeds v_z , based on the validated v_w. This research is executed by moving a suction pipe through a tank with a see-through Plexiglas wall and filled with conditioned iron sand.

Three configurations were tested:

- Natural breaching of the face without suction.
- Active breaching with suction without water jets.
- Active breaching of the face with water jets at the suction pipe and jets penetrating the slope.

All these tests were executed with both loose and dense material (compacted by vibration) and for both low and high grade iron content sand.

This report will give insight into the model used and explain how the performed experiments are connected to the validation of the model.

Chapter 2 describes the breaching theory which will be validated with the test setup as described in chapter 3.The production model of Vlasblom is verified with cleaned sand samples of which the permeability has been determined. The test results are described in chapter 4 and compared with the theory. In chapter 5 the verified v_w is used to estimate the breaching production of iron sands in situ and a sensitivity analysis is performed to present an indication of the main causes of variability in the production calculations. Chapter 5 and 6 describe the conclusions and recommendations.

Note: Production as stated in this report means that material has moved from its normal state to a flowing state (so called breach production). It does *not* imply that the material is actually produced through the suction pipe.

2 Breaching production theory

In the literature the breaching theory is described by Vlasblom and Van der Schrieck {1}. The pit production for a forward moving suction pipe, P_B [m^3/s], for the breaching process is calculated by:

$$P_B = \frac{v_z}{\tan(\alpha)} \cdot H^2 \quad (1)$$

Here v_z [m/s] is the forward suction pipe velocity, α [°] the internal friction angle and H [m] the breach height. In this calculation it is assumed that suction occurs from a point source. If however we are producing with a large diameter pipe additional breaching production will take place, changing equation 1.

$$P_B = v_z H\left(\frac{H}{\tan(\alpha)} + D\right) \quad (2)$$

Here D [m] is the diameter of the pipe. If the suction pipe slews, the production can increase as though material is produced with a larger diameter pipe. The assumption is made that the effective suction pipe diameter, D, can be taken equal to the length of the pipe swing. This approach is used to calculate the in situ pit production. Equation 2 is acquired on basis of geometry arguments.

The forward suction pipe velocity, v_z, is in practice a function of the headwall velocity. It is suggested {1} that for an operation in which no large slides occur that:

$$v_z \leq 0.4 \cdot v_w \quad (3)$$

Here v_w [m/s] is the head wall velocity. However it is expected that production can occur at higher suction pipe velocity speeds. This leads to:

$$v_z = n \cdot v_w \quad (4)$$

Here n [-] is the velocity prefactor.

The headwall velocity has been related to the hydraulic conductivity in the following way {1}:

$$v_w = \frac{\rho_m - \rho_w}{\rho_w} \cdot \frac{k}{\Delta n} \cdot \cot(\alpha) \quad (5)$$

Here ρ_m [kg/m^3] is the in-situ density, Δn [-] is the dilatancy. The hydraulic conductivity, k [m/s], can be rewritten as:

$$k = \frac{K \rho_w g}{\mu_w} \quad (6)$$

Here K [m^2] is the (intrinsic) permeability, ρ_w [kg/m^3] is the density of water, g [m/s^2] the gravitational acceleration and μ_w [kg/(ms)] the dynamic viscosity of water.

The in-situ density, ρ_m, can be rewritten as:

$$\rho_m = (1-\varepsilon)\rho_s + \varepsilon\rho \tag{7}$$

Here ρ_s [kg/m^3] is the density of the material grains, or specific gravity of the material, ε [-] is the porosity of the material through which the fluid flows.

The dilatancy, Δn, is expressed as:

$$\Delta n = \frac{\varepsilon_{loose} - \varepsilon}{1 - \varepsilon_{loose}} \tag{8}$$

Here ε_{loose} [-] is the highest possible porosity of the material. Combining equations 5 up to 8, gives:

$$v_w = \frac{(1-\varepsilon)(1-\varepsilon_{loose})}{\varepsilon_{loose} - \varepsilon} \cdot \frac{\rho_s - \rho_w}{\rho_w} \cdot \frac{K\rho_w g}{\mu_w} \cdot \cot(\alpha) \tag{9}$$

The permeability, K, can be rewritten as:

$$K = \frac{\varepsilon^3 d_p^2}{180 \cdot (1-\varepsilon)^2} \tag{10}$$

Here d_p [m] is the relevant particle diameter and 180 is an empirical fit based on experimental results {3}. The relevant particle diameter depends on the particle size distribution, however the d_{10} to d_{15} is in most cases a good approximation.

Combining equations 9 and 10 we obtain:

$$v_w = \frac{(1-\varepsilon_{loose})}{\varepsilon_{loose} - \varepsilon} \cdot \frac{\rho_s - \rho_w}{\rho_w} \cdot \frac{\varepsilon^3 d_p^2 \rho_w g}{180(1-\varepsilon)\mu_w} \cdot \cot(\alpha) \tag{11}$$

Combining this result with equations 1 to 4, we obtain an expression for the in-situ production in [m^3/s]:

$$P_B = \frac{(1-\varepsilon_{loose})}{\varepsilon_{loose} - \varepsilon} \cdot \frac{\rho_s - \rho_w}{\rho_w} \cdot \frac{\varepsilon^3 d_p^2 \rho_w g}{180(1-\varepsilon)\mu_w} \cdot \cot(\alpha) \cdot n \cdot H\left(\frac{H}{\tan(\alpha)} + D\right) \tag{12}$$

If we want to determine the production in ton/hour instead of cubic meters per second we need to perform a multiplication with the dry density and multiply by 3600 to obtain kg/hour and divide by 1000 to obtain ton/hour.

$$P_T = \frac{3600}{1000} \cdot (1-\varepsilon)\rho_s \cdot P_B \tag{13}$$

The loose porosity is calculated based on the specific gravity and minimum dry density.

$$\varepsilon_{loose} = 1 - \frac{\rho_{min,dry}}{\rho_s} \quad (14)$$

The dry production equation for the sensitivity analysis is then obtained as:

$$P_T = \frac{\rho_{min,dry}}{\left(1 - \frac{\rho_{min,dry}}{\rho_s}\right) - \varepsilon} \cdot (\rho_s - \rho_w) \cdot \frac{\varepsilon^3 d_p^2 g}{50 \mu_w} \cdot \cot(\alpha) \cdot n \cdot H \left(\frac{H}{\tan(\alpha)} + D \right) \cdot C \quad (15)$$

In this equation C is the relation between the v_w of the theory and experiments as determined in chapter 4.4.

All the relevant parameters are mentioned in table 1. Interesting to notice is that of the 12 parameters only 2 (n, D) can be influenced given a specific mine site.

Table 1: Parameters used to determine dry production (eq. 15)

Symbol	Description	Dimension
n	Velocity prefactor	[-]
ρ_s	Specific gravity iron sand	[kg/m^3]
ρ_w	Density water	[kg/m^3]
μ_w	Viscosity water	[kg/(ms)]
g	Gravitation acceleration	[m/s^2]
ε	Porosity iron sand	[-]
d_p	Relevant particle diameter	[m]
H	Breach height	[m]
α	Internal friction angle iron sand	[°]
D	Effective suction pipe diameter	[m]
C	Correction factor v_w	[-]
$\rho_{min,dry}$	Minimum dry bulk density	[kg/m^3]

3 Test procedure

The originally planned test procedure was described in memo “Laboratory test plan - breaching behaviour irons sands” (M10002-0002). In this chapter the tests that were actually performed are described.

The main objective of the tests was to determine the v_w for the different soil types and under different soil conditions (loose and dense). With the experimentally determined v_w the theoretically calculated v_w can be validated. Besides the validation of the model, the maximum forward suction pipe velocity was also a point of interest. This in respect to the occurrence of slides which can cause unsafe working situations.

The breaching tests have been performed with the same soil type as the one encountered in the mining site. This implies that the same length scale between model and prototype concerning the soil particle size can be used. Under these circumstances it is not necessary to scale the breaching process. Two types of iron sand (low and high grade) have been tested in loose and dense states.

A basic setup of the testing facility as used during testing is given in figure 1.

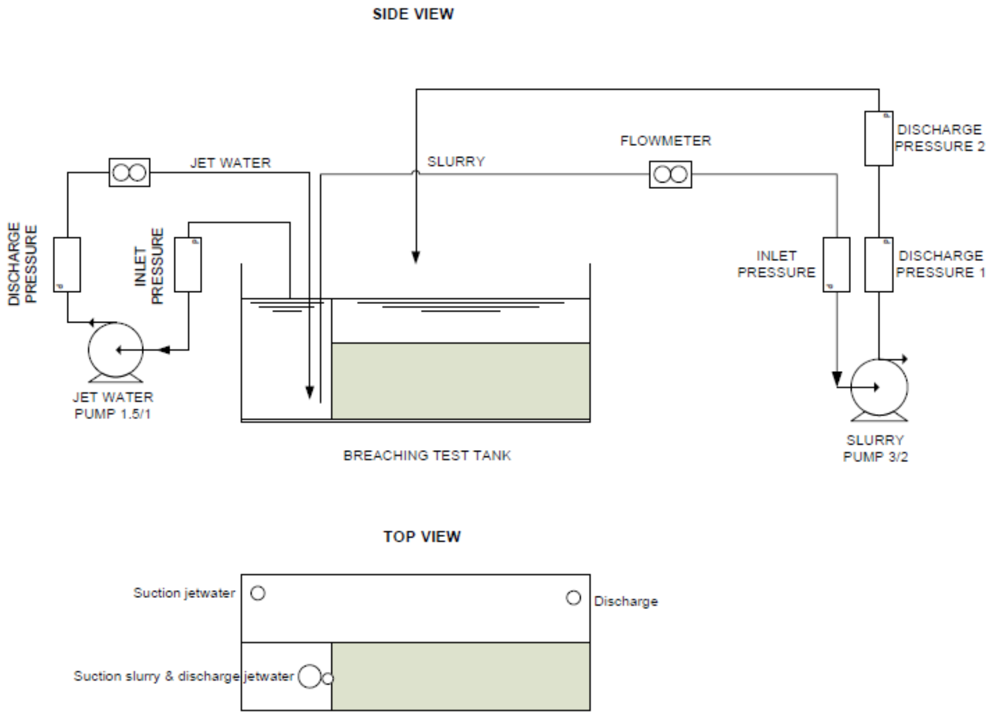


Figure 1: Basic setup testing facility

4 different type of tests have been performed:

- Test Series 1: Determination of head wall velocity without the influence of the suction process and suction pipe movement.
- Test Series 2: Determination of the head wall velocity by using an inclined suction pipe at different forward velocities.
- Test Series 3: Determination of the head wall velocity by using an inclined suction pipe and water pressure jets in the suction pipe and on the face of the slope.
- Test Series 4: Effect of lateral and forward movement of a suction pipe on breaching process.

Sketches of the 4 different type of tests are shown in figure 2.

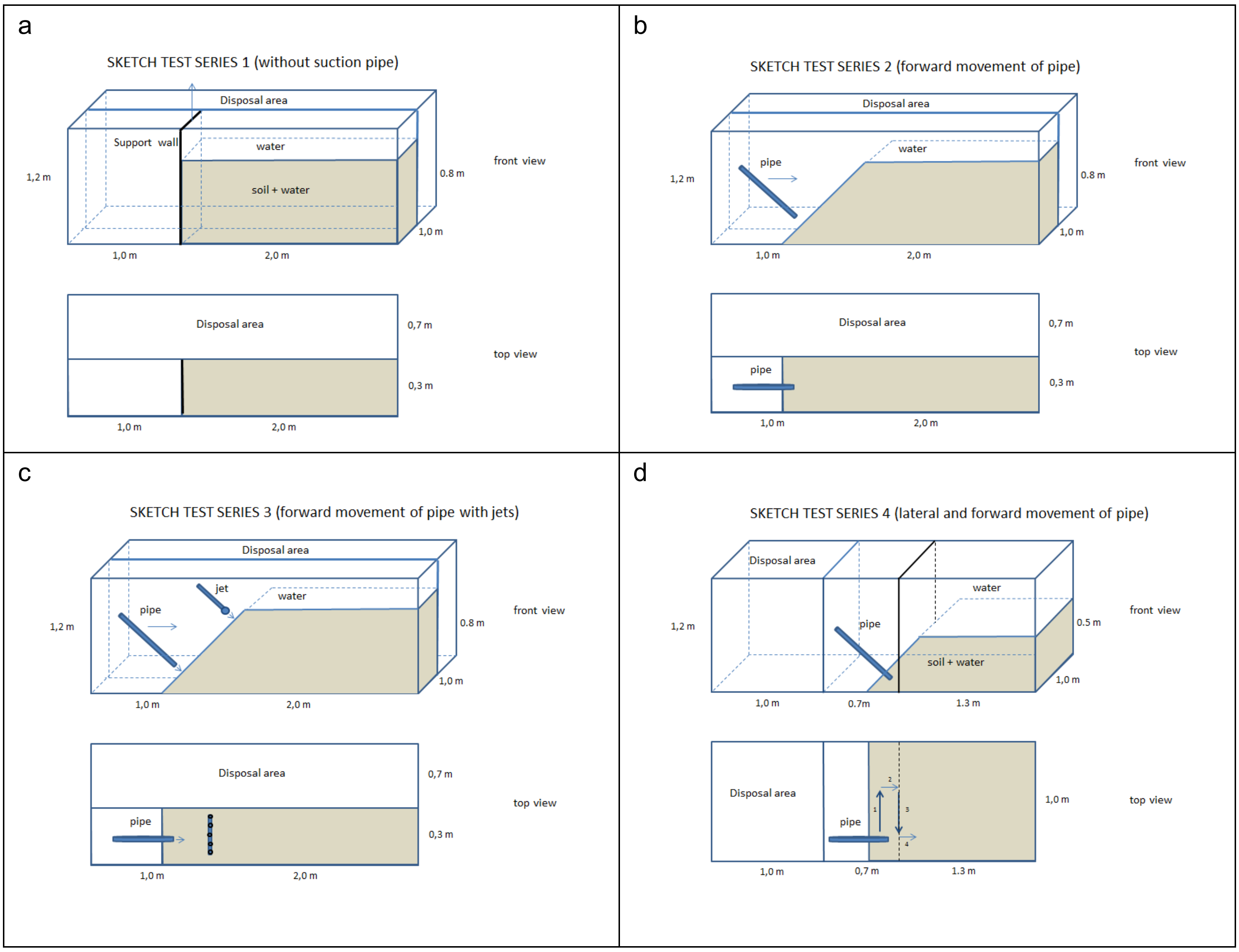


Figure 2: The different type of tests performed

Objective of the test series:

Test series 1:
The objective of these tests is to assess the head wall velocity without the influence of the suction process and/or movement of the suction pipe. First the soil is brought into the test tank. The condition of the soil can be either loose or compacted, depending on the type of test that will be carried out. A supporting wall will keep the soil in its initial position before starting the test (situation a).

By removing the plate the nearly vertical soil wall will move at a given speed (head wall speed) depending on the properties of the soil along the length of the test tank till an equilibrium condition is achieved. The equilibrium condition corresponds to the angle of repose of the soil.

In order to get insight into the effect of the soil density and permeability; these tests will be executed for both soil conditions (i.e. loose soil condition and maximum possible compacted soil condition). The test is executed as part of the preparation of all the other tests series (2,3,4).

Test series 2:
The objective of these tests is to assess the head wall velocity by using an inclined suction pipe for different forward velocities of the suction pipe. The suction pipe will be moved at a given speed in the horizontal direction. The speed of the suction pipe will be selected based upon the results found in test series 1.

Test series 3:
The objective of these tests is to investigate the effect of water pressure jets on the forward velocity of the suction pipe. The inclined suction pipe will be moved at a constant horizontal speed based upon the results of the previous tests. The water jets will be located at the top of the slope face. By doing so, it is expected that the production speed can be safely increased. In case that the suction pipe cannot cope with the increase in soil production, the material will be deposited behind the suction pipe as spillage. This must be considered as breach production and must be taken into account in the measurements.

In these test series also the effect of the speed of the suction pipe will be investigated. That is, moving the suction pipe at a speed higher than the head wall speed determined in test series 1 for the compacted soil.

Test series 4:
The objective of these tests is to investigate the effect of lateral and forward movement of the suction pipe on the pit production. The suction pipe will be moved laterally from right to left, then it will be moved forward (step) and then it will be moved laterally again to the right. In this way we can get an indication of the effect of the swing speed in relation with the pit production and spillage. The movement of the pipe will be only a part of the full width of the tank in order to correctly assess the spillage.

It was not possible to conduct these tests due to limitation by the test setup.

Procedures followed to prepare the tests

The hereafter mentioned steps have been executed to prepare and execute each test.

Step 1: Install the supporting walls in the test tank as indicated.
Step 2: Bring the soil mass into the test tank and condition (compact) the soil to obtain the possible maximum soil compaction following the soil compaction procedure.
Step 3: Prepare camera/video for test recording.
Step 4: Prepare the measuring devices (pump, jet pumps) for data logging (i.e. flow velocity suction pipe, jet pressure, jet flow speed).
Step 5: Series 1-4: Remove the supporting vertical wall so that an initial face is formed.
Step 6: Series 2: Move the inclined suction pipe in a horizontal direction at a defined constant speed; measure and log the data.
Series 3: Move the inclined suction pipe in a horizontal direction at a defined constant speed along with the jetting system. Jets in the suction pipe, in front of the face and situated at the top of the face (3 different tests); measure and log the data.
Series 4: Move the inclined suction pipe to the left-forward-right-forward following the schematization (c).
Step 7: Measure the amount of solids that have been transported from the test tank to the disposal tank.
Step 8: Measure the spillage (breach production) deposited behind the suction pipe.

The whole test matrix with executed test is indicated in Appendix C

4 Test results

To calculate the v_w according to equation 9, the permeability is required. As stated in equation 10 this requires the porosity and the relevant particle diameter as input. However, equation 10 is only valid for uncleaned material. During and prior to testing the material was cleaned and permeability measured to obtain a correct relation between v_w and permeability. This experimentally determined permeability has been used in the comparison between the theoretical v_w and the actual measured v_w.

4.1 Porosity

For the theoretical calculation of the permeability the porosity values are required. The loose and dense porosity values of the samples are determined by performing experiments. Equation 7 has been used to calculate the porosity of the material based on the performed experiments. The weight of the saturated material has been measured in a container with known volume both in loose and compacted situation. The density of the water is taken equal to 1000 [kg/m^3]. The specific gravity is 3530 [kg/m^3] and 2950 [kg/m^3] for the high grade and low grade respectively {2}. The results of these tests and the calculated porosities can be found in table 2.

Table 2: Loose and dense porosities for high and low grade material

#	Description	M0 (kg)	M1 (kg)	M2 (kg)	M3 (kg)	Volume (m^3)	Porosity, loose (-)	Porosity, dense (-)
1	high grade	0,68	14,73	34,14	37,35	0,01405	0,454	0,364
2	high grade	0,75	14,91	35,29	37,69	0,01416	0,431	0,364
3	high grade	0,78	14,9	35,32	38,23	0,01412	0,428	0,347
4	low grade	0,87	23,4	49,9	51,9	0,02253	0,397	0,351
5	low grade	0,87	23,4	48,5	51,74	0,02253	0,429	0,355
6	low grade	0,87	23,4	48,69	51,65	0,02253	0,424	0,357

M0: mass of the empty container
M1: mass of the container filled with water
M2: mass of the container filled with loose saturated material
M3: mass of the container filled with dense saturated material

4.2 Permeability

The permeability as expressed in the theory (eq. 10) is checked. This is done by comparing the theoretical calculation with experimental data.

The experiments for determining the permeability were done by running a constant head permeability test. In this setup a cylinder is filled with up to 20 cm of iron sand material and a water level up to 1 m above the sand. The volume flow of the water through the pores of the iron sand is measured using weight scales.

The results of the experiments and the theoretical calculations are shown in table 3. The difference between them is presented in the last column.

Table 3: Comparison permeability tests with theory for a range of cleaned and uncleaned samples

Experiment	Condition	Measured Permeability (m^2)	Porosity based on experiments (-)	Calculated permeability (m^2)	Difference (%)
HG, uncleaned	loose	2,6E-11	0,44	2,7E-11	-4
HG, cleaned	loose	3,7E-11	0,44	2,7E-11	39
HG, cleaned	dense	1,9E-11	0,36	1,1E-11	68
HG, cleaned	loose	4,0E-11	0,44	2,7E-11	49
HG, cleaned	loose	4,2E-11	0,44	2,7E-11	55
LG, uncleaned	loose	2,8E-11	0,42	2,2E-11	29
LG, cleaned	loose	3,4E-11	0,42	2,2E-11	57
LG, cleaned	loose	3,6E-11	0,42	2,2E-11	67
LG, cleaned	loose	3,5E-11	0,42	2,2E-11	64
LG, cleaned	loose	3,5E-11	0,42	2,2E-11	60
LG, cleaned	dense	1,5E-11	0,35	1,1E-11	37
LG, cleaned	loose	3,9E-11	0,42	2,2E-11	80
LG, cleaned	loose	3,8E-11	0,42	2,2E-11	74
LG, cleaned	loose	4,3E-11	0,42	2,2E-11	99
LG, cleaned	dense	1,5E-11	0,35	1,1E-11	43
LG, cleaned	loose	4,3E-11	0,42	2,2E-11	97
LG, cleaned	loose	3,9E-11	0,42	2,2E-11	79

The diameter used in determination of the calculated permeability is based on the particle size distribution tests executed earlier and presented in the soil report {2}. Based on the soil report a relevant particle diameter of 135 micron is taken which corresponds to the d_{15} of the material.

The permeability calculated with equation 10 agreed well with the permeability values determined in the laboratory for the uncleaned samples. This shows that the equation can be used to calculate the in situ permeability needed for the calculation of the in situ breach production. For the theoretical calculation of the permeability the mean values of the porosity in table 2 are used.
Thus this equation will be used for future calculations of the breach production with uncleaned samples.

Washing out the fines increase the permeability and this explains the difference between permeability of the cleaned and uncleaned samples.

For validation of the v_w theory with the experiments the theoretical calculation for permeability is not used. Instead the experimentally determined permeability is used in order to reduce errors that are caused by the fact that fines are washed out of the material during the experiments.

4.3 Angle of internal friction

The angle of internal friction is determined from the experiments and compared with the values mentioned in the soil report {2}. In table 4 the values are presented.

Table 4: Angle of internal friction measured by experiment and as reported {2}.

Angle of internal friction	Experiment (deg)	Soil report (deg)
Low Grade	30,3	25,3
High Grade	29,3	26,7

The difference in values between the experiment and the soil report can probably be explained with the way the angles are determined (experimental setup vs standardized laboratory test). For validating the v_w theory the angles of the soil report are used, these are expected to be the most correct values.

4.4 Head wall velocity

An elaborate equation is proposed for the calculation of the head wall velocity (eq .9), repeated below

$$v_w = \frac{(1-\varepsilon_{loose})}{\varepsilon_{loose}-\varepsilon} \cdot \frac{\rho_s - \rho_w}{\rho_w} \cdot \frac{K(1-\varepsilon)\rho_w g}{\mu_w} \cdot \cot(\alpha) \qquad (16)$$

The loose porosity is calculated based on the specific gravity and the minimum dry density.

$$\varepsilon_{loose} = 1 - \frac{\rho_{\min,dry}}{\rho_s} \qquad (17)$$

The equation for v_w now changes to:

$$v_w = \frac{\rho_{\min,dry}}{(1-\varepsilon)\rho_s - \rho_{\min,dry}} \cdot (\rho_s - \rho_w) \cdot \frac{K(1-\varepsilon)g}{\mu_w} \cdot \cot(\alpha) \qquad (18)$$

Furthermore the porosity is based on the measurements as shown in table 2. The calculated porosity is also based on the information of the specific gravity. The equation for the v_w now changes to:

$$v_w = \frac{\rho_{\min,dry}}{\left(1-\left(\frac{M_s/V_t - \rho_s}{\rho_w - \rho_s}\right)\right)\rho_s - \rho_{\min,dry}} \cdot (\rho_s - \rho_w) \cdot \frac{K\left(1-\left(\frac{M_s/V_t - \rho_s}{\rho_w - \rho_s}\right)\right)g}{\mu_w} \cdot \cot(\alpha) \qquad (19)$$

Equation 19 is used to determine the theoretical v_w for the case of the preformed experiments, with parameter input as shown in table 5 .

Table 5: Parameter input for theoretical calculation of v_w

Soil parameter	Symbol	Value (LG)	Value (HG)	Dimensions
Weight sand / Vt , loose	M_s / V_t	2175	2475	kg/m^3
Weight sand / Vt , dense	M_s / V_t	2300	2675	kg/m^3
Specific gravity	ρ_s	2950 ; 2980	3360 ; 3530	kg/m^3
Minimum density, dry	$\rho_{\min,dry}$	1460	1800	kg/m^3
Permeability, loose	K	3,46e-11 ; 4,33e-11	3,75e-11 ; 4.19e-11	m^2
Permeability, dense	K	1,4e-11 ; 1,6e-11	1,8e-11 ; 2e-11	m^2
Internal friction angle	α	23 ; 26	26 ; 27	[°]
Density water	ρ_w	1000	1000	kg/m^3
Viscosity water	μ_w	1,2e-3	1,4e-3	kg/(m s)

Note: there are two different specific gravities reported in the soil report {2}. The specific gravity has a significant impact on the test results and should be further investigated. The “ ; “ indicates that a range of values is used.

Based on a telephone conversation with Mark Thomas on 14/10/13 the dry bulk densities in the soil report by Jeremy Batchelor are found to be most indicative. The viscosity of water is based on a temperature between 8 and 12 degrees Celsius, the expected temperature of the water while performing the tests.

The theoretical calculated v_w is compared with the experimentally determined v_w. The results of the experiments are interpreted by looking at the recordings and determining the v_w as function of the breaching angle, β, by the following equation. Here the v_z and β are determined from the recordings.

$$v_w = \frac{v_z}{\left(1 - \frac{\tan(\alpha)}{\tan(\beta)}\right)} \tag{20}$$

From the tests it can be concluded that both the high and low grade material breaches naturally in both loose and dense conditions. The theoretical (eq.19) and experimentally determined v_w are shown in table 5.

The data suggests a factor between 3 and 4,3 difference between theory and experiment, see table 6. This factor is incorporated in equation 15 as factor C (Correction factor v_w) resulting in equation 21 which is used to calculate the in situ production. The spread of this factor is taken to between 2,5 to 4,5 for the production calculations. This is because it is feasible that the correlation factor needs to be lower in some situations, which haven’t been measured at this moment. The data in table 6 is based on test results (see appendix C).

Table 6: Theoretically and experimentally determined v_w for the soil types as mentioned.

Soil type	Theory (cm/s)	Experiment (cm/s)	Difference (-)
Low grade, loose	0,35	1,08	3,08
Low grade, dense	0,094	0,40	4,25
High grade, loose	0,58	2,34	4,03

Soil type	Theory (cm/s)	Experiment (cm/s)	Difference (-)
High grade, dense	0,16	0,54	3,38

4.5 Suction pipe velocity

One of the goals of the experiments was to determine the range of the factor between v_w and the suction pipe velocity and the corresponding behaviour of the breaching process. Based on this factor 3 different regimes are distinguished.

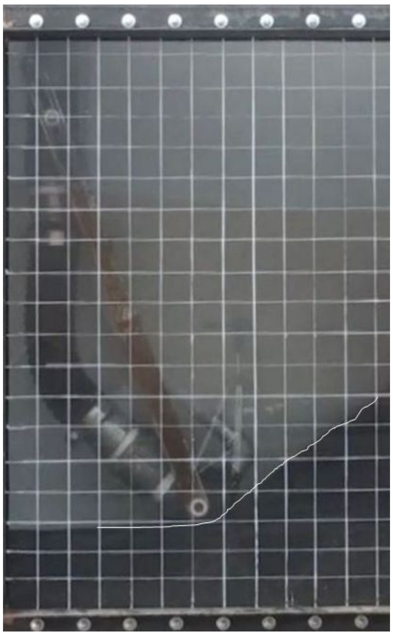


Figure 3: $v_z = 0.4*v_w$

Figure 4: $v_z = 1*v_w$

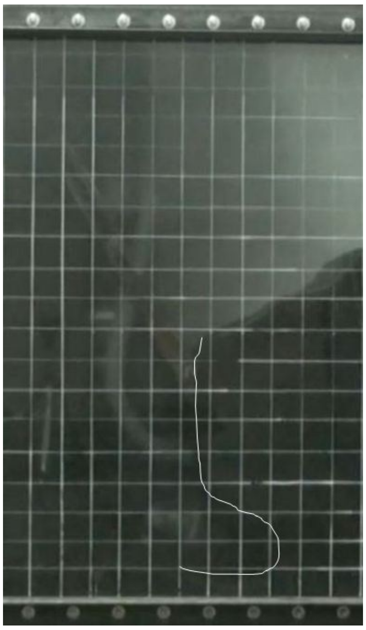


Figure 5: $v_z = 1,5*v_w$

Based on the experiments the following can be said about the 3 regimes:
If the suction pipe is progressing at a low speed of $0,4*v_w$ a small amount of slides are to be expected. The slope of the material will be close to the angle of internal friction, this behaviour is seen is figure 3.

In figure 4 the suction pipe is progressing at a speed equal to v_w. This results in a nearly vertical wall and larger slides will occur.

If the speed of the suction pipe is further increased the situation pictured in figure 5 is found. This situation can only be realized by the aid of extra mechanical / hydraulical means. During the experiment jet in the suction pipe and jets above the face of the soil have been used.

In this situation large slides will occur continuously and the suction pipe will undercut the material. A steady state will still be possible but not without the occurrence of large slides and increased spillage.

The experiments show it is possible to increase the forward suction pipe velocity beyond $0,4*v_w$, however for the design of a crawler system this will increase the complexity.

4.6 The effect of erosion on the v_w

If the mining face is high enough, the material that is breaching can initiate another mechanism called erosion. During the breaching process the soil grains will pull other grains along the face and create a kind of avalanche effect. This effect has an positive effect on the breaching process, but to what extend is not clear at this moment.

The erosion effect is not included in the current breaching model and will need to be further investigated. To determine the erosion effect on an experimental scale face heights of at least 2,5 m must be present, which was not the case during this campaign. However, by adding a loose layer on top of a compacted layer an attempt is made to simulate the erosion process. The test showed for the low grade material as well as for the high grade an increase in v_w of respectively 0,11 cm/sec and 0,17 cm/sec.

Table 7: The effect of a loose layer on top of a dense layer on v_w.

V_{wall}	Loose (cm/sec)	Dense (cm/sec)	Loose/Dense (cm/sec)
Low Grade	1,08	0,40	0,51
High Grade	2,34	0,54	0,70

Even on small scale a loose top layer can result in a significantly increase of the average v_w. It is expected that this effect will increase even more, when breach heights of 5 m are considered.

5 Breaching production calculation

In this section the breaching production for the two soil types and three different regimes is calculated using the following equation with the validated v_w (correction factor C).

$$P_T = \frac{\rho_{\min,dry}}{\left(1 - \frac{\rho_{\min,dry}}{\rho_s}\right) - \varepsilon} \cdot (\rho_s - \rho_w) \cdot \frac{\varepsilon^3 d_p^2 g}{50 \mu_w} \cdot \cot(\alpha) \cdot n \cdot H \left(\frac{H}{\tan(\alpha)} + D \right) \cdot C \qquad (21)$$

For the calculations the following assumptions are made:

Porosity (ε):
The porosity ranges from 0,35 to 0,45 for both the low and the high grade material. This corresponds to the values given in the soil report {2} for the high grade material. For the low grade material the soil report suggests a lowest porosity of 0,395. However during experiments performed on the sample used during testing lower porosity values have been measured. Due to this, the range of porosity for the low grade material is different than suggested by the soil report. The complete breach is assumed uniform for the porosity and there is no erosion taken into account.

Minimal dry density ($\rho_{min,dry}$):
There are two different values for the minimal dry density reported by the soil report. After discussions with the writer of the report, Mark Thomas, the suggestion was made that the results of the dry bulk density test are most applicable and those have been incorporated in the calculations.

Specific gravity (ρ_s):
Multiple measurements of the specific gravity are available from the soil report. The measurements performed have been taken as range of the expected specific gravity in the mining area and used in the calculation.

Internal friction angle (α):
The internal friction angle is reported in the soil report and the full range of the measurements has been taken, excluding one outlier in the internal friction angle of the low grade material. It is assumed that the soil laboratory measurements provide a more truthful internal friction angle as opposed from the breach test setup.

Relevant particle diameter (d_p):
The relevant particle diameter is estimated from the d_{10} to d_{15} of the particle size distribution as given in the soil report.

Velocity pre-factor (n):
The velocity pre-factor is regime dependent and can either be 0,4, 1 or 1,5 times v_w.

Velocity correction factor (C):
The velocity correction ranges from 2,5 to 4,5 and is based on the results of the comparison of the theoretical and experimental v_w.

Effective suction pipe diameter (D):
The suction pipe will slew to the sides and have a complete reach of 18m in total. The effective suction pipe

diameter has been changed to this value. It is however not clear whether this is a suitable value for the parameter and will depend on the operation. For the calculations it is taken equal to the breach width.

Water density (ρ_w) / viscosity (μ_w) and gravitational acceleration (g):
The water density is taken equal to 1025 kg/m^3, this is the typical density of salt water in the ocean. The gravitation acceleration is taken equal to 9.81 m/s^2 and the water viscosity ranges from 1.6e-3 to 1.35e-3 kg/(ms) typical for salt water between 4 and 10 degrees (respectively).

Breach height (H):
The breach height is assumed to be 5 m high for the full field of the production. The height of the breach does have a strong influence on the actual breaching production. As a rule of thumb the production scales quadratic with the height of the face.

Erosion (-):
The effect of erosion has not been included in the calculated since no suitable (validated) model has been found. Erosion could have a very significant (positive) impact on the actual production.

Please note: that the mean production level state on the following page is the mean of all the possible production levels by parameter variation. The confidence intervals have been calculated by determining the standard deviation from the mean. This gives a decent indication of the expected variation. For more precise information, please consult appendix A.

5.1 Sensitivity analysis of the breach production

For each velocity regime ($v_z = 0{,}4 * v_w$, v_w, $1{,}5 * v_w$) 3 different production distribution graphs based on the in-situ porosity of the to be mined material are determined. The porosities for the 3 production graphs are 0,35, 0,40 and 0,45, which are the maximum compaction, average compaction and the loosest state, respectively. The summary in table 9 is based on the production distribution graphs in appendix A.

A color coding has been added to the production levels to better understand the implication and feasible modes of operation.

Table 8: Explanation color coding table 9.

Color	Explanation
Green	No large slopes are expected to occur, slewing with the suction pipe will be feasible. This seems to be a possible scenario.
Orange	Large slopes can occur, slewing the suction pipe will be difficult. It is unclear if this is a possible scenario for production.
Red	Very large slopes are expected to occur, slewing the suction pipe will be difficult if not impossible. Slopes could mean further problematic situations. This is not a realistic scenario.

A full mining face with the loosest state (porosity equal to 0,45) is not expected to occur and is marked red. The validation of the theory for the calculations with loosest state is doubtful due to strong influence of minimum density measured in the soil report {2}.

Table 9: Interpreted results of the sensitivity analysis (appendix A).

Grade	Porosity	n = Vz/Vw	Mean production (t/h)	Production within 66% confidence (t/h)	Production within 95% confidence (t/h)
Low grade	0,35	0,4	823	638 – 1008	452 – 1194
		1	2057	1594 – 2509	1131 - 2984
		1,5	3086	2391 – 3781	1696 - 4477
	0,4	0,4	1838	1423 – 2253	1009 – 2668
		1	4595	3558 – 5632	2521 – 6669
		1,5	6893	5338 – 8449	3782 - 10004
	0,45	0,4	5198	4014 – 6383	2830 – 7567
		1	12996	10036 – 15957	7075 - 18917
		1,5	19494	15053 – 23935	10612 - 28376
High grade	0,35	0,4	1311	1006 - 1616	701 - 1921
		1	3278	2516 – 4040	1754 - 4803
		1,5	4917	3774 – 6060	2630 - 7204
	0,4	0,4	3252	2431 – 4074	1610 - 4895
		1	8131	6078 – 10019	4024 - 12238
		1,5	12197	9117 - 15277	6037 – 18357
	0,45	0,4	14750	8065 – 21436	1380 – 28121
		1	36876	20163 – 53589	34493 - 70303
		1,5	55314	30244 – 80384	51740 - 105450

Please note: that the mean production level state on the following page is the mean of all the possible production levels by parameter variation. The confidence intervals have been calculated by determining the standard deviation from the mean. This gives a decent indication of the expected variation. For more precise information, please consult appendix A.

5.2 Spillage

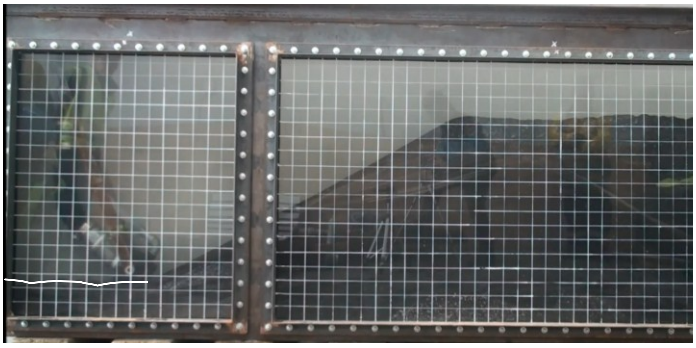
The production levels in paragraph 5.1 are valid for the breaching of the face. The final production level of the crawler will be based on several factors of which spillage is an important factor. As the whole mining face is continuously breaching, the suction mouth of the crawler is only a moving point along the entire swing width. This is a dynamic system and the material is only mined close to the location of the suction mouth. Outside this area the material will continue to breach, thereby creating a shallower slope. When the suction mouth swings back it will encounter this deposited material. Depending on the step size, face height and time for swinging this can result in a reduction of the slewing speed or even blockage of the sideways movement.

During the 2D experiments it is noticed that at higher forward suction pipe velocity the face tends to fall behind the suction mouth. Two experiments were carried out:

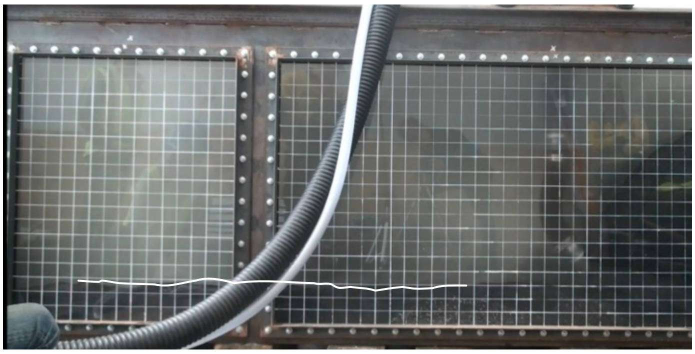
1) In case of testing at high velocities with no jets the construction of the test setup prevented the material to fall behind the suction mouth. Therefore an increase in spillage at higher velocities was not noticed. Spillage as percentage of the face height of averaged around 3% and is shown in figure 6.

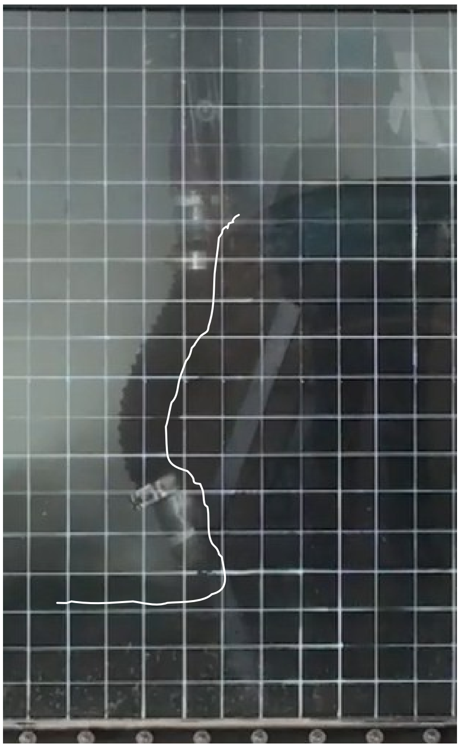
Figure 6: spillage calculation for test 2,4 (High grade loose v_z=v_w no jets)

Start



End



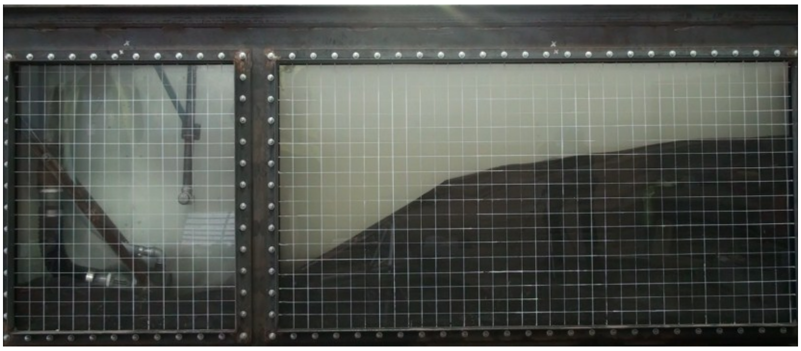


±2 cm spill as percentage of a face of 65 cm results in 3% spill

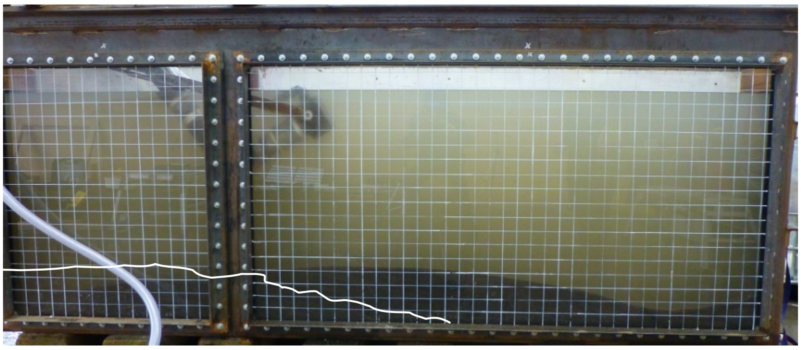
2) The spillage levels of the tests including jets resulted in much higher spillage levels as can be seen in figure 7.

Figure 7: spillage calculation for test 2,18 (Low grade dense v_z=1.5 x v_w Jet lance horizontal)

Start



End



±12 cm spill as percentage of a face of 51 cm results in 24% spill

During test series 4 the slewing of the suction tube was simulated. During these tests the sideways movement of the suction tube was blocked due to material at the side of the suction mouth. This is shown in figure 8.

Figure 8: Low grade dense including slewing, jets v_z=0.6 cm/sec resulting in steps of 2,5 cm (Test 3.21)

Start

End

At the end of the test a lot of material is deposited at the back of the tank (location 1). This has been noticed by the 2D test including jets as well. Furthermore the breached material at location 2 is hindering the sideways movement of the suction tube.

6 Conclusions

Breaching production:
Fully saturated low and high grade material with porosities between 0,35 and 0,45 do breach.
The breaching production level is strongly depended on the porosity of the material. The measured v_w values are presented in the report and in table 10 below.

Relation v_z to v_w:
The research shows it is possible and beneficial for production to increase the suction pipe velocity beyond $0,4*v_w$. However this increase in speed comes at a potential hazard risk of slope instability and an increase of spillage. This is best explained in figures 3,4 and 5.

Impact of Jets:
The suction pipe velocity could be increased to above v_w in a stable process by the addition of water jets as shown in section 4.5. By using water jets it is possible to improve the breaching process and usage of jets leads to a safer operation. The increase of v_w as result of jets is indicated in table 10 below.

Slewing:
For the sideways movement of the crawler boom it can be expected that spillage will hinder the movement.
The severity of the hindered movement is dependent of the amount of spillage.
During testing sideways movement was hindered by spillage and no possibilities where available to overcome this issue. Therefore the series 4 tests initially planned could not be performed.

Soil report:
There is a large difference between the lowest porosity for the low grade material in the soil report {2} and the experiments performed during testing. This difference has a huge impact in the production ranges for the low grade material.

Erosion effect:
The material located on the top of the breach can have a positive impact on the v_w when it falls down and starts an erosion process. A minimal breach height is necessary before this effect can be noticed.

The breach height in the current test setup was not high enough to make this process visible. By adding a loose layer on top of a compacted layer an attempt is made to simulate the erosion process. The test showed for the low grade material as well as for the high grade an increase in v_w of respectively 0,11 cm/sec and 0,17 cm/sec.

Table 10: The effect of a loose layer on top of a dense layer on v_w

V_{wall}	Loose (cm/sec)	Dense (cm/sec)	Loose/Dense (cm/sec)	Dense with jets (cm/sec)
Low Grade	1.08	0.40	0.51	1.12
High Grade	2.34	0.54	0.70	1.30

Even on small scale a loose top layer can result in a significantly increase of the average v_w. It is expected that this effect will increase when breach heights of 5m are produced.

7 Recommendations

Characterization mining field:
The production levels are greatly influenced by grade and porosity of the to be mined material. However at this stage there is no clear characterization of the mining field in terms of grades and porosities of the mined volume. Therefore it is vital that a clear mining plan, including grades and porosities by volume, is created in order to determine yearly productions.

The effect of loose top layer and erosion:
The loose top layer can have a large positive impact on the erosion and should be further investigated. Furthermore erosion of a uniform layer can already have a large impact on the production level and should be investigated.

Soil investigation:
The large difference between the lowest porosity for the low grade material given in the soil report {2} and the experiments performed during testing should be further investigated by performing a more extended soil measurement campaign to reduce errors in the production calculations.

Spillage:
Spillage has not been taken into account and is a point of interest. Spillage will increase as the production is increased and especially when water jets are incorporated. Values of 30% spillage are possible in typical dredging operations. The effect of spillage for the production of a crawler type system and the sideways movement of the crawler boom should be further investigated.

Interaction crawler, breach face:
Due to the interaction of the crawler (suction from one point) with the breach the breaching production will not be a stable 2D process. Instead it will become an irregular 3D process influenced by the slewing speed and forward steps make by the crawler. This interaction is not well understood and needs to be viewed to determine the parameters for the crawler system.

8 References

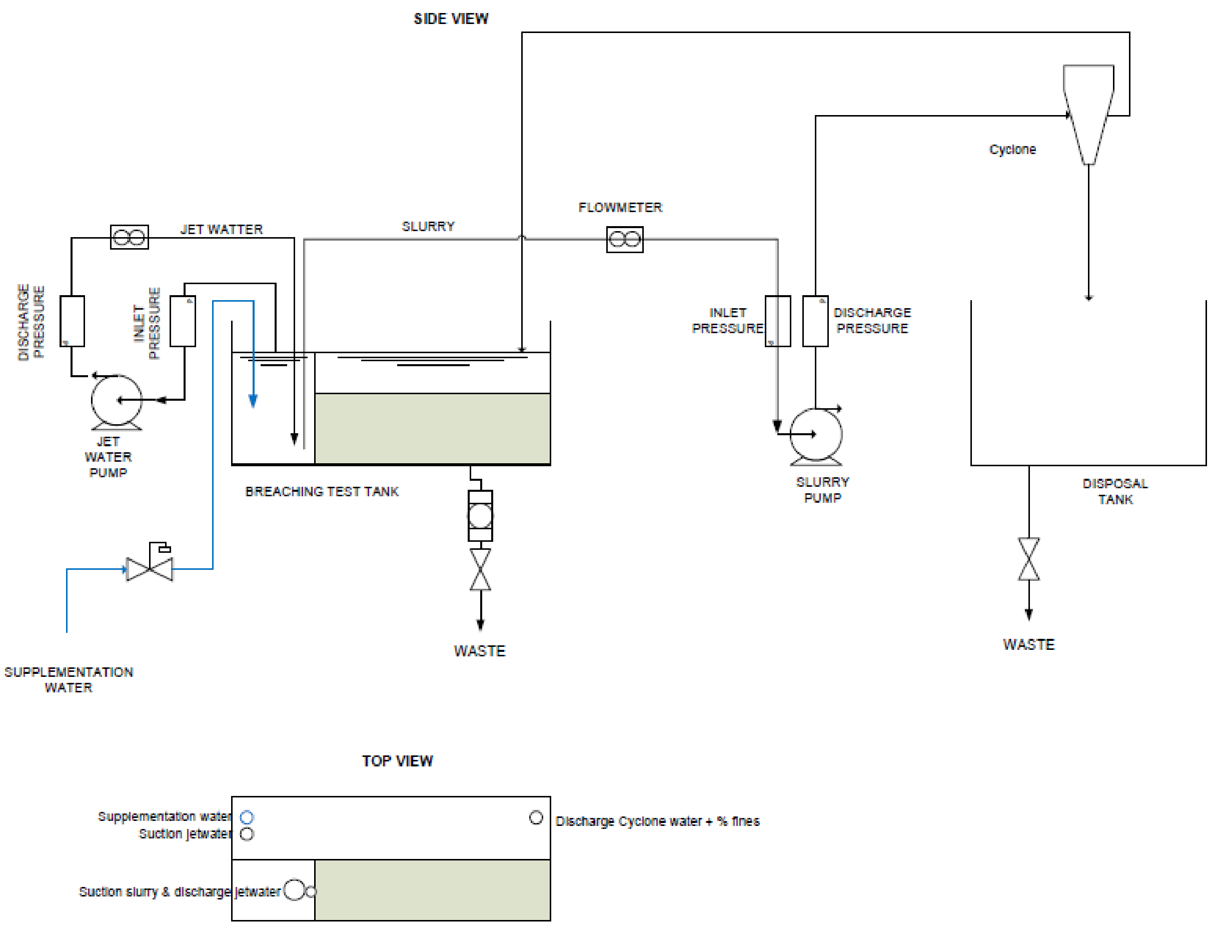
{1}: Dredging Technology, Guest lecture notes CIE5300 Issue 2013, G.L.M. van der Schrieck.

{2}: Ironsand Laboratory testing Factual report, T&T Ref: 29473

{3}: Flow through Porous Media – The ergun equation revisited, IF Macdonald, 1979

Appendix B: Overview original and new test setup

Original setup with cyclone
During the preparation phase the following setup was determined.
The idea was to remove the material from the breaching tank through the suction pipe with the slurry pump. The discharge was connected to a cyclone with the purpose of separating the solids from the water. To maintain the volume balance in the breaching tank the water from the cyclone was fed back and the dry material in the disposal tank could be easily placed back in the breaching tank after performing a test.

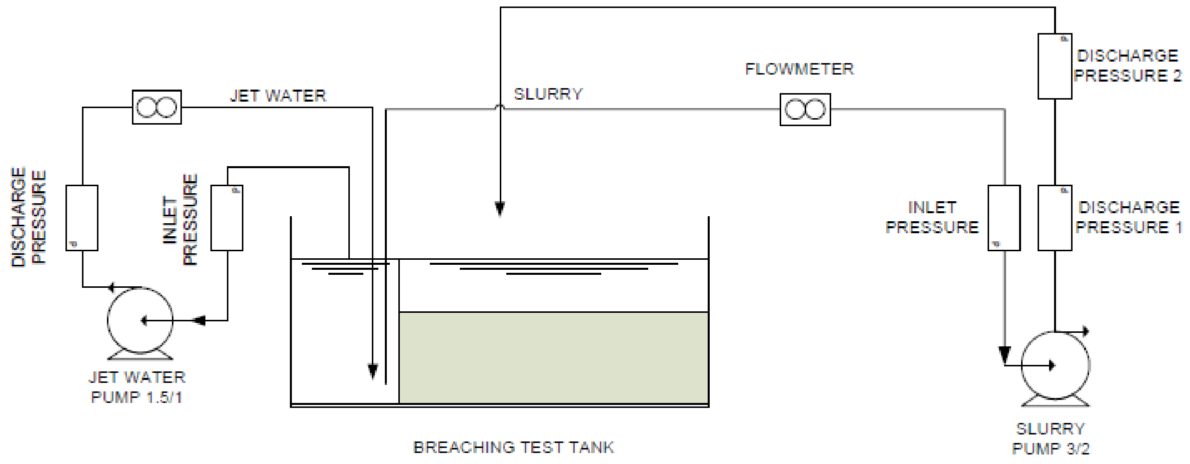


During the first trails with this setup it was soon concluded that the cyclone was not going to work. As result of this a new setup was determined.

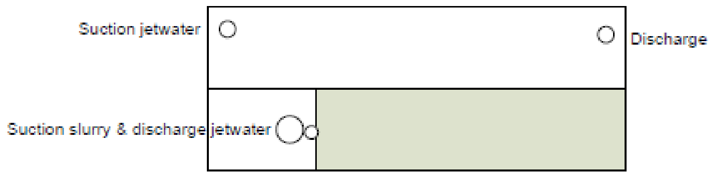
The idea of the new setup was that the compartment to the side of the compartment which includes the sand was uses as disposal tank. In this way the volume balance was maintained. The new test was prepared by exchanging the location of the suction and discharge pipe and pump the material back.
This setup eventually worked fine.

New setup which has been used to perform the test.

SIDE VIEW



TOP VIEW



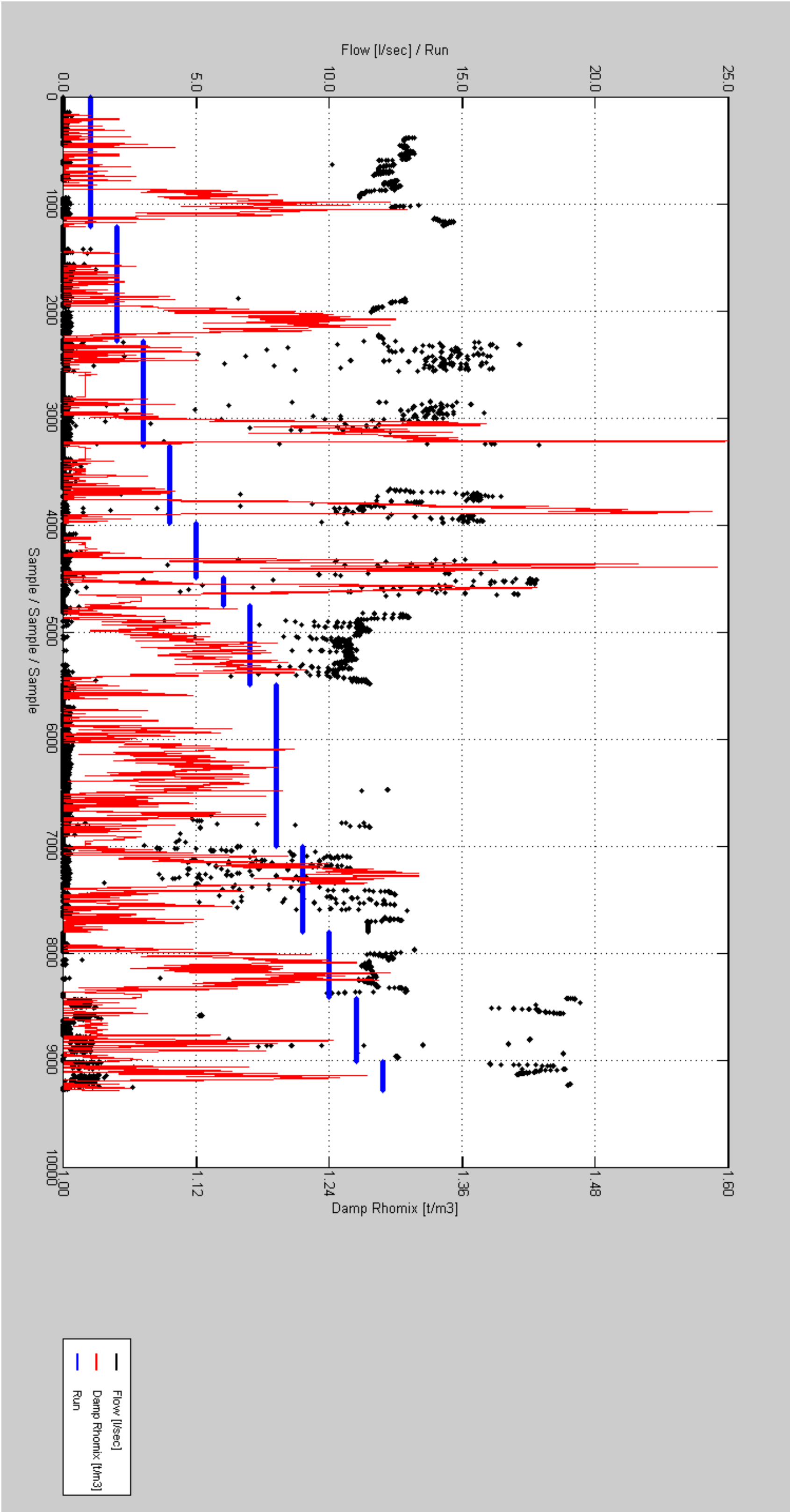
Main components used in the test setup:

Flowmeter:	Krohne Sonartrack VF100
Slurry pump:	WEIR, Warman Horizontal Pump 3 / 2 AH
Jetpump:	Aquaplus AP 40-20 working point realized (5.5 m3/hr at 5 bar)
Pressure sensors:	Aquaplus 3 stage working point realized (2.5-4 m3/hr at ± 7 bar)
Frequentie drives:	Elettronica Santerno (for surry pump and each jetpump one drive)
Datalogger:	Yokogawa MV2000
Camera's	Camera 1_Lumix DMC FT3
	Camera 2_Sony HDR SR12
Vibrator:	25 mm electric vibrator (vibrator for compacting soil)

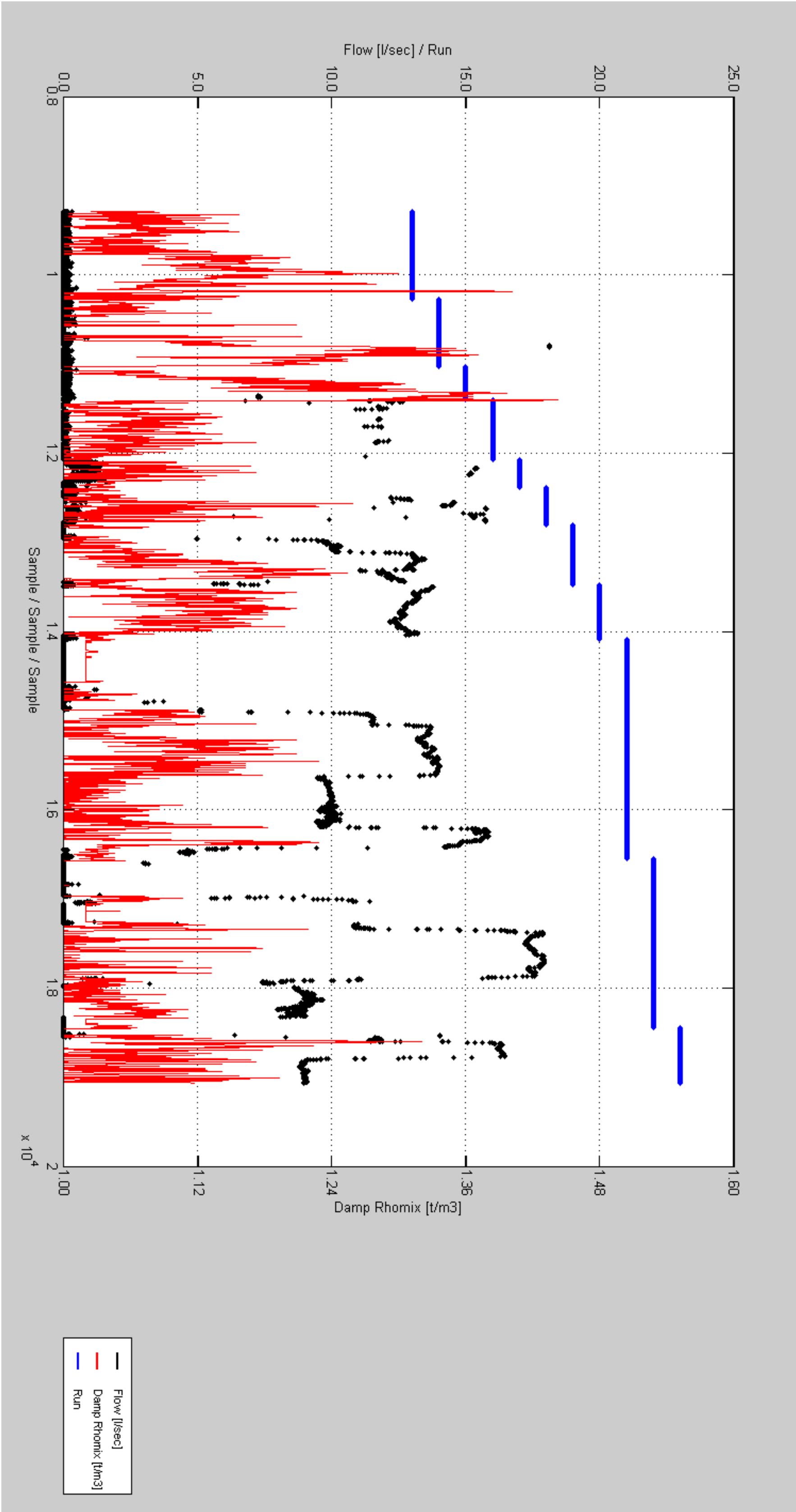
Appendix C: list executed experiments.

No	Test series	Test #	Soil condition	Vz (cm/sec)	Jet P1 (bar)	Jet P1 (m3/hr)	Jet P2 (bar)	Jet P2 (m3/hr)	Soil height (m)	Soil Width (m)	Soil Length (m)	Soil Type	Remarks	Mixture flow (l/sec)	Suction depth (m)	Face (m)	internal friction angle (deg)	Vwall (cm/sec)
1	1	1.1	loose	0	0	0	0	0	0.75	0.3	2	High Grade 503		0	97.5	67.5	29/31	-
2	2	2.1	loose	0.8	0	0	0	0	0.75	0.3	2	High Grade 503		12.5				-
3	1	1.2	loose	0	0	0	0	0	0.75	0.3	2	High Grade 503	Duplicate	0	97.5	62.5	29	-
4	2	2.2	loose	0.8	0	0	0	0	0.75	0.3	2	High Grade 503	Duplicate	12.5				1.99
5	1	1.3	loose	0	0	0	0	0	0.7	0.3	2	High Grade 503		0	97.5	62.5	29	-
6	2	2.3	loose	2	0	0	0	0	0.7	0.3	2	High Grade 503		14				2.28
7	1	1.4	loose	0	0	0	0	0	0.7	0.3	2	High Grade 503	Duplicate	0	97.5	65	29	-
8	2	2.4	loose	2	0	0	0	0	0.75	0.3	2	High Grade 503	Duplicate	15				2.75
9	2	2.5	loose	3	0	0	0	0	0.75	0.3	2	High Grade 503		?	97.5	62.5	29	x
10	2	2.6	loose	3	0	0	0	0	0.75	0.3	2	High Grade 503	Duplicate	16	100	65	x	x
11	1	1.7	dense	0	0	0	0	0	0.75	0.3	2	High Grade 503		0	97.5	47.5	30	-
12	2	2.7	dense	0.32	0	0	0	0	0.55	0.3	2	High Grade 503		11				0.57
13	1	1.8	dense	0	0	0	0	0	0.55	0.3	2	High Grade 503	Duplicate	0	97.5	52.5	30	-
14	2	2.8	dense	0.32	0	0	0	0	0.55	0.3	2	High Grade 503	Duplicate	11				0.50
15	1	1.9	loose / dense	0	0	0	0	0	0.25 / 0.45	0.3	2	High Grade 503		0	97.5	60	29	-
16	2	2.9	loose / dense	1	0	0	0	0	0.25 / 0.45	0.3	2	High Grade 503		10				0.76
17	1	1.10	loose / dense	0	0	0	0	0	0.35 / 0.35	0.3	2	High Grade 503	Duplicate	0	98.75	63.75	29	-
18	2	2.10	loose / dense	1	0	0	0	0	0.35 / 0.35	0.3	2	High Grade 503	Duplicate	11				0.65
19	2	3.11	dense	0.8	3	4.85	0	0	0.65	0.3	2	High Grade 503	Jet in suction mouth	17.5	96	53.5	x	1.09
20	2	3.12	dense	1	4.7	5.6	0	0	0.65	0.3	2	High Grade 503	Duplicate; the previous test was the first test incl. jets in suction	17.5	96	51	x	1.51
21	1	1.13	loose	0	0	0	0	0	0.85	0.3	2	Low Grade 502		0	102.5	82.5	31	-
22	2	2.13	loose	0.32	0	0	0	0	0.85	0.3	2	Low Grade 502		?				0.87
23	1	1.14	loose	0	0	0	0	0	0.85	0.3	2	Low Grade 502		0	102.5	70	31	-
24	2	2.14	loose	0.8	0	0	0	0	0.85	0.3	2	Low Grade 502	clogged discharge	?				x
25	2	2.15	loose	0.8	0	0	0	0	0.85	0.3	2	Low Grade 502	duplicate	?	102.5	72.5	32	1.29
26	1	1.16	dense	0	0	0	0	0	0.7	0.3	2	Low Grade 502		0	102.5	67.5	31	-
27	2	2.16	dense	0.3	0	0	0	0	0.7	0.3	2	Low Grade 502		12				0.40
28	2	3.17	dense	1.5	4.7	5.5	0	0	0.6	0.3	2	Low Grade 502	Jet in suction mouth	15	96	51	x	1.12
29	2	3.18	dense	1.5	0	0	7.1	3.8	0.65	0.3	2	Low Grade 502	Jet lance horizontally at the first 20 cm of the breach, 5 holes	15	96	51	31	1.12
30	2	3.19	dense	1.5	0	0	7.45	2.8	0.65	0.3	2	Low Grade 502	Jet lance vertically on the top of the breach, 4 holes	12.5	97	52	x	1.13
31	1	1.20	loose / dense	3	0	0	0	0	0.25 / 40	0.3	2	Low Grade 502		0	97.5	57.5	32	-
32	2	2.20	loose / dense	3	0	0	0	0	0.25 / 40	0.3	2	Low Grade 502		12.5				0.51
33	1	1.21	dense	0	0	0	0	0	0.5	1	1.3	Low Grade 502		0	96	41	x	-
34	3	4.21	dense	0.6 steps 2.5 cm	4.7	5.6	0	0	0.5	1	1.3	Low Grade 502	Start no jets, blocked swinging, start jet, still blocked swinging	14				x
35	3	4.22	dense	1.2 steps 5 cm	4.7-0.3	4.9-1	0	0	0.5	1	1.3	Low Grade 502	problems with jets	17	96	41	30	x
36	3	4.23	dense	1.2 steps 5 cm	4.7	5.5	0	0	0.5	1	1.3	Low Grade 502	Duplicate; blocked swinging process due to spillage	16	96	41		x

Appendx D: Logdata of the first 12 runs for the High Grade material



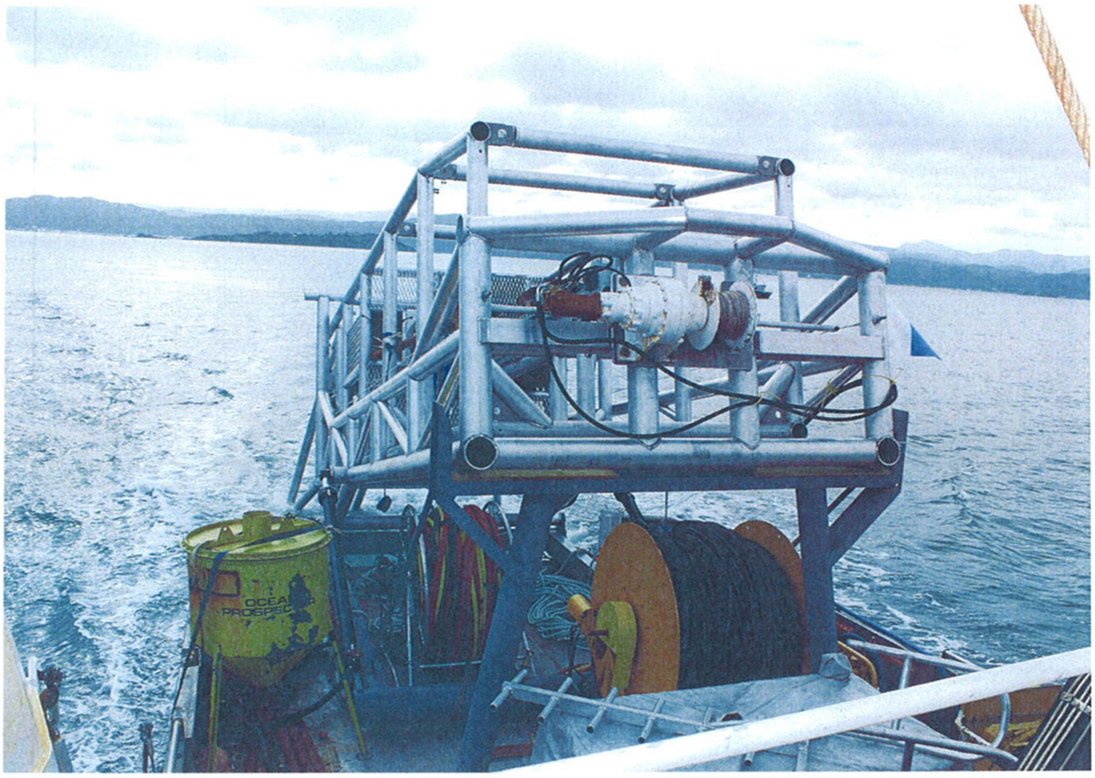
Logdata of the runs 13 till 23 for the Low Grade material



Appendix 19.19 - OCEL SPT Geotechnical Drill Report

Trans-Tasman Resources Limited

SPT TESTING TO ASSESS DREDGE ABILITY OF THE SAND RESOURCE



by

CONSULTANTS NZ LIMITED

49 Crownhill Street
PO Box 151
New Plymouth 4340

Telephone 06 7512310
Fax 06 7512310
Email: ocel@clear.net.nz

OCEL House
276 Antigua Street
PO Box 877
Christchurch 8140
Telephone 03 3790444
Fax 03 3790333
Email: mail@ocel.co.nz

1.0 INTRODUCTION

Trans-Tasman Resources Limited (TTRL) is proposing to dredge ironsand from the seabed in the South Taranaki Bight to recover titanomagnetite material using magnetic separation techniques. In order to design the dredging program it is necessary to determine the 'dredging effort' required to dredge the material. The 'effort' is directly related to the in situ soil strength parameters of the material to be dredged.

The dredging target material is non cohesive sand underlying a thin, soft, silty, weakly cohesive surface layer. The principal soil strength parameters for the sand are the angle of internal friction φ, and the relative density D_r. It is virtually impossible to obtain undisturbed soil samples for non cohesive sediments, the only effective way to determine the soil strength parameters is through in-situ testing. The most common form of in situ testing for sands is the Standard Penetration Test (SPT) technique. The number of blows required to drive a sampling tube a set distance by dropping a standard weight is recorded as the SPT N value. The soil strength parameters – φ and D_r – can be inferred from the N value using well established correlations between the soil strength parameters of interest and the SPT N values.

A NZ Diving and Salvage Limited (NZDS) diver operated, subsea geotechnical drilling rig which includes SPT equipment as part of its suite of drilling and test equipment was mobilised to determine SPT N values at two test locations located in the proposed dredging recovery area in the South Taranaki Bight. The surface support for the drilling operation was provided by the NZDS vessel 'Island Leader'.

The purpose of this report is to present the results of the in situ soil testing work and to translate the results, expressed as SPT N values, into inferred soil strength properties, φ and D_r.

2.0 LOCATION

The SPT testing work was undertaken at two locations:

39° 50.67196' S, 174° 11.36866' E
39° 50.62777' S 174° S, 11.38270' E

in 30 m water depth.

At the first location one SPT value was obtained at 1.5 m before a combination of equipment problems and weather forced 'Island Leader' to recover the equipment and return to port. Once back on site at the second location, approximately 80 m away from the first location, the first SPT run was undertaken at 3 m penetration followed by two further SPT runs at 1.5 m depth intervals. Maximum depth of penetration 6.5 m. The test location is shown in Figure No 1.

3.0 SUBSEA DRILL RIG AND EQUIPMENT

The NZDS sub sea drilling rig is a purpose built hydraulic top drive unit with a 4 m feed. The drilling head is attached to a face plate which is part of a simple roller carriage unit running on a vertical track fixed on the drilling mast. A hydraulically powered chain drive system is used to run the carriage and head up and down the mast. The weight applied to the drill bit is controlled by the pull down force that is monitored on a pressure gauge. A winch unit is provided at the level of the diver – so that he can oversee and control wire spooling – for lifting drill string elements and running wire line tools. The hydraulic power for the rig functions is supplied by a hydraulic power pack mounted on the deck of the NZDS surface support vessel, 'Island Leader', and connected to the drill rig via a hydraulic umbilical. The hydraulic system runs at 2500 psi.

The rig is enclosed in a rectangular frame structure mounted on fold out feet designed both to stabilise the frame and to exert minimal bearing pressure on the seabed. The frame provides protection for the drilling equipment as the frame is either launched from, or recovered back onto, the surface support vessel. The drill floor platform is mounted 6 m above the base plate to put the diver above the turbid layer close to the seabed. The use of the tower enabled the diver/drillers to work above the seabed at a shallower depth, reducing the decompression times required and putting the divers further above the turbid bottom layer. The arrangement for the work is shown in Drawing Nos DR-110901-014, 015 and 016 attached in Appendix A.

To undertake SPT testing a borehole is opened by drilling down to the SPT test depth then, once the test depth is reached, the drilling bit and drill string is retrieved and the SPT equipment run down the borehole.

4.0 THE SPT TECHNIQUE AND ITS MODIFICATION FOR UNDERWATER USE

The SPT consists of driving a standard split-barrel sampler a total distance of 18" into the bottom of the borehole using a 140 lb (63.5 kg) hammer dropped through a height of 30" (762 mm). The imperial system measurements reflect the American origins of the test. The technique was developed for use in air and has to be adapted for use under water.

The exposed drill rod, exposed above the top of the borehole casing, is referenced with three crayon marks (chalk in air) 6" (150 mm) apart prior to initiating the hammer drops. The number of blows required to drive the sampler each increment of 150 mm are recorded.

The results are expressed in the form of SPT numbers, N values, derived by adding the number of hammer blows required to drive the sampling tube the last two increments of 150 mm, 300 mm total. The first 150 mm increment is taken as the distance required to seat the tube on undisturbed soil. An N value ≥ 50 is taken as refusal. Once the N value has reached this level before full penetration has been attained the test is stopped, further hammering will only damage the gear. In the case of the TTR tests when refusal was apparent hammering stopped to avoid both damage and jamming of the gear.

The standard test is carried out in air, the submerged SPT results then need to be corrected for the submerged weight of the SPT hammer and the hydrodynamic drag generated as the weight drops through water. Both these effects result in a decrease in the impact energy applied to the hammer anvil.

The hammer used for the subsea work was modified/weighted to compensate for the buoyancy effect in seawater. The air weight is then 73.0 kg.

The drag on the cylindrical weight as it is dropped through water is given by the expression:

$$F_D = 0.5 \cdot \rho \cdot C_D \cdot A \cdot u^2$$

Where:
- ρ is the water density, 1025 kg/m^3
- C_D is the hydrodynamic drag coefficient
- A is the area of the cylinder perpendicular to the velocity
- u is the instantaneous velocity of the hammer.

The hammer falls through 30", 762 mm. The velocity at the end of that travel distance in air is 3.87 m/sec. The corresponding velocity in water, allowing for the hydrodynamic drag and calculated using an iterative process, is 3.23 m/sec.

The SPT N value is directly related to the driving energy E;

$$E = 0.5 \cdot m \cdot u^2$$

where u is the velocity of the hammer at the moment of impact on the anvil.

The submerged weight of the hammer is 63.5 kg. When the hammer drops through water however the surrounding sea water moves with it in a manner exactly analogous to the hydrodynamic mass associated with a berthing vessel. Based on vessel berthing principles the displaced volume of the hammer is multiplied by a mass factor, C_M = 1.3. The effective mass is then 63.5 + 73 x 1.025 / 7.850 x 1.3 = 75.9 kg.

The submerged impact energy is 395.9 Nm, or 83% of the standard impact energy in air, 474.8 Nm. The energy multiplied by the blow count should be a constant for any soil, a higher impact energy requiring a lesser number of blows to drive the sampling tube 300 mm. To convert the submerged N values recorded to equivalent, standard, in air values the recorded numbers are multiplied by the energy ratio, .83. The N values obtained for the SPT locations are set out in Table No 1, along with the corrected values.

The standard or theoretical driving energy E_{in} (E_{in} = 474.8 kN.m) is not the same as the actual driving energy E_a which is a percentage of the theoretical figure, typically in the range 30-80%. The discrepancy or inefficiency results from the different types of equipment or drilling rigs used for the work. The SPT number is normally standardised to some energy ratio E_r, computed as

$$E_r = E_a/E_{in}.100$$

The E_r figure used here is 70 since this is consistent with modern drilling rigs using automatic hammers. The SPT N values are designated as $(N_1)_{70}$ values.

The SPT value for cohesionless soil at a particular relative density increases with increases in effective overburden pressure. The measured value of N is corrected to a value normalised to an effective overburden pressure of 1 ton/ft^2 (100 kPa) by the formula

$$N_1 = C_N \,.\, N$$

Where N_1 denotes the corrected value of N and C_N is the adjustment for effective overburden pressure

$$C_N = (100 / p_o')^{0.5}$$

Where p_o' is the effective overburden stress in kPa. p_o' is less than 100 kPa for penetration depths under 11 m and only reduces N values below that depth. The correction was not applied for the TTRL borehole.

The SPT N value is used in correlations to derive unit weight Υ, relative density D_r, angle of internal friction φ and undrained compressive strength q_u. The N value correlations used in this report have been taken from Tables 3-4 and 3-5 from Foundation Analysis and Design by Joseph Bowles. The N values are $(N_1)_{70}$ values.

The angle of friction φ can also be obtained from the expression:

$$\varphi = \sqrt{(18 .(N_1)_{70})} + 15$$

5.0 PARTICLE SIZE ANALYSIS

In addition to the SPT N value the particle size distribution of the sand needs to be known to able to classify it as coarse, medium or fine sand. No sand samples were recovered from the SPT work to determine the particle size distribution. The particle size distribution for the sand has been taken from a bulk sample taken near the SPT location. The sample is from the < 2 mm particle size part of the sample (gravel > 2 mm is approximately 4% of the total sample) and is a composite of the hole down to 9 m penetration. The bulk of the material can be classified as fine sand. The particle size distribution is as follows:

Particle/Screen Size (µm)	Weight Retained (g)	Weight Distribution (%)	Passing (%)
1000	2.04	1.00	99.00
710	4.48	2.21	96.79
500	12.44	6.12	90.67
355	30.36	14.95	75.72
250	55.19	27.17	48.55
212	29.55	14.55	34.00
150	48.2	23.73	10.27
125	14.1	6.94	3.33
106	4.45	2.19	1.14
90	0.92	0.45	0.69
63	0.6	0.30	0.39
45	0.24	0.12	0.28
38	0.12	0.06	0.22
-38	0.44	0.22	0.00
	203.1	100	

Table No 1

6.0 RESULTS

The fine sand encountered in both test boreholes is dense to very dense. This is inferred from the SPT N values obtained having first corrected them for submergence. The SPT results are summarised in Table No 1, all achieved refusal within the test penetration depth. Based on OCEL/NZDS experience on subsea investigation work carried out prior to the installation of jackup drill rigs at a number of wellhead locations off shore Taranaki the result is not unexpected. It is also indicated by the extent to which the NZDS geotechnical drilling rig sank into the seabed – it didn't.

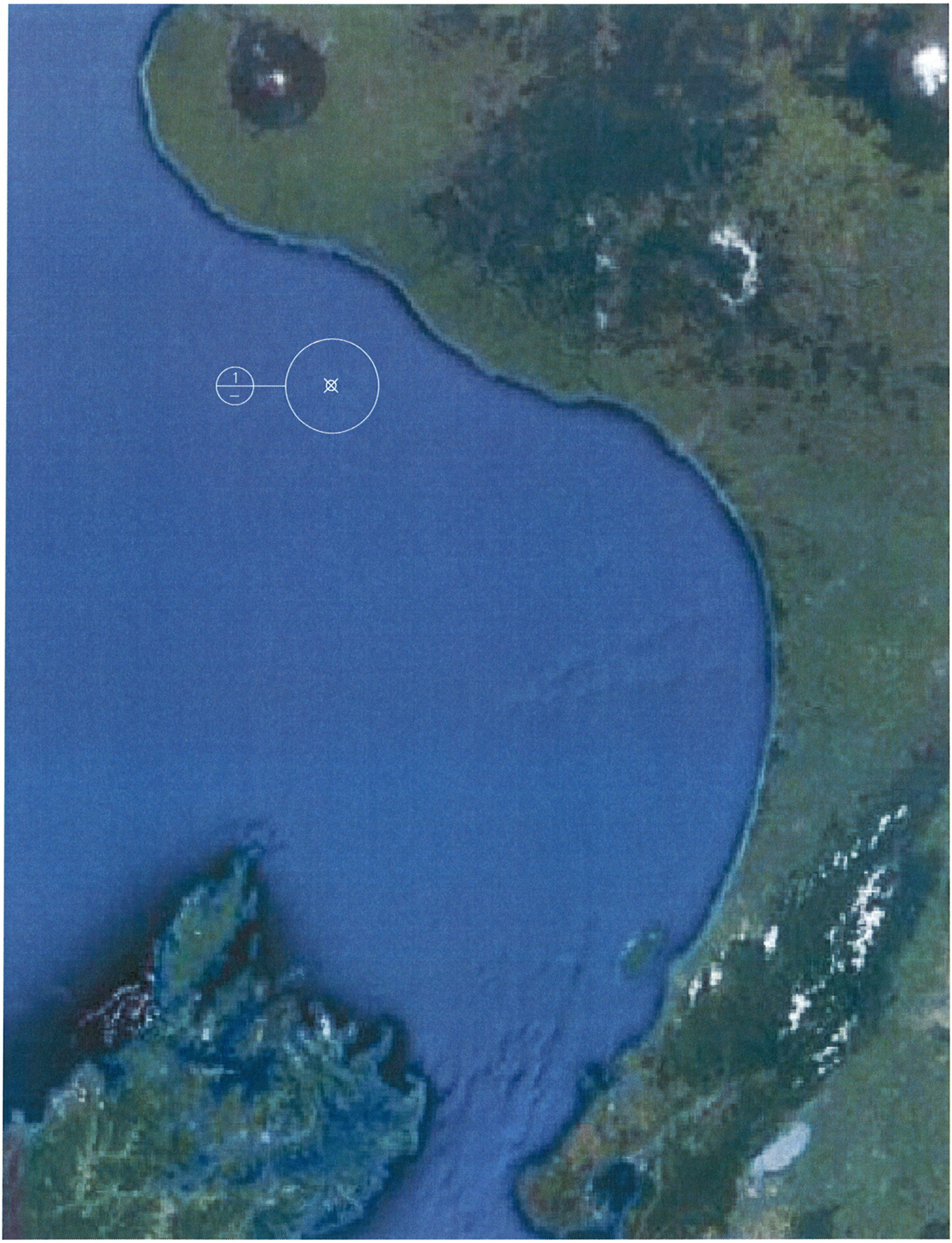
The reference to SNAME (Society of Naval Architects and Marine Engineers) in Table No 1 refers to the Guidelines for Site Specific assessment of Mobile Jack-Up units 2002. These are the rules used by OCEL for assessing the extent to which the jack-up rig spud cans on the bottom of the jack-up legs will sink into the seabed. The SNAME rules conservatively reduce φ inferred from the N value by 5°.

The implications in terms of dredging are also clear. Some sort of mechanical disturbance or cutting action will be required to dredge the sand, suction alone won't do it unless it is particularly powerful. This type of problem was encountered by the trailing suction dredge, 'New Era' when she attempted to dredge the trench for the OCEL designed Christchurch ocean outfall. A very dense fine sand layer was encountered within the 4 m dredged trench prepared for the outfall pipe. The draghead of the 'New Era' skidded along the top of the dense sand without entraining significant quantities. Port Otago the owners of the 'New Era' are planning to add a water jet system to the draghead to deal with this type of problem. A much larger dredge with a commensurately bigger, heavier draghead fitted with cutting teeth would probably not have a problem dredging the ironsand. If a subsea crawler is used then the machine could be fitted with hydraulically powered cutters or a water jet system.

Depth m	SPT N	Corrected for Submerged Nsub	Soil Description	Density Description	Friction Angle Phi	Corrected Angle 5°	Qu kPa	SNAME Angle	Density kN/m³
1.5	50+	41	Fine sand	Very dense	40	35	-	35	22
3	50+	41	Fine sand	Very dense	40	35	-	35	22
4.5	50+	41	Fine sand	Very dense	40	35	-	35	22
6.5	50+	41	Fine sand	Very dense	40	35	-	35	22

Table No 2

APPENDIX



SPT
39° 50.62777' S
174° 11.38270' E

84m

SPT
39° 50.67196' S
174° 11.36866' E

DETAIL 1
Scale 1:5

Appendix 19.20 - Transfield Worley Marine Operations Risk Review

TRANSFIELD WORLEY

TRANS-TASMAN RESOURCES LTD

Offshore Iron Sand Extraction and Processing Project
Marine Operations Risk Review

TTRL-02-EXT-05000-R2
TW Document No. 120092-TCN-R0001-R0
November 2013

Transfield Worley Ltd
25 Gill Street, New Plymouth 4310
PO Box 705, New Plymouth 4340

Telephone +64-6-759 6300
Facsimile +64-6-759 6301

www.transfieldworley.co.nz

Rev	Description	Originator	Reviewer	TW Approver	Date	Client Approval	Date
A	Issued for Review/Comment	J Lilly	R Johnson	R Johnson	10/2013		
0	Issued for Use	J Lilly	R Johnson	R Johnson	11/2013		

TABLE OF CONTENTS

1. ABBREVIATIONS **1**

2. INTRODUCTION **2**

2.1 Purpose and Scope 2

3. WORKSHOP DETAILS **3**

3.1 Schedule 3
3.2 Attendees 3
3.3 Workshop Methodology 3

4. HAZID OUTCOMES **4**

4.1 Key Issues 4
4.2 Actions 5

APPENDICES

APPENDIX 1. HAZARD REGISTER

APPENDIX 2. GUIDEWORDS

APPENDIX 3. RISK MATRIX

1. ABBREVIATIONS

AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable
ERP	Emergency Response Plan
FPSO	Floating Production, Storage, and Offloading unit
MAE	Major Accident Event
OIM	Offshore Installation Manager
SIMOPS	Simultaneous Operations
TTR	Trans-Tasman Resources Ltd
TW	Transfield Worley Ltd

2. INTRODUCTION

Trans-Tasman Resources Ltd (TTR) is currently undertaking the required preparation for the company's Offshore Iron Sand Extraction and Processing Project. This HAZID workshop is to be included as part of the resource consent process and identified the hazards and assessed the risks associated with the following operational activities:

- Mining and processing;
- Marine vessel operations including those of the FPSO, FSO, export vessel, anchor handling tugs, and replenishment vessel;
- Transfer operations from the FPSO to FSO, FSO to export vessel, and fuel transfer;
- Biosecurity and operational discharges including sewage/garbage, de-ored sand and brine, brackish fresh water from the ore washing process, oil products, and other hazardous materials;
- Navigational impacts and maritime safety of the project including marine traffic and activities, proximity to other mining operations, other TTR operational vessel movements, and Automatic Identification System issues;
- FPSO exclusion zone;
- Anchor Handling.

2.1 Purpose and Scope

The intent of this HAZID workshop was to:

- Identify hazards associated with the activities being undertaken and document proposed controls;
- Prepare a feasibility stage Hazard Register; and
- Identify any areas where improvements can be made such that the risk can be minimised and reduced to As Low As Reasonably Practicable (ALARP).

The HAZID workshop was focused on identifying hazards related to the area of operation while normal production and concurrent activities are undertaken.

As the project is in the feasibility stage, the workshop focused on the identification of major and significant hazards rather than development of an exhaustive list of all possible hazards. The Hazard Register should become a live document for the project and be revisited and updated at key stages in the lifecycle of the project.

3. WORKSHOP DETAILS

3.1 Schedule

The TTR Marine Operations Risk Review was conducted on Friday, 11 October 2013 at the TTR Ltd's offices in Wellington, New Zealand.

3.2 Attendees

Table 3.1 Marine Operations Risk Review

Name	Company	Role/Position
Tim Crossley	Trans-Tasman Resources Ltd	Chairman/CEO
Shawn Thompson	Trans-Tasman Resources Ltd	Project Director
Andy Sommerville	Trans-Tasman Resources Ltd	Environmental Manager
Rhys Thomas	Trans-Tasman Resources Ltd	Offshore Operations Manager
Bruce Pope	Taranaki Regional Council	Compliance Manager
Evan Lloyd	Horizon Regional Council	Risk Management Coordinator
Rex Moir	MBIE High Hazard Unit	Business Analyst
Ray Barlow		Marine Advisor
Bruce Barton	Maritime New Zealand	Analyst
Garry Venus	ARGO	Environmental Consultant
Roisin Johnson	Transfield Worley Ltd	Technical Manager Safety and Risk (Facilitator)
John Lilly	Transfield Worley Ltd	Graduate Safety and Risk Eng. (Scribe)

3.3 Workshop Methodology

Following introductions the workshop began with an animation of the main operations and a brief overview of the operation and key activities by Shawn Thompson (TTR Project Director). The HAZID study then commenced with the identification of the major and significant hazards associated with the proposed activities.

As an aid to hazard identification, reference was made to a set of hazard guidewords (refer Appendix 2). Once a new hazard was identified, the event, cause, consequence, and safeguards associated with the hazard were identified and recorded in the HAZID worksheet. Risk Ranking was completed post-workshop with reference to the Transfield Worley Risk Assessment Matrix (refer Appendix 3).

4. HAZID OUTCOMES

A total of 47 hazards were identified during the workshop. With reference to the Transfield Worley Risk Matrix, each hazard was risk ranked before and after mitigation and control measures are in place.

Table 4.1 Marine Operations HAZID Risk Ranking

Hazard Risk	Before Mitigation and Control Measures	After Mitigation and Control Measures
Extreme	15	0
High	14	3
Moderate	13	23
Low	5	21

4.1 Key Issues

The following major hazards with potential for multiple fatalities, major environmental impact or total loss of a vessel were identified during the workshop:

- Vessel collision, largely due to there being numerous vessels operating and interacting with each other during production, processing, offloading, maintenance, anchor movement, and supply transfer activities. There is the potential for as many as 89 different vessel transfer operations per month. An additional risk was posed by other vessel traffic in the region.
- Vessel movements and manual handling for connection & disconnection of the product transfer hose from FPSO to FSO. The Anchor Handling Tug is vulnerable to impact from both larger vessels during this operation and there is the potential for involvement of multiple people on the AHT and FSO during connection and disconnection of the hose.
- Release of HFO during transfer & refuelling. The HFO will not easily disperse on spill and it is likely that even a relatively small release in the 10's of litres will travel far from the point of release.
- Helicopter crash onto a vessel.
- Loss of anchors and FPSO being swept off station with the potential to impact on neighbouring facilities such as Kupe WHP.

There are several key risk reduction measures for the major hazards that may require further development or consideration to ensure that they are effective:

- Exclusion Zone/Safety Zone – the FPSO will require a mobile Safety Zone of up to 1km to cover the vessel and the anchor spread. There is no current legal prerogative that can be applied and therefore work is required (in consultation with the appropriate regulators) to develop an appropriate safety zone arrangement and process for notifying mariners of the changes every 10 days.
- Four point mooring system for the FPSO. This is a critical safety feature. It is also a critical operational feature as the FPSO cannot mine and produce if it cannot maintain station. Although sea state conditions appear to be similar to those in Namibia where there is a similar vessel in operation, this design feature should be closely assessed and highlighted as critical throughout the whole project so that its ability to perform and its weaknesses are well understood.

The following significant hazards with potential for single fatality or permanent disability were identified:

- Heavy lifts and craneage on deck – there are a considerable number of vessel and marine operations that require lifting and craneage. This is a high cause of offshore facility occupational fatalities.
- High Voltage Electricity. In order to reduce the hazardous chemicals etc on the FPSO, all the mining and processing equipment is run on electricity. This means that there is a requirement for very large power generation including High Voltage equipment.

The following hazards have specific potential for impacting on operations and causing down time:

- Failure of dewatering equipment on FSO. There is considerable redundancy built into the systems on the FPSO and also for offloading from FSO to the Bulk Carrier, there is potential for inability to dewater the product to stop operations until a remedy is worked out.
- Weather and sea state conditions. The FPSO is designed to operate in up to 4m significant wave height sea conditions. Although the FPSO and equipment may be able to operate, the ability of the humans onboard to also continue working may be significantly reduced. Other vessels in the field have lesser ability to operate in high sea states.

4.2 Actions

The actions generated from this study are summarised in Table 4.2.

Table 4.2 Marine Operations HAZID Actions

Action Item	Item Number	Hazard Guideword	Event(s)
1. Consider options for monitoring of sea-state and weather conditions local to operations.	3	Sea-state	High sea-state. Caused by hazardous weather conditions, high winds.
2. Further work may be required to understand extent of exposure as design progresses.	22	Toxic Material	High sulphur exhaust discharge close to loading point on the FSO
3. Review options available for design of coupling points and semi-automation of process to reduce hazards.	26	Manual Handling	Manual handling around connection and de-coupling of transfer hose at FSO. Potential for release of stored energy and use of heavy equipment.
4. Review potential for assigning designated areas for transfer operations to provide operational flexibility and manage risks.	29	Anchor/Seabed	Bulk storage vessel anchor damaging seabed. Sensitivity of the seabed and restrictions on where the bulk storage vessel can anchor.
5. Further assessment is required to understand the full impact of tsunami on in field operations.	41	Tsunami	Bottoming out or breaking of moorings and drag on anchors and crawler.

Appendix 1.
Hazard Register

Risk Assessment

Process: Marine Operations Risk Review		Core Team:	Date:	Friday 11 October 2013
			Date Orig:	
Internal Customer:	TTR		Date Rev:	

	Hazard Description	Hazard: Threat/Cause	Hazard: Consequence	Initial Risk: Hazard Severity	Initial Risk: Likelihood of Occurrence	Initial Risk: Risk Rating	Controls: Mitigation	Residual Risk: Hazard Severity	Residual Risk: Likelihood of Occurrence	Residual Risk: Risk Rating	Action Taken	Responsible Person and Target Completion Date
A	**Mining and Processing Activities**											
1	Hydraulic oil release from crawlers.	Equipment failure, hose damage.	Minor Oil release into the environment. Expected to be of the order of 100s of litres in volume.	Moderate	Moderately Occurs	High	Hydraulic oil is marine biodegradable. Routine maintenance and repair work. Certified equipment. Redundancy - only use one crawler at a time.	Slight	Unlikely to Occur	Low		
2	Suspended solids plume formation aft of FPSO.	Sand disturbance from crawler operations	Visual impact from air and/or reputation damage and minor additional elevated turbidity.	Slight	Almost certain to Occur	Moderate	Can not eliminate. Visual effect in the water column. Plume will dissipate. Modelling has been completed to show that the plume will dissipate to acceptable levels similar to existing natural levels.	Slight	Almost certain to Occur	Moderate		
3	High sea-state.	Hazardous weather conditions, high winds.	Vessel, crawler, and/or processing equipment damage.	Moderate	Likely to Occur	High	FPSO designed for sea-state of 4 meters. Crawler operations are in relatively shallow areas and sea-state restrictions on operation of crawlers. Wave rider buoy or equivalent and discussion with neighbouring installations.	Minor	Unlikely to Occur	Moderate	Consider options for monitoring of sea-state and weather conditions local to operations.	
4	Crawler malfunction on the seabed.	Equipment failure.	Disruption to operations.	Minor	Moderately Occurs	Moderate	Crawlers undergo routine maintenance. Redundancy with second crawler.	Minor	Rarely Occurs	Low		
5	Heavy equipment (hoses, crawlers) moving on mining area of FPSO deck.	High sea state resulting in vessel instability and shifting of equipment.	Equipment damage and/or personal injury/fatality.	Major	Likely to Occur	Extreme	Crawlers stored in vessel and secured with shackles. Hoses reeled up. Deck monitored remotely. Manual intervention has been designed out.	Minor	Unlikely to Occur	Moderate		
6	Dropping of equipment during crane lifting operations.	Failure of crane/lifting equipment.	Equipment damage and/or personal injury.	Major	Likely to Occur	Extreme	Certified cranes, standards, and lifting plans. Use of experienced personnel. Engagement with, and approval of, classification society.	Moderate	Unlikely to Occur	Moderate		
7	Damage to aft section of hull of the FPSO.	Crawler collision with vessel during deployment or recovery.	Vessel damage and/or crawler damage (3 1/2 tonne weight).	Major	Likely to Occur	Extreme	Use of certified equipment. Use of experienced personnel. Sea-state restrictions. FPSO hull designed and strengthened to withstand any unexpected crawler impacts.	Minor	Moderately Occurs	Moderate		
8	Manual handling during crawler lifting.	Heavy equipment and moving vessel.	Personal injury/fatality.	Major	Likely to Occur	Extreme	Lifting of crawlers remotely handled from control room. Manual handling designed out of operation as far as is practicable.	Slight	Rarely Occurs	Low		
9	Electricity (HV and LV).	Electric shock.	Personal injury/fatality.	Major	Likely to Occur	Extreme	HV and LV qualified electricians on-board for maintenance purposes.	Major	Moderately Occurs	High		
10	Chlorides in iron ore concentrate.	Seawater source not processing elevating levels of chloride in concentrate.	Product off spec for shipping.	Minor	Almost certain to Occur	High	Desalination plant to produce water for flushing concentrate. Application of international standards for chloride levels in concentrate.	Slight	Almost certain to Occur	Moderate		

	Hazard Description	Hazard		Initial Risk			Controls	Residual Risk			Action Taken	Responsible Person and Target Completion Date
		Threat/Cause	Consequence	Hazard Severity	Likelihood of Occurrence	Risk Rating	Mitigation	Hazard Severity	Likelihood of Occurrence	Risk Rating		
11	Release of brine into the environment.	Continual discharge of residual brine from FSO.	Marine water quality.	Slight	Almost certain to Occur	Moderate	Brine discharged with hydrocylcone enhanced mixing at depth just above seabed. Brine is heavier than surrounding seawater, aiding dissipation. Flushing activities reduce concentration of brines.	Slight	Moderately Occurs	Moderate		
12	Diesel spill.	Diesel for emergency generator spilt during transfer.	Damage to the environment.	Minor	Unlikely to Occur	Moderate	Spill containment on vessel. Waste oils are transferred to shore.	Slight	Unlikely to Occur	Low		
13	Fire on-board vessel.	Ignition of flammable atmosphere/material.	Personal injury/fatality, equipment damage, and disruption to operations.	Catastrophic	Unlikely to Occur	High	Anchor management vessel has fire fighting equipment. Concentrate oxidised and damp so is not combustible. Fire fighting equipment/systems on-board vessels. Process operations are on the deck of the FPSO. Flammable products kept to a minimum on FPSO as all equipment run by electricity.	Slight	Unlikely to Occur	Low		
14	Hazardous chemical/substance release.	Equipment failure.	Personal injury.	Minor	Unlikely to Occur	Moderate	Hazardous chemicals/substances stored in small quantities. MSDS and hazardous substance storage control. Dispersants on FPSO/support vessels if required. Design of processing plant requires limited chemicals, mainly lube and seal oils.	Minor	Rarely Occurs	Low		
15	Failure of processing equipment.	Faulty equipment, lack of maintenance, and mechanical failure.	Equipment damage and/or disruption to operations.	Minor	Likely to Occur	High	Routine maintenance and shutdown procedures. Redundancy in processing plant.	Moderate	Rarely Occurs	Moderate		
16	Loss of moorings.	Hazardous weather conditions (eg high sea-state and damaged equipment.	Loss of vessel control and drift off station.	Moderate	Likely to Occur	High	Weather warning and sea-state limits. One engine reserved for propulsion on FPSO. Four anchored moorings that are maintained regularly. Dynamic positioning.	Minor	Unlikely to Occur	Moderate		
17	Cargo movement on FPSO.	High sea-state, free surface effects.	Vessel capsize.	Catastrophic	Likely to Occur	Extreme	Limited storage of iron ore on FPSO. Water flush added as cargo is transferred to FSO. Design of cargo storage tanks.	Minor	Rarely Occurs	Low		
18	Release of product.	Rupture of buffer tank and leak.	Disruption to operations.	Minor	Unlikely to Occur	Moderate	Buffer tanks kept as small as possible to ensure effect of leak due to rupturing is minimised. Inspection and certification processes.	Slight	Rarely Occurs	Low		
19	Stored energy in winches.	Anchor winches are under load at all time.	Equipment damage and personal injury.	Major	Likely to Occur	Extreme	Safety guards and structural support. Certified equipment. Snap back zones (no go areas).	Minor	Unlikely to Occur	Moderate		
20	Loss of power to agitation system.	Emergency shutdown.	Setting of product resulting in clogging of equipment and down-time.	Moderate	Likely to Occur	High	Agitation system connected to emergency generator to keep products in the tanks fluid. Staged shutdown and flush process.	Slight	Rarely Occurs	Low		
21	Manual operation of machinery.	Rotating machinery.	Personal injury.	Moderate	Likely to Occur	High	Equipment guarded, machine shutdown buttons on all equipment, and shutdown procedure. JHA.	Minor	Unlikely to Occur	Moderate		

	Hazard Description	Hazard		Initial Risk			Controls	Residual Risk			Action Taken	Responsible Person and Target Completion Date
		Threat/Cause	Consequence	Hazard Severity	Likelihood of Occurrence	Risk Rating	Mitigation	Hazard Severity	Likelihood of Occurrence	Risk Rating		
22	High sulphur exhaust discharge.	Close to loading point on the FSO.	Health exposure for people on deck AHV and FSO.	Slight	Likely to Occur	Moderate	Bow into wind so that dispersion should be away from AHV and FPSO. Use of low Sulphur fuels.	Slight	Unlikely to Occur	Low	Further work may be required to understand extent of exposure as design progresses.	
B	**Product Transfer Operations**											
B1	**FPSO to FSO**											
23	Unable to de-water product.	Malfunction of FSO filter system.	Disruption to operations/halt to offloading. Transfer can not take place unless product is de-watered.	Major	Moderately Occurs	High	Maintenance of filter system.	Minor	Unlikely to Occur	Moderate		
24	Spillage of slurry.	Damage to transfer hose whilst offloading slurry.	Discharge of product to sea and loss of revenue.	Slight	Unlikely to Occur	Low	Product is water and seabed materials. Design of hose on reel, FSO is on dynamic positions, and anchor handling tug assists with connection and disconnection of hose.	Slight	Rarely Occurs	Low		
25	Vessel collision - TTR in field vessels.	Loss of FSO power and control. Vessel proximity during transfer operations. (AHV is most vulnerable to being damaged between two large vessels).	Vessel damage/oil spill.	Major	Likely to Occur	Extreme	FPSO and FSO kept about 100 meters apart. Vessels dynamically positioned and FPSO moored. Bow to bow transfer so that any collision unlikely to cause damage. Sea-state restrictions. Anchor handler on standby to assist.	Minor	Unlikely to Occur	Moderate		
26	Manual handling around connection and de-coupling of transfer hose at FSO.	Release of stored energy and use of heavy equipment.	Personal injury/fatality.	Major	Likely to Occur	Extreme	Hoses flushed with water until no product is coming through. Personnel proximity restrictions. Procedures. JHA.	Minor	Unlikely to Occur	Moderate	Review options available for design of coupling points and semi-automation of process to reduce hazards.	
B2	**FSO to Bulk Tanker**											
27	Vessel collision.	Vessel proximity during transfer operations and size differentiation.	Vessel damage/oil spill.	Major	Likely to Occur	Extreme	Location of transfer based on weather and sea-state. Sea-state restrictions. Magnets/suction moorings used in connection of FSO to bulk tanker. Procedure. Reduced speed/caution.	Major	Rarely Occurs	Moderate		
28	Failure of connection magnets or vacumm connections.	High sea-state.	Vessel damage.	Moderate	Unlikely to Occur	Moderate	Sea-state restrictions (approx. 3-4m). Shutdown of transfer.	Moderate	Rarely Occurs	Moderate		
29	Bulk storage vessel anchor damaging seabed or unable to anchor.	Sensitivity of the seabed and restrictions on where the bulk storage vessel can anchor.	Environmental damage and/or disruption to operations.	Minor	Moderately Occurs	Moderate	Appropriate vessel anchorage location used (potential anchorage areas identified).	Slight	Unlikely to Occur	Low	Review potential for assigning designated areas for transfer operations to provide operational flexibility and manage risks.	
30	Spilling of product during transfer.	Hazardous weather conditions (eg high sea-state/wind).	Discharge of product into the environment though this would have minimal seabed impact.	Slight	Unlikely to Occur	Low	Conveyors enclosed and product dropped into tanks on deck. Sea-state restrictions.	Slight	Rarely Occurs	Low		
C	**Transfer and Supply Operations**											

	Hazard Description	Hazard		Initial Risk			Controls	Residual Risk			Action Taken	Responsible Person and Target Completion Date
		Threat/Cause	Consequence	Hazard Severity	Likelihood of Occurrence	Risk Rating	Mitigation	Hazard Severity	Likelihood of Occurrence	Risk Rating		
31	Release of product during transfer operations (HFO, diesel)	Rupturing of transfer hose.	Damage to equipment, significant oil spill release, and coastal impact.	Catastrophic	Likely to Occur	Extreme	Exercises with MNZ. Dry break connections to limit size of spill. Certified hoses used in transfer operations. Oil spill plan and AHV equip with spill equipment. Weather and sea-state limits, seabed surveys and dispersion modelling.	Moderate	Unlikely to Occur	Moderate		
32	Discharge of waste.	Disposal of sewage/garbage into the environment.	Environmental damage.	Slight	Likely to Occur	Moderate	Sewage, garbage, sludge etc removed from FPSO to anchor handling vessel for transfer to shore.	Slight	Rarely Occurs	Low		
33	Helicopter emergency/crash.	Crew transfers.	Personal injury/fatality and equipment damage.	Catastrophic	Likely to Occur	Extreme	Helidecks designed to CAA standards. Secondary helipad on FPSO. FSO has own helipad. Safety/life saving equipment and requirements met for all POB. Emergency response team on-board. Fire fighting systems. Weather and sea-state restrictions. Crew induction and emergency response training. Anchor handling vessel/coastguard response. Coastguard informed of helicopter operations. Rescue centre coordination (familiarisation with operations).	Catastrophic	Unlikely to Occur	High		
34	Evacuation/man over board.	Emergency on vessels.	Personal injury/fatality.	Major	Moderately Occurs	High	Life rafts sufficient for amount of POB. Life saving equipment, emergency response team/plan.	Major	Rarely Occurs	Moderate		
35	Cranage of provisions.	Moving cargo on deck is a threat to personnel. Large/heavy equipment being changed out.	Personal injury and/or equipment damage.	Moderate	Likely to Occur	High	Four cranes available on FPSO. Certified cranes and equipment. Experienced personnel. Constraints on handling of heavy/large items. Sea-state and weather restrictions.	Minor	Rarely Occurs	Low		
D	**Marine Operations**											
36	Marine mega-fauna.	Vessel impact. Congregation of fauna in field and around ships.	Injury/fatality to marine mammal.	Slight	Unlikely to Occur	Low	Speed limits of vessels in field of operations. Response plan. Monitor and report sightings to document movements.	Slight	Rarely Occurs	Low		
37	Vessel collision.	Errant vessels/neighbouring vessels. Increased traffic density.	Vessel damage and/or disruption to operations.	Major	Likely to Occur	Extreme	Limited small/recreational vessel traffic through mining area/AIS/exclusion zone, navigation lights, surveillance, precautionary area on charts, maritime rules and regulations. Monitor marine traffic and communicate by radio.	Major	Unlikely to Occur	Moderate		
38	Security breach.	External interference.	Disruption to operations and reputation damage.	Minor	Moderately Occurs	Moderate	Report to police. Surveillance and AIS system. Develop necessary relationships (police, coast guard). Security/emergency response plan and procedure.	Minor	Rarely Occurs	Low		

	Hazard Description	Hazard		Initial Risk			Controls	Residual Risk			Action Taken	Responsible Person and Target Completion Date
		Threat/Cause	Consequence	Hazard Severity	Likelihood of Occurrence	Risk Rating	Mitigation	Hazard Severity	Likelihood of Occurrence	Risk Rating		
39	Vessel collision with Kupe platform.	Loss of moorings and vessel power/control.	Vessel damage and third party installation damage.	Catastrophic	Unlikely to Occur	High	Four anchor moorings. Emergency generator to maintain propulsion. 6-9 tonne anchor to provide sufficient pull. Certified chains. Full engagement of DP system whilst anchored. AHT in field most of the time.	Major	Rarely Occurs	Moderate		
40	Regional oil spill.	Oil spill from neighbouring platform/vessel drifting through mining area.	Environmental damage and disruption to operations.	Major	Moderately Occurs	High	Have no control over this event and can only support the clean-up effort. Oil spill emergency response plans.	Major	Moderately Occurs	High		
41	Tsunami.	Bottoming out or breaking of moorings and drag on anchors and crawler.	Vessel and/or equipment damage.	Major	Rarely Occurs	Moderate	Operations in 20+ meters of water. Retrieval of crawlers in case of tsunami warning. Production shutdown. Early warning system. Civil defence plan.	Moderate	Rarely Occurs	Moderate	Further assessment is required to understand the full impact of tsunami on in field operations.	
42	Earthquake.	Liquefaction.	Limited potential for impact on operations as there are no permanent structural foundations.	Slight	Rarely Occurs	Low	No controls indentified.	Slight	Rarely Occurs	Low		
43	Climate change.	Increased frequency and severity of storm events.	Vessel and/or equipment damage.	Slight	Rarely Occurs	Low	Storm response plan. Weather restrictions on operations. Review of operating limits if change is significant enough.	Slight	Rarely Occurs	Low		
E	**Anchor Handling Operations**											
44	FPSO swept off position.	Breaking of anchor chain(s).	Injury to personnel on FPSO deck and equipment damage. Vessel collision/impact with other installations.	Catastrophic	Moderately Occurs	Extreme	6-9 tonne anchor to provide sufficient pull. Certified chains. Full engagement of DP system whilst anchored. Annual inspections and surveys. Diving inspections. AHT in attendance and FPSO has own propulsion system.	Moderate	Rarely Occurs	Moderate		
45	Anchor relocation damage to rejuvenating seabed.	Pull of anchor and chains through seabed.	Seabed disturbance.	Slight	Likely to Occur	Moderate	Capture the anchor impact on seabed. Systematic anchor movement and progress through mining block. Regular seabed survey.	Slight	Rarely Occurs	Low		
46	Vessel collision.	Vessel SIMOPS - other marine activities concurrent with anchor handling.	Vessel damage. Anchor chain damage.	Minor	Likely to Occur	High	No transferring operations during anchor handling activities.	Slight	Rarely Occurs	Low		
47	Manual handling/deck work.	Heavy equipment.	Personal injury/fatality.	Major	Likely to Occur	Extreme	Experienced personnel/contractor. Plan and procedures. Plan before commencement of work. JHA.	Major	Rarely Occurs	Moderate		

Appendix 2.
Guidewords

TRANSFIELD WORLEY

Hazard List

No.	HAZARD DESCRIPTION
H-01	**Hydrocarbons**
H-01.01	Crude oil under pressure
H-01.02	Hydrocarbons in formation
H-01.03	LPGs
H-01.04	LNGs
H-01.05	Condensate, NGL
H-01.06	Hydrocarbon gas
H-01.07	Crude oil at low pressure
H-01.08	Wax
H-01.09	Coal
H-02	**Refined Hydrocarbons**
H-02.01	Lube and seal oil
H-02.02	Hydraulic oil
H-02.03	Diesel fuel
H-02.04	Aviation fuel, petrol
H-02.05	Hydrocarbons above auto ignition temp
H-02.06	Asphalt
H-03	**Other Flammable Materials**
H-03.01	Cellulosic materials
H-03.02	Pyrophoric materials
H-03.03	Carbon fibre reinforced material
H-03.04	Dry vegetation
H-03.05	Hydrogen
H-04	**Explosives**
H-04.01	Detonators
H-04.02	Conventional explosives
H-04.03	Perforating gun charges
H-04.04	Explosive gases
H-05	**Pressure Hazards**
H-05.01	Hydrocarbons under pressure
H-05.02	Bottled gases under pressure
H-05.03	Water under pressure
H-05.04	NonHC gas under pressure in pipework
H-05.05	Air under high pressure
H-05.06	Hyperbaric operations
H-05.07	Decompression
H-05.08	Trapped pressure in equipment
H-05.09	High pressure equipment
H-06	**Hazards associated with differences in height**
H-06.01	Personnel at height
H-06.02	
H-06.03	Overhead equipment
H-06.04	Personnel under water
H-06.05	Personnel below grade
H-06.06	Falling ice/snow
H-07	**Objects under induced stress**
H-07.01	Objects under tension
H-07.02	Objects under compression
H-08	**Dynamic Situation Hazards**
H-08.01	On land transport (driving)
H-08.02	On water transport (boating)
H-08.03	In air transport (flying)
H-08.04	Boat collision hazard to other vessels and offshore structures
H-08.05	Equipment with moving/ rotating parts
H-08.06	Use of hazardous hand tools
H-08.07	Use of knives, machetes etc
H-08.08	Transfer from boat to offshore platform
H-09	**Physical Environment Hazards**
H-09.01	Weather
H-09.02	Sea state/river currents
H-09.03	Tectonic activity
H-10	**Hot Surfaces**
H-10.01	Process piping equipment 60-150°C
H-10.02	Piping equipment > 150°C
H-10.03	Engine & turbine exhaust systems
H-10.04	Steam piping
H-11	**Hot Fluids**
H-11.01	Temperatures 100-150 °C
H-11.02	Temperatures >150 °C
H-12	**Cold Surfaces**
H-12.01	Process piping -25 to -80°C
H-12.02	Piping equipment < -80°C

No.	HAZARD DESCRIPTION
H-13	**Cold Fluids**
H-13.01	Oceans, seas & lakes < 10°C
H-14	**Open Flame**
H-14.01	Heaters with fire tube
H-14.02	Direct fired furnaces
H-14.03	Flares
H-15	**Electricity**
H-15.01	Voltage > 50 - 600V in cables
H-15.02	Voltage > 50- 600V in equipment
H-15.03	Voltage > 600V
H-15.04	Lightning discharge
H-15.05	Electrostatic energy
H-15.06	Batteries
H-15.07	Stored charge (e.g. capacitors)
H-16	**Electromagnetic Radiation**
H-16.01	Ultraviolet radiation
H-16.02	Infra red radiation (e.g. fired eqpt)
H-16.03	Microwaves
H-16.04	Lasers
H-16.05	E/M radiation: high voltage ac cables
H-17	**Ionizing Radiation - Open Source**
H-17.01	Alpha, Beta - open source
H-17.02	Gamma rays - open source
H-17.03	Neutron - open source
H-17.04	Naturally occurring ionizing radiation /NORM
H-18	**Ionizing Radiation - Closed Source**
H-18.01	Alpha, Beta - closed source
H-18.02	Gamma rays - closed source
H-18.03	Neutron - closed source
H-19	**Asphyxiates**
H-19.01	Insufficient oxygen atmospheres
H-19.02	Excessive CO_2
H-19.03	Drowning
H-19.04	Excessive N_2
H-19.05	Halon
H-19.06	Smoke
H-20	**Toxic Gas**
H-20.01	H_2S, sour gas
H-20.02	Exhaust fumes
H-20.03	Nickel Carbonyl
H-20.04	SO_2
H-20.05	Ammonia
H-20.06	Chlorine
H-20.07	Welding fumes
H-20.08	Tobacco smoke
H-20.09	CFCs (Old Freons)
H-20.10	HCFCs (New Freons)
H-21	**Toxic Liquid**
H-21.01	Mercury
H-21.02	PCBs
H-21.03	Biocides
H-21.04	Methanol
H-21.05	Brines
H-21.06	Glycols
H-21.07	Degreasers
H-21.08	Isocyanates
H-21.09	Sulphanol
H-21.10	Amines
H-21.11	Corrosion inhibitors
H-21.12	Scale inhibitors
H-21.13	Liquid mud additives
H-21.14	Odorant additives
H-21.15	Alcoholic beverages
H-21.16	Recreational drugs
H-21.17	Used engine oils
H-21.18	Carbon tetrachloride
H-21.19	Grey and/or black water
H-21.20	Poly Aromatic Hydrocarbons
H-21.21	Methyl Tertiary Butyl Ether (MTBE)
H-21.22	BTEX
H-21.23	Hexane
H-21.24	Furfaral
H-21.25	MEK

No.	HAZARD DESCRIPTION
H-22	**Toxic Solids**
H-22.01	Asbestos
H-22.02	Man made mineral fibre
H-22.03	Cement dust
H-22.04	Sodium hypochlorite
H-22.05	Powdered mud additives
H-22.06	Sulphur/Sulphur dust
H-22.07	Pig trash
H-22.08	Oil based muds
H-22.09	Pseudo oil based muds
H-22.10	Water based muds
H-22.11	Cement Slurries
H-22.12	Dusts
H-22.13	Cadmium compounds & other heavy metals
H-22.14	Oil based sludges
H-22.15	Catalysts (fresh)
H-22.16	Catalysts (spent)
H-23	**Corrosive Substances**
H-23.01	Hydroflouric acid
H-23.02	Hydrochloric acid
H-23.03	Sulphuric acid
H-23.04	Caustic soda
H-23.05	Spent caustic
H-24	**Biological Hazards**
H-24.01	Poisonous plants
H-24.02	Large animals
H-24.03	Small animals
H-24.04	Food borne bacteria
H-24.05	Water borne bacteria (e.g. Legionella)
H-24.06	Parasitic insects
H-24.07	Disease transmitting insects
H-24.08	Cold & flu virus
H-24.09	HIV
H-24.10	Other communicable diseases
H-25	**Ergonomic Hazards**
H-25.01	Manual materials handling
H-25.02	Damaging noise
H-25.02	Loud, steady noises >85dBA
H-25.03	Heat stress
H-25.04	Cold stress
H-25.05	High humidity
H-25.06	Vibration
H-25.07	Work stations
H-25.08	Lighting
H-25.09	Incompatible hand controls
H-25.10	Awkward location of workplaces and machinery
H-25.11	Mismatch of work to physical abilities
H-25.12	Mismatch of work to cognitive abilities
H-25.13	Long & irregular working hours/ shifts
H-25.14	Poor organization and job design
H-25.15	Work planning issues
H-25.16	Indoor climate
H-26	**Psychological Hazards**
H-26.01	Living on the job/away from family
H-26.02	Working and living on a live plant
H-26.03	Post traumatic stress
H-27	**Security Related Hazards**
H-27.01	Piracy
H-27.02	Assault
H-27.03	Sabotage
H-27.04	Crisis
H-27.05	Theft, pilferage
H-28	**Use of Natural Resources**
H-28.01	Land take
H-28.02	Surface/Ground Water
H-28.03	Air
H-28.04	Trees, vegetation
H-28.05	Gravel
H-28.06	Habitat and Wildlife
H-29	**Medical**
H-29.01	Medical unfitness
H-29.02	Motion sickness
H-30	**Hazardous Goods**
H-30.01	Dangerous goods in transport activities

Appendix 3.
Risk Matrix

RISK ASSESSMENT MATRIX - BUSINESS MANAGEMENT TABLE

	Likeliness Criteria / Increasing Probability									
	Business and Financial	**People**	**Physical Assets**	**Environmental**	**Reputation and Legal**	**Rarely Occurs** **Never/Rarely Heard of in the Industry**	**Unlikely to Occur** **Heard of in the Industry**	**Moderately Occurs** **Has happened more than once per year in the Industry**	**Likely to Occur at Location**	**Almost certain to Occur at Location**
Catastrophic	Financial errors require immediate correction, Senior Management Team and Directors involved	Multiple fatalities and multiple serious Injuries / Illness	Extreme damage to facilities and surrounds. Extensive rework required.	Very serious, long term environmental impairment of ecosystem functions.	Significant prosecution and fines. Serious litigation International Impact. Loss of all business	**HIGH** **8**	**HIGH** **7**	**EXTREME** **3**	**EXTREME** **2**	**EXTREME** **1**
Major	Financial errors require immediate correction, Senior Management Team and Directors involved	Permanent total disability (PTD) or 1 to 3 fatalities	Major damage, resulting in plant shutdown. Major rework required.	Serious, long term environmental impairment of ecosystem functions.	Major breach of regulation. Major litigation National Impact. Loss of business.	**MOD** **15**	**HIGH** **10**	**HIGH** **9**	**EXTREME** **5**	**EXTREME** **4**
Moderate	Financial errors sufficient to require immediate correction, Senior Management Team involved	Serious Injury / Illness (Hospitalisation and lost workdays)	Local damage, loss of production capabilities. Major rework required.	Serious medium term environmental effects	Serious breach of regulations with investigation or report to authority. Prosecution / moderate fine possible. Loss of business.	**MOD** **17**	**MOD** **16**	**HIGH** **12**	**HIGH** **11**	**EXTREME** **6**
Minor	Financial errors sufficient to require immediate correction, Department Manger involved	Medical Treatment (Doctor or Specialist treatment or Restricted work)	Minor damage, brief disruption to operations. Minor rework required.	Moderate, short term effects but not effecting ecosystem functions	Minor legal issues, non-compliance and breaches of regulations Limited Impact. Some loss of business.	**LOW** **23**	**MOD** **19**	**MOD** **18**	**HIGH** **14**	**HIGH** **13**
Slight	Minor financial errors that require addressing. Use of non-approved Suppliers	First Aid treatment for Injury or Illness or no treatment	Slight damage, no disruption to operations. Slight rework required.	Minor effects on biological / physical environment	Minor adverse local public or media attention Minor legal issues Slight Impact. Potential loss of business.	**LOW** **25**	**LOW** **24**	**MOD** **22**	**MOD** **21**	**MOD** **20**

Note: Based on AS/NZS 4360:2004

Appendix 19.21 - Updated 2025 Environmental Impact Statement

TARANAKI VTM PROJECT

VANADIUM RICH IRON SAND EXTRACTION AND PROCESSING PROJECT SOUTH TARANAKI BIGHT

ENVIRONMENTAL IMPACT ASSESSMENT

TTR Pre Feasibility Study

February 2025

1. Introduction

This section of the PFS provides a summary of the existing physical, social and environmental values of the project area and those parts of the STB in its general vicinity. It also, includes an overview of those persons and parties who have an existing interest in the STB which may be potentially affected by the project.

The summary of the existing environment in this section has been informed by a number of technical assessments commissioned by TTR and provides the context against which the actual and potential effects of the project (including potential cumulative effects) have been assessed.

Whereas the STB is defined as the large bay to the south and west of the coastline of Taranaki, extending down to Farewell Spit and the western entrance to Cook Strait, for the purpose of this section it means that portion of the South Taranaki marine environment in the general vicinity of the project.

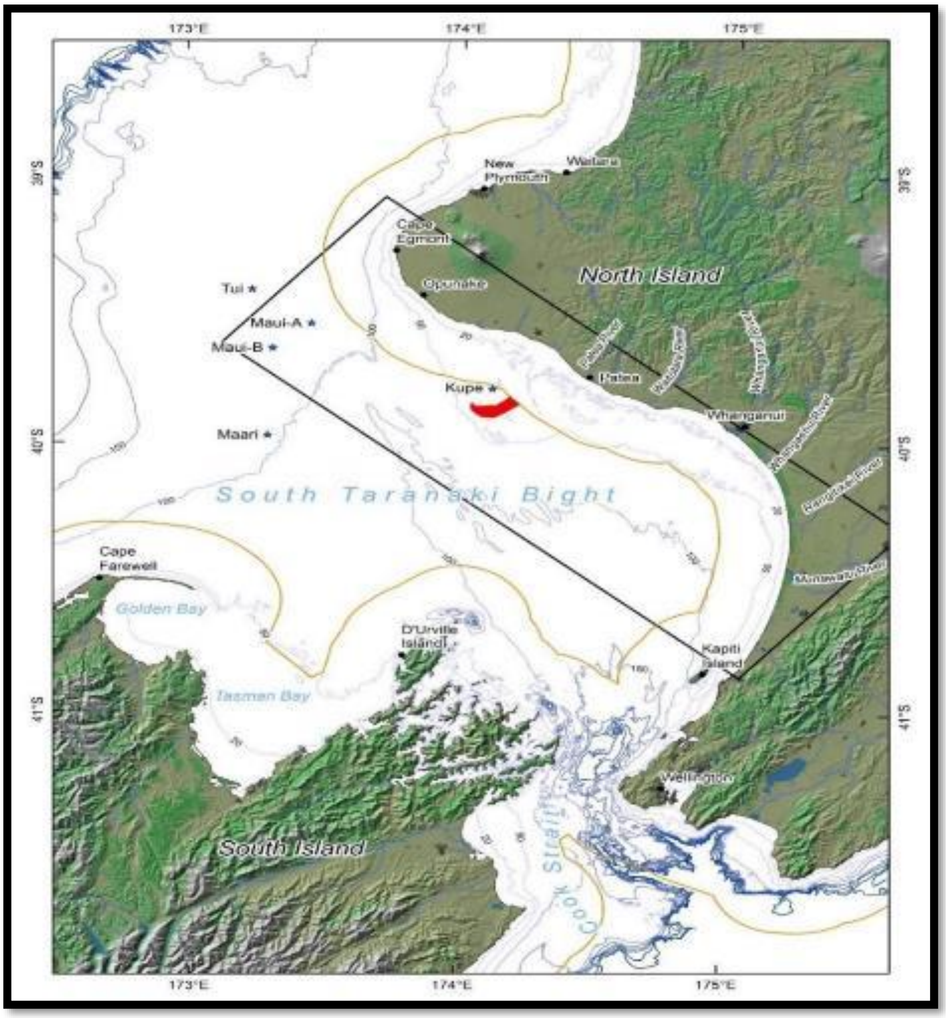


Figure 1 The South Taranaki Bight (STB) showing the Sediment Model Domain (SMD) (oblique black rectangle). The approximate project area is shown in red and the 12 NM boundary of the Territorial Sea is shown in yellow.

2. Existing Communities

Corydon Consultants was commissioned by TTR to undertake a social impact assessment for the project, which included an outline of the existing social environment.

The area with regard to the project is defined at two scales in recognition that the potential project effects could occur across a wide geographic area, with different communities and groups potentially affected in different ways:

The ‘local area’ covers the coastal communities from Opunake to Whanganui city. It is the area with the closest association to the project; and

The ‘wider area’ covers the districts of New Plymouth, South Taranaki and Whanganui, which is the area most likely to experience employment-related effects.

The social setting with regard to the local and wider communities of interest to the project is further summarised in the sections below.

3. Physical Environment

3.1. Climate

TTR commissioned an assessment of the climate and weather of the Taranaki Region by NIWA. This assessment notes that the climate of the Taranaki Region, and by extension the STB, is largely determined by its position in relation to the large scale weather patterns that affect New Zealand. In this regard, the region is exposed to weather systems migrating in an easterly direction across the Tasman Sea and the predominant westerly airstream makes it one of the windiest regions in New Zealand.

The Taranaki Region is generally sunny, with a good supply of evenly distributed rainfall throughout the year and moderate temperatures.

As the project will be located 22 to 36 km offshore it will be highly exposed to winds. The Maui A platform, which is located 70 km northwest of the project area, has had a weather station installed since the 1970s and this has provided a large dataset of weather patterns for the STB. Table below shows the monthly variation in wind speed at Maui A. NIWA considers that a similar pattern can be expected within the project area due to the proximity to the Maui A platform and the lack of any land mass or other factors that may influence the passage of wind in the area.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Maui A Platform	33.3	34.5	37.4	39.4	39.6	39.5	37.8	37.3	43.3	38.8	35.8	34.1	37.6

Table 1 Mean Monthly and Annual Wind Speed (kph) for Maui A Platform.

Other climatic features of the STB and the Taranaki Region:

- Sea surface temperature: averages 14 – 15 ºC throughout the year;
- Air temperature: summer 15 – 22 ºC, winter 8 – 12 ºC;
- Rainfall: 140 days of rain per year, 1,100 – 1,200 mm/year as measured at Hawera;

- Sunshine hours: 2,025 – 2,050 hours per year, as measured at Hawera; and

- Frosts: ground frosts occur 8.5 days/year and air frost occur 1.3 days/year, as measured at the New Plymouth Automated Weather Station.

Data from seven onshore weather stations in the Taranaki Region illustrates that fog occurs approximately 15 days / year, thunder occurs approximately seven days / year, and hail occurs approximately five days / year. It should, however, be noted that the occurrences of these phenomena within the project area is likely to differ from occurrences on land.

4. Oceanography

TTR commissioned an oceanography field programme involving the measurement of currents, waves and sediment transport in the STB. NIWA prepared an assessment of oceanographic measurements data as well as a shoreline monitoring data.

Subsequent to this programme, TTR commissioned NIWA to undertake further field surveys measuring background optical water quality and suspended sediment concentrations within 2.5 km of the coastline of the STB. The various assessments by NIWA are summarised below.

4.1. Oceanographic Measurements

4.1.1. Currents and Tides

Current velocities were measured at five sites across the STB, with recordings taken at various depths through the water column. These results provided a velocity profile over the entire water column. These current velocities show the prevailing patterns of water movement in the STB.

Tidal currents account for a significant proportion of the measured currents in the project area and the STB, covering depths from the 50 m contour to the coast, with the proportion explained by the tidal constituents ranging from 40% to 78%. Between 40 – 80% of the variability in currents was explained by tidal currents occurring on the twice-daily lunar tidal cycle. Peak and ebb current speeds of an averaged twice-daily lunar tidal cycle ranged between 0.13 – 0.25 m/s, with higher and lower speeds occurring on spring and neap tides respectively. The orientation of the tidal flow is in a southeast - northeast direction (i.e. parallel to the coast), which has important implications for sediment plume dispersion.

Current direction and strength can also be substantially affected by wind conditions at the surface. Current speeds of approximately 1 m/s were measured in the upper water column on a number of occasions as a result of high wind speeds. The predominant wind direction recorded was from the west and southeast, with strong winds producing currents in a constant direction for more than 24 hours.

Under calm conditions there is a prevailing current towards the southeast as a result of the influence of the D'Urville Current, which flows past Farewell Spit and into the STB and then towards the southeast. This current drift direction is significantly altered by moderate to strong southeast winds, which reversed the drift towards the northwest.

4.1.2. Wave Environment

The coastal environment out to a water depth of 50 m is a high-energy environment with significant wave heights in excess of 2 m routinely experienced. Significant wave heights of up to 7.1 m were measured during the seven-month instrument deployment as part of the oceanographic studies carried out for TTR. The higher waves recorded generally came from either a south - south-southeast or southwest - west-southwest direction, with a reduction in wave heights as they move towards the coast or down the coast in a south-southeast direction.

4.1.3. Suspended Sediment Concentrations

Measurements taken around the project area and across the Patea Shoals as part of the oceanographic studies by MacDonald et al. (2015a) recorded typical maximum concentrations of suspended fine sediment concentrations of up to 25 milligrams per litre ("**mg/L**"), with higher peaks inshore after significant rainfall or following significant wave activity.

Offshore near-surface suspended fine sediment concentrations were typically less than 10 mg/L. Near the seabed suspended fine sediment concentrations were typically less than 10 mg/L, but were recorded up to 80 mg/L. The highest concentrations were not always associated with rainfall events or wave activity, but could also be a result of advection up current of the area.

Inshore suspended fine sediment concentrations of up to 1,900 mg/L were recorded close to the seabed, mostly associated with high wave activity. It is estimated that sediment transport along this coast is up to 2.1 cubic metres ("$\mathbf{m^3}$") per meter width of seabed during large storm events.

The data demonstrated that periods of increased suspended sediment concentrations coincided with large wave events. During calm periods no suspended sand sediment concentrations were recorded.

Records showed that the largest instantaneous sediment flux, of 0.13 kilograms per second per metre ("**kg/s/m**"), occurred during the highest current speeds at a monitoring site approximately 15 km from shore - between the shoreline and boundary of the project area. During this time the maximum sediment flux within the project area was 0.0519 kg/s/m at the shoreward limit and 0.0002 kg/s/m at the seaward limit of the project area.

5. Nearshore Optical Water Quality

To establish the existing nearshore optical water quality, NIWA completed two boat surveys and collected water samples from 11 nearshore sites across the project area. Further, a six-week deployment of instruments on nearshore moorings in approximately 10 m of water was undertaken to assess temporal variability and establish relationships of optical properties.

Measurements from the boat surveys showed that suspended sediment concentrations and optical variables vary significantly over distance from the shoreline. Suspended sediment concentrations and diffuse light attenuation are greatest closest to shore, and visual clarity increases rapidly with depth and distance offshore.

Data showed there is also a reduction in suspended sediment concentrations and a subsequent increase in visual clarity in the south-southeast direction of the STB. Further, both coloured dissolved oxygen matter and chlorophyll *a* concentrations decreased with depth and distance offshore.

Suspended sediment concentrations also increased as result of increased river flows (and related sediment load inputs), with high suspended sediment concentrations resulting in reduced visual clarity. The data also showed that few nearshore increases in suspended sediment concentrations occurred during periods of high wind speeds and low river discharges, when typically wave stirring entrains seafloor sediment into the water column and affects visual clarity.

6. Sediment Movement

An assessment of the nearshore and offshore sediment movement process occurring in the STB was undertaken by NIWA. They identified that the coastline along the STB is exposed, highly energetic and has been subjected to continual tectonic uplift and erosion over the past 15,000 years. This has produced almost continuous near-vertical, 30 – 50 m tall cliffs along the shoreline. These cliffs are subject to high levels of wind and wave erosion that has left behind a hard shore platform covered by sandy beaches.

Erosion of the sea cliffs and deposition of sediment on the beaches ensures that a continual supply of fresh sediment is transported along the shoreline of the STB, predominantly by wave processes and in a south east direction. Beaches along the coastline of the STB are primarily erosional with a few sections varying between erosional and accretionary, with no set pattern of erosion and accretion along the coast.

South of the Whangaehu River the beaches transition to being primarily accretionary.

NIWA identified that the coastal sediment budget in the STB is largely made up of inputs from longshore transport into the area, onshore transport, river transport and sea cliff erosion. Sediment is lost through longshore transport out of the area, wind transport away from the beach, offshore transport, and solution and abrasion.

The longshore sediment transport is considered large and in the order of 20 million cubic metres (“**m^3/yr**”) per year in the northwest at Ohawe. This reduces south eastward along the coastline to approximately 2 million m^3/yr at Kai Iwi.

7. Shoreline Monitoring

An 11-month beach monitoring programme along the South Taranaki coastline was undertaken to provide background data from which rates of change along the shore could be established.

A network of 32 beach profiles at eight sites was established to monitor the shoreline stability along the STB from Kai Iwi to Ohawe. The sites were selected as lying landward of the project area, away from rivers and headlands which may influence beach processes locally, and where there was public access to the beach.

NIWA identified that the beach profiles show that the shoreline along the South Taranaki coastline is very dynamic, with large changes in the beach profiles occurring at nearly all of the 32 profiling sites. At six sites there was little accommodation space for beach sand, which appears to form a veneer only several metres thick over the rocky shore platform left by the retreating cliff line. Very high tides and waves reach right to the top of the beach and the toe of the cliffs, thus there is no space for sand dunes to build out of the reach of waves.

Given the limited storage, NIWA considers that a large fraction of the entire beach volume is being washed offshore and onshore on a regular basis.

8. River Inputs

Rivers along the South Taranaki coastline deliver sediment derived from the erosion of sedimentary and volcanic rocks in their catchments. These sediment inputs are visible as nearshore plumes of muddy water, some of which can extend several kilometres offshore and along the coast after flood events.

Estimates of the suspended sediment yield from the major rivers along the South Taranaki coastline are provided in Table 3.2 below. The most sediment derives from the Patea, Whenuakura, Waitotara and Whanganui Rivers. The total annual yield from the various rivers is approximately 2,930,600 m^3/year (or 5,861,200 tonnes/year).

River	Catchment Area (km^2)	Mean Flow (m/s)	Sediment Yield	
			tonnes/year	m^3/year
Waiaua	46.4	3.6	4,900	2,450
Kaupokonui Stream	146.3	8.6	9,700	4,850
Waingongoro	233.1	7.8	9,100	4,550
Tangahoe	285.1	4.2	43,900	21,950
Manawapou	120.9	1.9	15,000	7,500
Patea	1,048.5	30.4	310,600	155,300
Whenuakura	465.3	9.9	275,900	137,950
Waiotara	1162.0	23.3	475,400	237,700
Kai Iwi Stream	191.0	1.8	16,900	8,450
Whanganui	7,113.8	229.0	4,699,800	2,349,900

Table 2 Suspended Sediment Inputs from Rivers into the STB.

9. Existing Surface Suspended Sediment Concentrations

As part of the sediment plume modelling for the project, NIWA completed remote sensing to evaluate the background suspended sediment concentrations in the STB. The STB environment can be split into three sections with 5th, 50th (median) and 90th percentiles modelled. Table below identifies the modelled and remote sensed suspended sediment concentrations at three different locations within the STB.

Suspended Sediments Concentration (percentile)	Near coast between Hawera and Whanganui	At the shoreward side of the project area	Beyond the 12 NM territorial limit (near the bottom of the figures)
5th	Modelled - 2 mg/L; Remote-sensed ~ 2 mg/L (but highly variable)	Modelled = 0.01 mg/L; Remote-sensed ~ 0.1 mg/L	Modelled < 0.001 mg/L; Remote-sensed ~ 0.1 mg/L
50th (medium)	Modelled = 10 – 15 mg/L; Remote-sensed = 10 – 20 mg/L	Modelled = 0.3 – 0.4 mg/L; Remote-sensed = 0.5 mg/L	Modelled ~ 0.001 mg/L; Remote-sensed = 0.2 – 0.5 mg/L
90th	Modelled = 40 – 60 mg/L (100 mg/L at Whanganui River mouth); Remote-sensed = 40 – 60 mg/L.	Modelled = 3 mg/L; Remote-sensed ~ 3 mg/L	Modelled ~ 0.01 mg/L; Remote-sensed ~ 1 mg/L

Table 3 Comparison of modelled and remote sensed suspended sediment concentrations within the STB.

The purpose of this exercise was two-fold:

- To establish the existing suspended sediment concentrations in, and around, the project area; and
- To confirm the agreement between the modelled and measured data.

10. Seabed Morphology and Sediments

The assessment of sediment transport notes that the inner continental shelf, out to 50 m depth, is approximately 30 km wide off Hawera, widening to approximately 40 km off Patea, and then narrows immediately south to widths of approximately 20 km wide at Whanganui.

The topography of the shelf off Patea and Waitotara is characterised by banks, shoals and ridges. These features are generally large in size with some individual features offshore from Patea being more than 20 km long and 5 to 10 m in elevation. These features are typically aligned with the dominant north-west to south-east current direction in the STB.

Bedforms in the STB generally consist of two basic types:

- Bedforms in the nearshore zone which are mainly erosional; and
- Bedforms located offshore zone which are depositional.

Erosional bedforms typically occur in water depths less than 30 m and comprise elements such as rock outcrops and ancient buried river valleys from differential weathering of the underlying Plio-Pleistocene mudstone. In contrast, at water depths greater than 30 m storm-generated depositional bedforms occur, including dunes and ridges, sand ribbons, symmetrical mega-ripples and sand waves.

The largest sediment body bedforms in the STB are situated immediately southeast of the mouth of the Whanganui River. These deposits are typically 4 – 12 m high, several hundred metres wide, several kilometres long, and aligned sub-parallel to the coastline. Their surface is composed of iron sand and volcanic pebbles, interpreted to be sourced from Mount Taranaki. These sand ridges are located on a relatively flat area of the seafloor of the STB.

Within the intervening troughs is a complex array of smaller active bedforms, including sand ribbons, ripples, symmetrical mega-ripples and sand waves. These bedforms persist to water depths greater than approximately 50 m and have presumably been formed by strong oscillatory currents approaching 1 m/s that occur during the passage of large storms.

Seabed sediments vary from fine sands to gravelly fine sands, although sediments are mostly fine to medium sands with a general trend of more fine sand to the north and west of the STB, and a greater proportion of coarse sand and gravel / shell to the south and west, as shown in Figure 2 below.

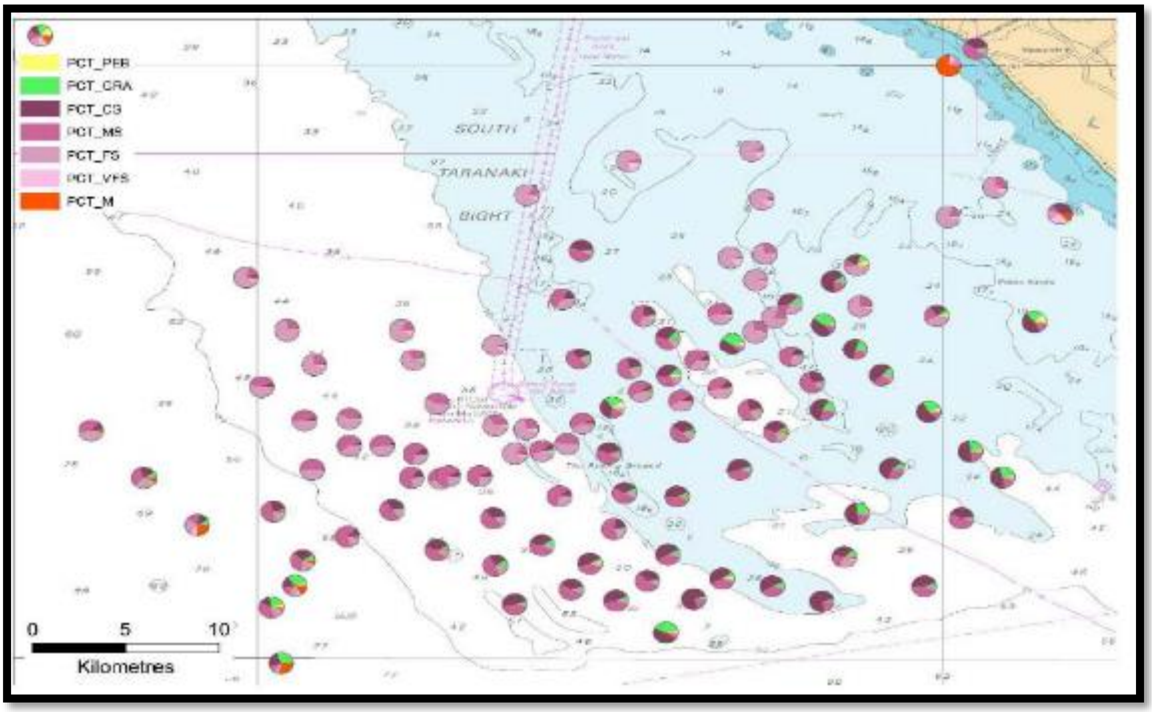


Figure 2 Grain size of the sediments in the STB. The data shown as percentages in different size classes. PCT_PEB: pebbles, PCT_GRA: gravel, PCT_CS: coarse sand (500 µm – 1.6 mm), PCT_MS: medium sand (250 µm – 500 µm), PCT_FS: fine sand (125 µm – 250 µm), PCT_VFS: very fine sand (63 µm – 125 µm), PCT_M: mud (<63 µm).

10.1. Seabed Sediments Chemistry

TTR commissioned Auckland University of Technology to assess the potential for the project to displace, modify and suspend anoxic sediment, and make sediment bound contaminants available to biota. To understand these potential effects, AUT (2013) investigated the following:

- Selected physical properties of the target sediment;
- The sediment content of acid volatile sulfides and simultaneously extracted trace metals; and
- The concentrations of trace metals in suspensions of sediment in seawater.

This was determined through the collection of one sediment core and 20 L of seawater at five sites within the project area in June 2012, and sediment slurry and 20 L of seawater at two further sites in February 2013. AUT (2013) found that, as expected for high-energy offshore environments, the low organic matter content (less than 1% dry weight) of the medium sand in the project area explained the low sediment content of acid volatile sulfides. There was no evidence for an increase with depth below the seafloor in sediment organic matter and acid volatile sulfides contents.

The concentrations of dilute-acid soluble cadmium, copper, lead and zinc in deep sediment were of the same order of magnitude as their maximum concentrations in surface sediment. For cadmium, copper and zinc, there was no evidence for consistent trend of increasing concentrations with increasing sediment depth below the seafloor. The sediment concentrations of lead decreased with depth below the seafloor at three of five sites.

The concentrations of dilute-acid soluble chromium and nickel in deep sediment were often one order of magnitude higher than their maximum concentrations in surface sediment. Furthermore, at four of five sites, chromium and nickel concentrations increased with increasing depth below the seafloor. Additional analyses of sediment slurry collected to a maximum depth below the seafloor of 18 m, however, did not reveal evidence for such trend. No consistent increase with depth in the concentrations of dissolved nickel in the slurry was found. The concentrations of chromium in the slurry were below the detection limit.

For all metals except nickel, the concentration in seawater suspensions of deep sediment (elutriate) were either below detection limit (chromium, copper, lead, zinc) or, if a metal was detected (cadmium), the concentration did not exceed the Australian and New Zealand Environment and Conservation Council ("**ANZECC**") and Agriculture and Resources Management Council of Australia and New Zealand ("**ARMCANZ**") guidelines for the protection of 99% of species. The detection limit of copper was below the guidelines for the protection of 95% of species.

The concentrations of nickel in the seawater suspensions of deep sediments (all five sites) and surface sediment (three of five sites) were equal or larger than the ANZECC & ARMCANZ guideline concentrations for the protection of 99% of species. However, the nickel concentration never exceeded the guideline concentrations for the protection of 95% of species.

11. Benthic Ecosystems

11.1. Nearshore Epibenthos / Shallow Infauna

An assessment of the benthic habitats, macrobenthos and surficial sediments of the nearshore environment was undertaken by NIWA.

Sampling of 36 seabed sites was undertaken between February to March 2013 using underwater video and still images, followed by the collection of representative grab samples and benthic dredge collections for sediment and microbenthic surficial samples. The location of the sampling sites along the South Taranaki coastline are shown in Figure below.

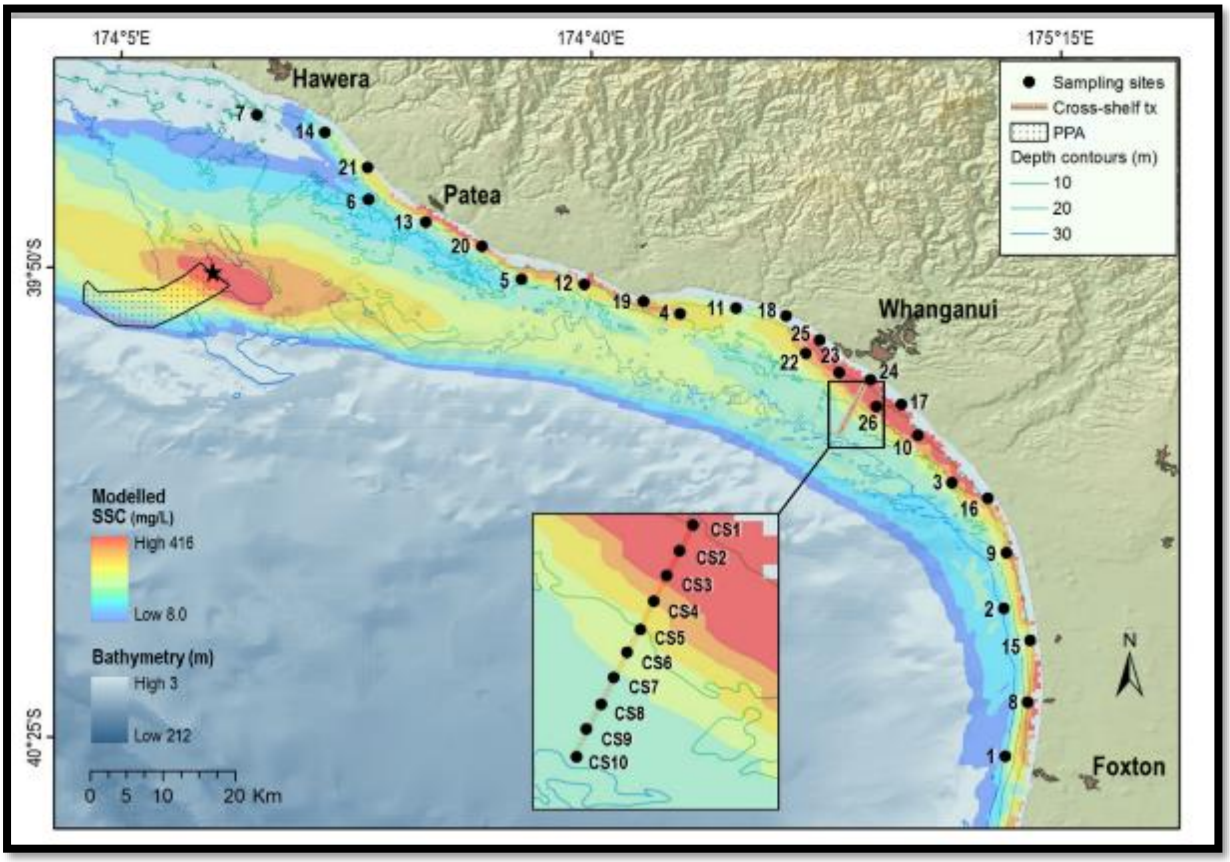


Figure 3 Location of sampling sites relative to the predicted bottom suspended sediment concentrations (SSC) of extraction-derived sediment within the STB. SSC values represent 95th percentile for releases from the dredging source (black star = Source B in NIWA, 2012) within the proposed project area (PPA). Sites 1-26 = nearshore sites (main figure), Sites CS1-CS10 = cross-shelf transect sites (insert).

Rocky outcrops made up five of the 36 sites and generally consisted of hard rock and soft to moderately soft mudstone. These outcrops supported more abundant and diverse epibenthic assemblages characterised by bryozoans, macroalgae and sponges, as well as more motile species, such as crabs, amphipods, starfish, brittle stars, gastropods and polychaete worms.

Hard rock outcrops accounted for more than 25% of all specimens and 61% of all species collected during the survey. Mudstone outcrops supported low or negligible amounts of epibenthos (less than 2.5% of specimens).

The remaining sites consisted primarily of soft-sediment structures, which are characterised by fine rippled sands with low and variable numbers of small motile epifauna – mostly hermit crabs, gastropods, and a few suspension-feeding bivalves. These species are presently subjected to regular sediment disturbances from storm events and river runoff, and are likely to be tolerant to deposition of sediments and constant disturbance.

The mudstone outcrops present in the nearshore area are typically covered in fine silt with few epibenthic organisms present. The typical seabed strata of the sites are shown in Figure 3.4 below.

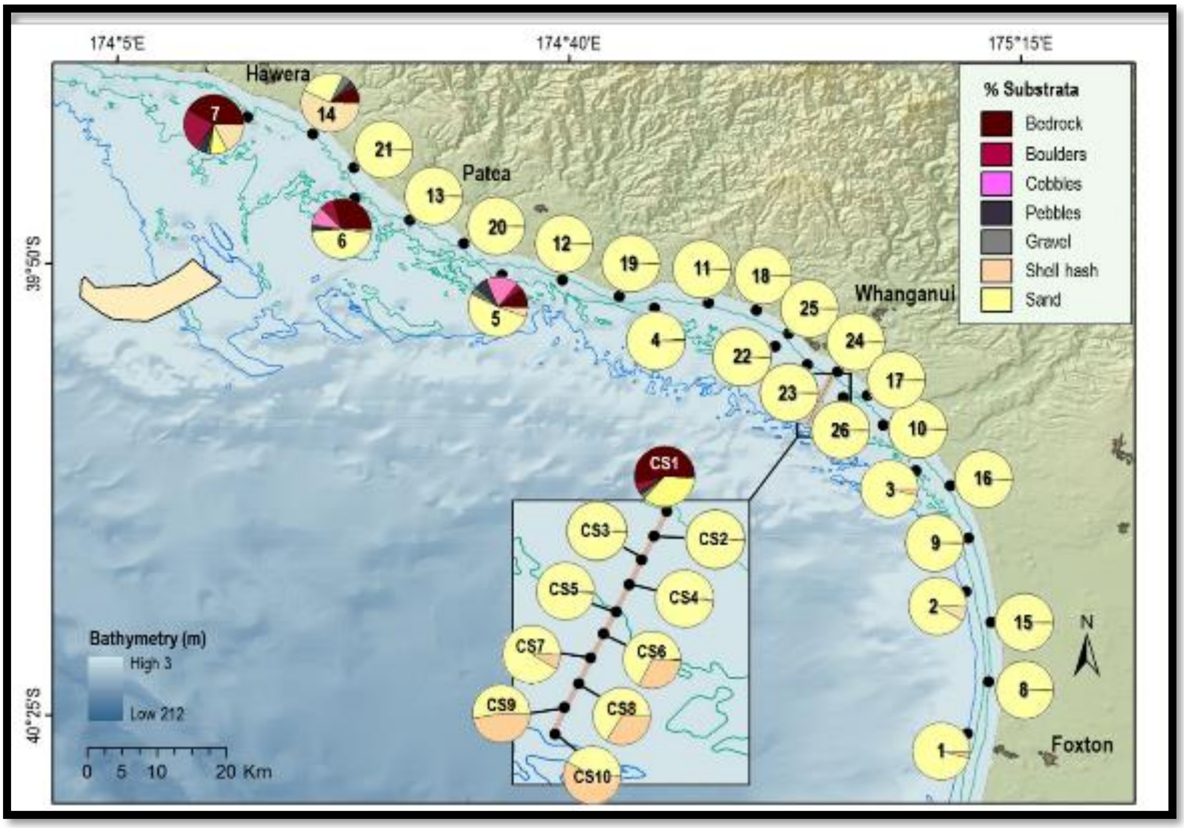


Figure 4 Seabed substratum types at nearshore (1-26) and cross-shelf transect (CS1-CS10) sites within the STB.

Other habitats and organisms present include macroalgal and suspension-feeding species associated with hard rock outcrops, primarily being diverse bryozoan and sponge dominated assemblages.

11.2. Offshore Benthic Ecology

The Patea Shoals is an area of seabed located between 25 and 40 km off the coast of Taranaki in water depths of between 25 and 45 m which includes the project area, as generally shown in Figure. NIWA conducted a survey on the benthic fauna in this area in 2013

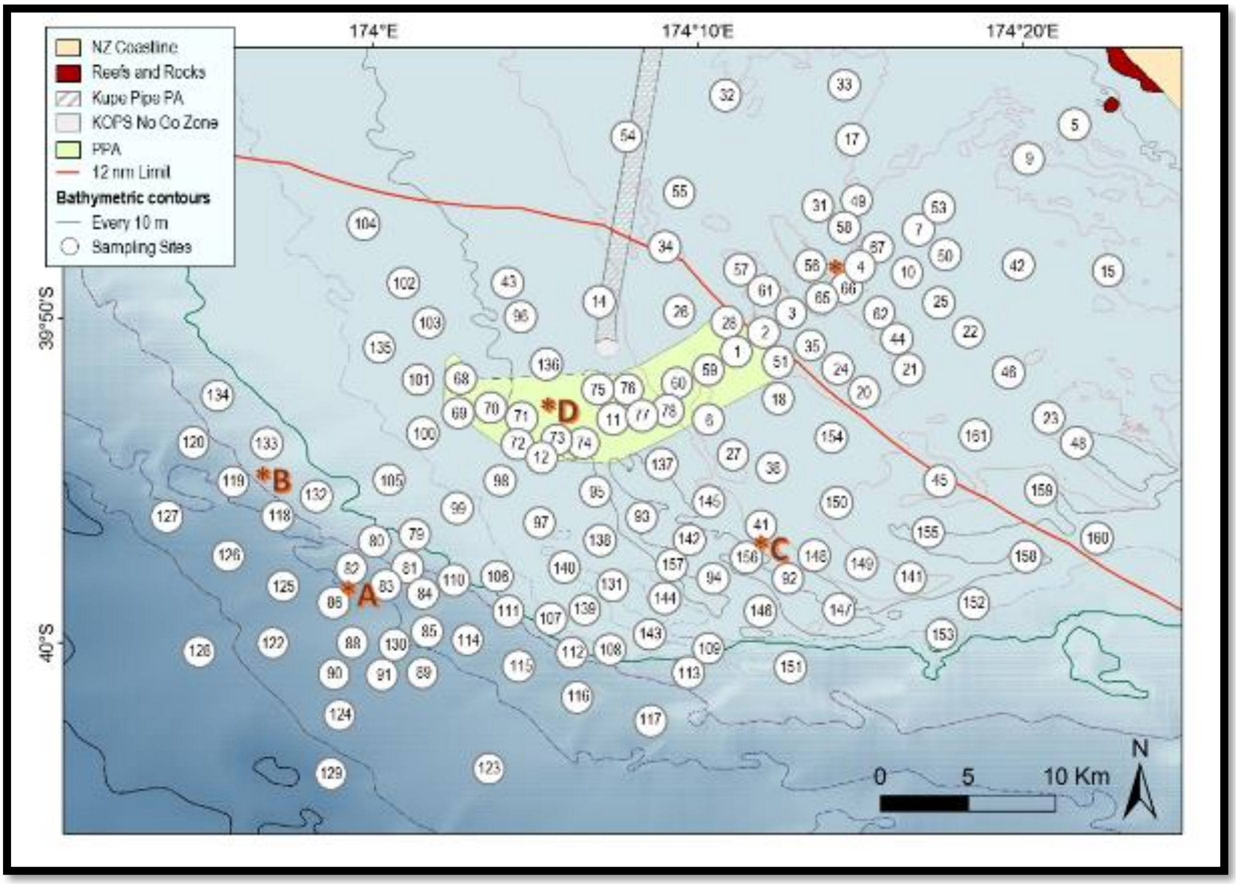


*Figure 5 Location of sampling sites across Patea Shoals within the STB. PPA= Proposed Extraction Area; Kupe Pipe PA = Kupe Pipe protected area; KOPS no go zone = Kupe Oil Platform Safety no go zone. Depth contours are in 10 m intervals. *A-*C indicate TTR's preliminary deposition-assessment areas, *D indicates TTR's proposed extraction/deposition area/PPA. '*' depicts the inner shelf area prior to contraction of the PPA area.*

Seabed habitats and macrobenthos were visually characterised at 144 sites using underwater video footage and still photographs. Surficial sediments and associated infauna were collected from 331 samples at 103 sites, while benthic macrofauna and macroflora specimens were collected from 116 sites using a benthic dredge. Figure 6 identifies the seabed habitat sites in and around the project area. It identifies that the sites typically consist of sand waves and worm communities (i.e. wormfields).

Seven habitat types were identified with the most common being rippled sand. Large parts of the seabed were characterised by wormfields which were dominated by *Euchone sp A,* with some very dense patches in the central and mid-shelf zone. Generally inner and mid-shelf habitats supported few visible epifauna apart from small scattered rocky outcrops on the inner shelf which had diverse epibenthic assemblages.

Deeper reefs offshore were characterised by two habitat types:

- The bivalve rubble habitats dominated by the large robust dog cockle (*Tucetona laticostata*), with live animals at depths of between 26 and 83.5 m and shell debris at depths of between 44 and 69 m; and
- The bryozoan rubble habitat at depths of greater than 60 m forming a habitat with generic shell debris.

These habitats support diverse assemblages dominated by sessile suspension-feeding taxa (e.g. bryozoans, sponges, ascidicans, brachiopods and epiphytic bivalves) and a number of motile taxa such as crabs and gastropods.

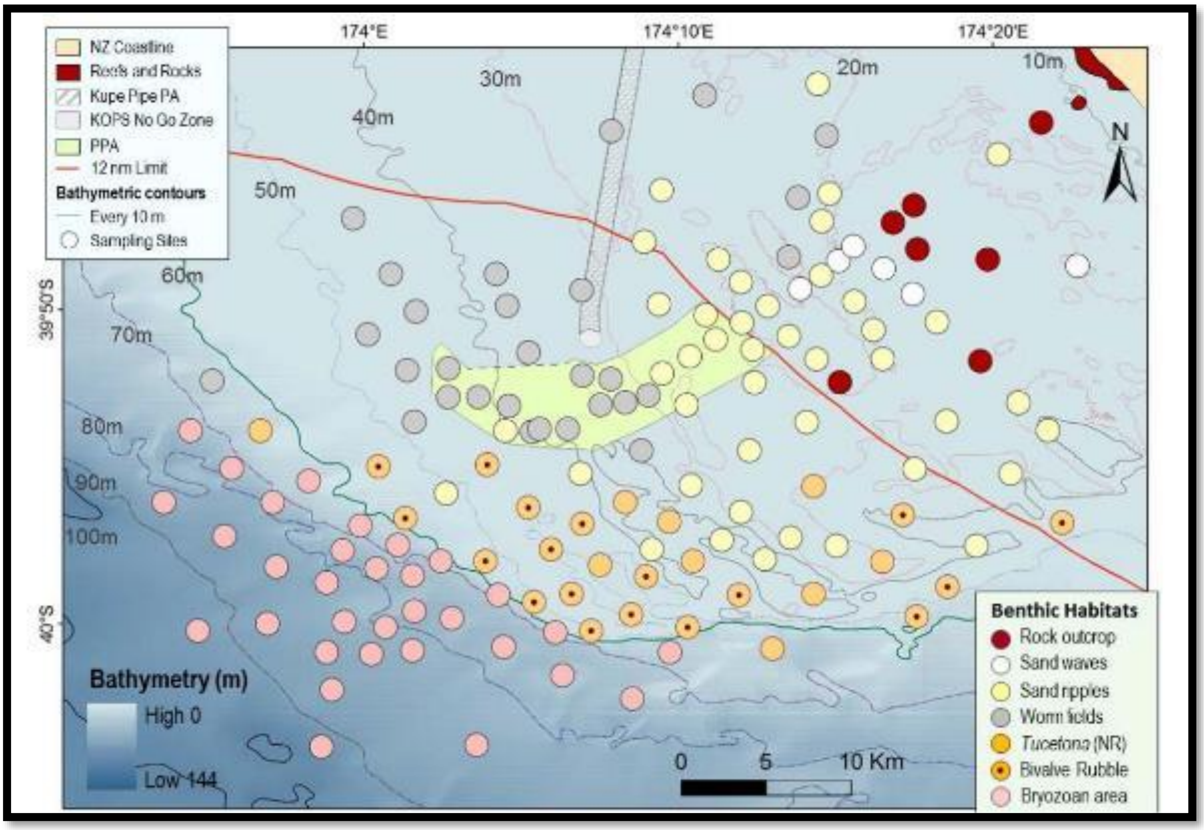


Figure 6 Seabed habitat types observed at each site within the Patea Shoals area of the STB.

Sediment and infauna sampling found that the mid and inner shelf habitats were characterised by low abundance and species richness, typical of highly disturbed sediments and the region in general. Beaumont et al. (2015) identifies that there is no evidence that the project area is unique with respect to benthic epifauna or infauna.

In contrast, the deeper offshore benthic habitat supports a diverse and abundant epifaunal community associated with shell hash and bryozoan rubble and is dominated by suspension-feeding taxa. The shallower bivalve rubble habitat supports early successional stages (encrusting corraline algae, small encrusting invertebrates), while the deeper bryozoan rubble habitat supports later successional stages (certain bryozoans, sponges and higher numbers of motile taxa). Bryozoan rubble habitats also supported significantly higher abundances of infauna.

Microphytobenthos (or small algae found on the seabed) are usually found on sandy sediments and where there is sufficient daily light reaching the seabed. Although there are no direct measurements of microphytobenthos from the Patea Shoals, as they are likely to occur there as they are found in similar environments in other parts of the world and seabed images have shown sediment-water interface features, such as colour, which is consistent with their presence.

12. Primary Productivity

12.1. Phytoplankton

TTR commissioned NIWA to undertake a baseline assessment of the STB. It identifies that the STB is a dynamic region with plankton communities and primary production influenced by local drivers such as light, nutrient availability and grazing. Plankton communities are also influenced by advective processes such as upwelling from the Kahurangi Shoals and the rivers that discharge into the STB. It is important to note that NIWA concludes that nutrients are the main limitation on primary production rather than light availability based on observed nutrient levels, phytoplankton biomass and primary production.

NIWA used locally-tuned algorithms and 10 years of satellite observations (2002 – 2012) to assess mean conditions and characterise water constituents such as chlorophyll *a* concentrations, which provide a proxy for phytoplankton biomass. Based on the satellite data and some ground-truthing, NIWA found that elevated levels of chlorophyll *a* could be attributed to two processes - nutrient input from rivers and advected material from further afield.

Long-term median chlorophyll *a* levels were highest close to the coast (5 microgram per litre ("**µg/l**")) as a result of river runoff, and decreased to an annual median of 0.2 µg/l offshore (greater than 10 km from the shoreline). Intermittent blooms occur offshore, but can be spatially large and cover much of the STB. It is thought that some of these larger blooms result from dynamic processes associated with the upwelling off the Kahurangi Shoals and possibly, at times, the Cook Strait. In some cases these blooms can exceed 4 µg/l.

NIWA also reported a seasonal component to satellite derived chlorophyll *a* concentrations, with spring peaks at most sites in the STB. However, there was evidence of winter peaks also occurring inshore and at the deeper sites to the north.

Median chlorophyll *a* concentrations are relatively high across the northern and eastern parts of the STB throughout the year, with an overall range of between 0.02 – 32 µg/l (median 0.57 µg/l). This compares to values less than 0.1 µg/l for clear blue waters. More recent surveys by NIWA have added to the database on phytoplankton and found chlorophyll *a* concentrations greater than 1 µg/l immediately to the east of the project area, which is an indication of localised algal blooms.

Further, phytoplankton blooms appear to peak in spring time from an offshore origin 80 km west of the project area and is transported by advection through the STB and into the Cook Strait. No significant long term trends in the chlorophyll *a* concentrations were observed.

12.2. Zooplankton

Zooplankton are microscopic animals which float around in the currents, mostly in surface waters. They range in size from small single celled protozoa to copepods and larval crabs, molluscs and fish as well as the large euphausiids or krill. They play a critical role in marine food webs and are the link between primary producers, fish and marine mammals.

As identified in the NIWA baseline environmental survey of studies of zooplankton where undertaken during the 1970s and 1980s, with additional studies completed in 2015. This information concluded that the zooplankton ecology of the STB was largely influenced by upwelling events off the Kahurangi Shoal and Cape Farewell.

An assessment of zooplankton for the project and concluded that zooplankton species in the STB are typical of those found in coastal waters around New Zealand. The STB is also considered to be very productive. In this regard, biomass estimates are among the highest recorded when considered against other coastal regions around New Zealand.

It was identified that the Greater Western Cook Strait Region (including the STB, Tasman and Golden Bays, and bounded by the Cook Strait Narrows) is impacted by several large-scale, highly variable, physical phenomena that structure the distribution and biomass of zooplankton. These large-scale physical processes include the Kahurangi upwelling plume, tidal mixing, river plumes and surf beach processes. Of these, the Kahurangi upwelling plume is the best understood in terms of plant nutrient renewal, which impacts primary production and dynamics, and its downstream impact on the zooplankton.

With respect to the STB, it is influenced by the D'Urville Current and the Kahurangi upwelling which bring in colder, nutrient rich waters. The nutrients drive primary production as the water is advected around the top of the western side of the South Island and into the STB. As upwelled water is advected into the STB, carbon production was found to exceed utilisation by larger zooplankton, potentially providing a net carbon source. However, much of this is likely to be utilised by smaller micro-zooplankton. These upwelling events are also thought to be important for the squid aggregations which occur in the lower reaches of the STB.

The zooplankton populations of coastal waters in the STB, when not dominated by the zooplankton species *salps*, are likely to be dominated numerically by the copepod *Oithona similis*, and moderately large numbers of *Acartia ensifera*, *Clausocalanus jobei*, *Paracalanus c.f. indicus* and copepod *nauplii*. The findings concluded that omnivorous copepods dominate (66%), with 34% herbivores and 0.1% carnivores. No information is available on zooplankton assemblages in very shallow nearshore waters (mean depth of 8 m)) where orbital velocities are very high.

There was no obvious spatial pattern in zooplankton biomass distribution when comparing inshore to offshore distribution, but highest biomasses were found to occur over the Patea Shoals and east towards Whanganui;

Copepods dominated most sites sampled with salps and juvenile euphausiids dominating the sites with the highest biomass. Most of the copepods were omnivores and dominated by *Oithona* and *Paracalanus*; and

The community was typical of nearshore waters and, as would be expected, was dominated by neritic or coastal species.

12.3. Polychaete Worm Communities

Beaumont et al. (2015) identifies that of the annelid worms, polychaetes were the most abundant (97% of annelid worms, 90% of all worms) with a total of 4,190 polychaete worms from 87 species / groups collected from the surface sediments within a study area that included the project area and the Patea Shoals.

Most seaworms are poorly known in New Zealand and not identified at species level. Figure below sets out the polychaete abundance within the top five centimetres of the seabed in, and around, the project area.

Polychaete abundance was highest inside, and to the north of, the project area - including sites along the Kupe wellhead pipeline. In contrast, the rippled sediments in the southern mid-shelf supports much lower abundances of worm. Species richness, however, was more evenly distributed across the STB.

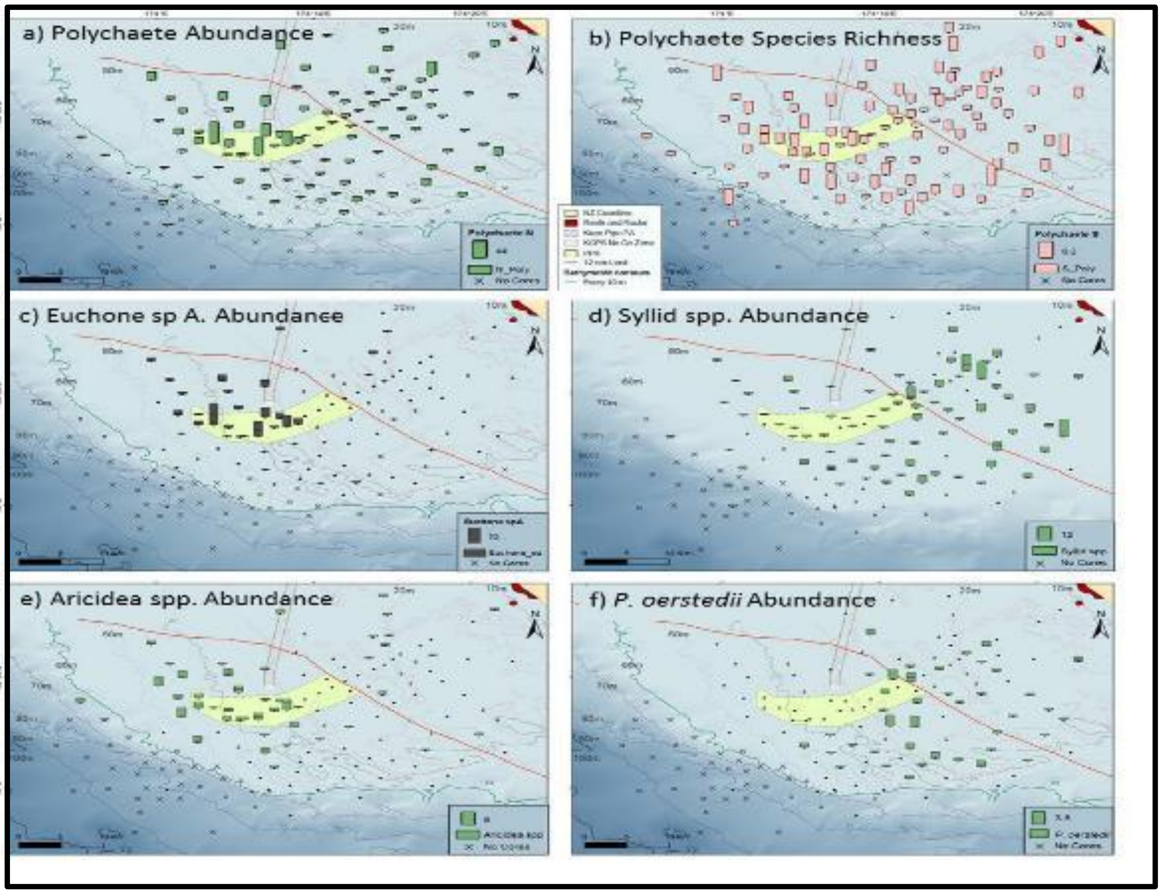


Figure 7 Spatial distribution of polychaete worms/site for top 0-5 cm section of sediment. Notes: a) The green bars represent the mean number of individuals (N) collected; b) The light brown bars represent the mean number of species/OTU's (S) collected. c-f) Mean numbers p/site of: c) Euchone sp A; d) Syllid spp; e) Aricidae spp; and f) Pisione oerstedii, per site. Relative scale bars are provided in the legend of each graph.

13. Fish Species

The following section contains a summary of the distribution and movement of fish species as they relate to the project area. This information is based on an assessment of the fishery in the STB that was undertaken by NIWA in 2013, and updated in 2015.

13.1. Oceanic Fish

A wide range of species have predicted distributions in the STB. The species present within the project area include barracoota, blue cod, carpet shark, eagle rays, John Dory, golden mackerel, kahawai, leatherjacket, lemon sole, red cod, red gurnard, rig, school shark, snapper, spiny dogfish, terakihi, trevally, common warehou and witch. None of these species are recognised or listed as being endangered or threatened.

13.2. Reef Fish

The distribution of reef fish in the STB was predicted based on models developed from comprehensive dive surveys and habitat information. MacDiarmid et al. (2015b) considers that the STB has a moderately diverse reef fish fauna with 38 species likely to be found (compared with 72 species modelled around New Zealand by Smith (2008)).

None of the modelled species are nationally threatened however, two species, being black angelfish and common roughy, are rare in the STB. They occur in low abundance on just a few coastal reefs and six other species have restricted distributions occurring at less than 50% of the reef sites in the STB.

All other 29 species are predicted to be much more widespread and either occur in low abundance throughout the STB (14 species), are moderately common over the entire area (13 species), or are abundant widely distributed species (two species).

13.3. Demersal and Pelagic Fish

Demersal (bottom dwelling) and pelagic (open water and in the water column) fish species occur throughout the STB, supporting commercial, recreational and customary fisheries.

MacDiarmid et al. (2015b) provides a description of the distribution of these species based on models developed from trawl surveys throughout New Zealand, statistical relationships with habitat, as well as from a literature review for all species. Depth, temperature and salinity have been found to be the main predictors of demersal species abundance.

MacDiarmid et al. (2015b) identifies 51 species of demersal fish occurring in the STB. The richness of this assemblage was similar to that recorded off the west coasts of both the North and South Islands, but was slightly lower than in depths less than 50 m off Patea and slightly higher compared with inshore to the southeast of the STB (i.e. Kapiti to Whanganui). Overall, the species richness is moderate on a New Zealand wide basis.

A few species are very widespread and abundant, but most species are common only within a restricted depth range. MacDiarmid et al. (2015b) also reported earlier work that found evidence of spawning activity by 13 demersal and pelagic fish species in the STB, along with juveniles of 24 species. However, the surveys were based on areas with water depths greater than 20 m.

Species with their main distribution along the coastline of the STB, that coincide with the project area and the surrounding environment, include anchovy, blue cod, eagle rays, red gurnard, golden mackerel, leatherjacket, lemon sole, snapper, rig and trevally.

13.4. Spawning and Juvenile Fish – General

MacDiarmid et al. (2015b) identifies that there is evidence of spawning, pupping or egg-laying along the ocean shelf in the southwest of the North Island by lemon sole, New Zealand sole, rig, sand flounder, yellow-belly flounder and yellow-eyed mullet, and possible breeding of blue cod, John Dory, kahawai, kingfish and sea perch.

Other reports reviewed by MacDiarmid et al. (2015b) show low abundances of juveniles of the following species were present within the STB: arrow squid, barracoota, blue warehou, giant stargazer, jack mackerel, John Dory, kahawai, kingfish, red gurnard, rig, sea perch, school shark, snapper, spiny dogfish, terakihi and trevally.

Juveniles of eight other species are listed but no abundance estimate is provided because of insufficient data. These species included blue cod, grey mullet, horse mackerel, New Zealand sole, red cod, silver warehou, yellowbelly flounder and yelloweyed mullet.

13.5. Crayfish

Crayfish are the largest and most abundant invertebrate predator on rocky coastal reefs throughout New Zealand.

Crayfish occur predominantly on rocky reefs from the shallow subtidal to depths of 50 m, but in some areas they are found as deep as 250 m. Crayfish are mobile for a number of reasons including moulting, reproduction and feeding. The distance travelled depends on the crayfish's maturity and typically ranges from a few metres to multiple kilometres. It has been identified that crayfish have a 'home reef' that they will return to throughout their lifetime.

Immediately after mating and malting in winter and summer respectively, crayfish migrate offshore across sand flats to feed off shellfish, and egg-brooding female make for offshore aggregations in areas of high water current in spring during larval hatching. Although the exact migration areas for crayfish are unknown, due to the distance offshore and lack of suitable habitat, it is not considered likely that crayfish would be present within the project area. However, they will be present within the rocky areas of the coastline as this is their preferred habitats outside of their mitigation areas.

13.6. Freshwater Migratory (Diadromous) Fish

New Zealand has 35 species of freshwater fish, most of which are endemic and almost half are diadromous – meaning that they spend part of their lifecycle at sea.

Depending on the species, the part of their lifecycle spent in a marine environment may be eggs and larvae, juveniles or adults. Important customary fisheries exist for a number of diadromous fish including lampreys, short and long fined eels and whitebait (galaxids).

13.7. Lampreys – Piharau

New Zealand has one species of lamprey, which is widely distributed and is likely to be found within the project area. Spawning occurs in freshwater where larvae spend approximately four years as filter feeders before metamorphosing and migrating to the marine environment. Lamprey typically spends three - four years of its lifecycle in the ocean where it feeds by attaching itself to other animals and feeding by rasping holes in their flesh. They then return to freshwaters and spend 16 months reaching sexual maturity before spawning and dying.

13.8. Freshwater Eels – Tuna

New Zealand has two species of eel; shortfin and longfin. The shortfin eel occurs throughout the South Pacific, while the longfin eel is endemic to New Zealand.
Adult eels are thought to breed in the deep ocean trenches to the northeast of New Zealand, although the migration routes are not entirely understood. Transparent leaf-like larvae drift on ocean currents for over a year before reaching the coastline of New Zealand and entering the freshwater environment in the more familiar eel shape.

Eels spend many years in streams, rivers and lakes (approximately 14 and 25 years for male and female shortfins respectively, and 25 and 40+ years for male and female longfins) before migrating downstream to make their way their tropical spawning sites.

While specific information on the presence of eels within the STB and the project area is unknown, it is considered that any presence of eels would be short-term in nature as they migrate towards their spawning sites in the South Pacific.

13.9. Whitebait – Inanga

Whitebait or inanga is a general term applied to juvenile galaxids of five different species; *Galaxias argentenus, G. brevipinnis, G. fasciatus, G. maculatus, and G. postvectis.* All five species occur in the Taranaki Region and have a similar life cycle.

Newly hatched larvae are swept down rivers and out to sea, where they spend their first six months feeding and growing. Where they live during this phase is unknown. Juvenile galaxids re-enter streams and rivers in spring, migrating back to their upstream environments.

However, due to the distances offshore, it is not considered likely that whitebait will be located within the project area.

14. Marine Mammals

Ching et al. (2015) includes a review of whale and dolphin populations in the STB using cetacean sighting data from the Department of Conservation ("**DOC**") and a dataset of incidental sightings by transit cargo ships in the STB provided in a cetacean monitoring report by Martin Cawthorn Associates on behalf of TTR (Cawthorn (2015)). This observation data noted in Ching et al. (2015) is only presence data (not presence / absence data) and because a species is not present does not necessarily mean that it does not frequent these waters.

In summary, Ching et al. (2015) identifies there has been relatively few cetacean sightings along the north and southern Taranaki Bight but the endangered or critically endangered Maui's dolphin, killer whale and southern right whale have been sighted within the Taranaki Bight. The full table of data is included in the table below.

Species	**Threat Classification**	**Spring**	**Autumn**	**Summer**	**Winter**	**Unknown**	**Total**
Blue whale (*Balaenoptera musculus*)	Migrant			1		1	2
Bottlenose dolphin (*Tursiops truncatus*)	Range restricted			1			1
Common dolphin (*Delphinus* spp.)	Not threatened	2	2	5	5	1	15
Dusky dolphin (*Lagenorhynchus obscurus*)	Not threatened	1	3				4
False killer whale (*Pseudorca crassidens*)	Not threatened			1			1
Fin whale (*Balaenoptera physalus*)	Migrant			1			1
Humpback whale (*Megaptera novaeangliae*)	Migrant	3		2	10		15
Killer whale (*Orcinus orca*)	Nationally critical			3		3	6
Maui's dolphin *Cephalorhynchus hectori maui*)	Nationally critical			2			2
Pilot whale (*Globicephala* spp.)	Not threatened	5	1	6			12
Sei whale (*Balaenoptera borealis*)	Migrant			1			1
Southern right whale (*Eubalaena australis*)	Nationally endangered	1			1		2
Sperm whale (*Physeter macrocephalus*)	Migrant			2			2
Total		**12**	**6**	**25**	**16**	**5**	**64**

Table 4 Cetacean sightings in the STB by season from DOC and Cawthorn datasets.

Maui's dolphin, which are a sub-species of Hector's dolphin, are classified as a critically endangered species. Their density has been identified for the STB as being less than 0.0005 dolphins per square nautical mile. Density increases north of Cape Egmont, peaking between the Raglan and Manukau Harbours, and extending to Kaipara Harbour. The distribution of Maui's dolphin is presented in Figure 3.8 below.

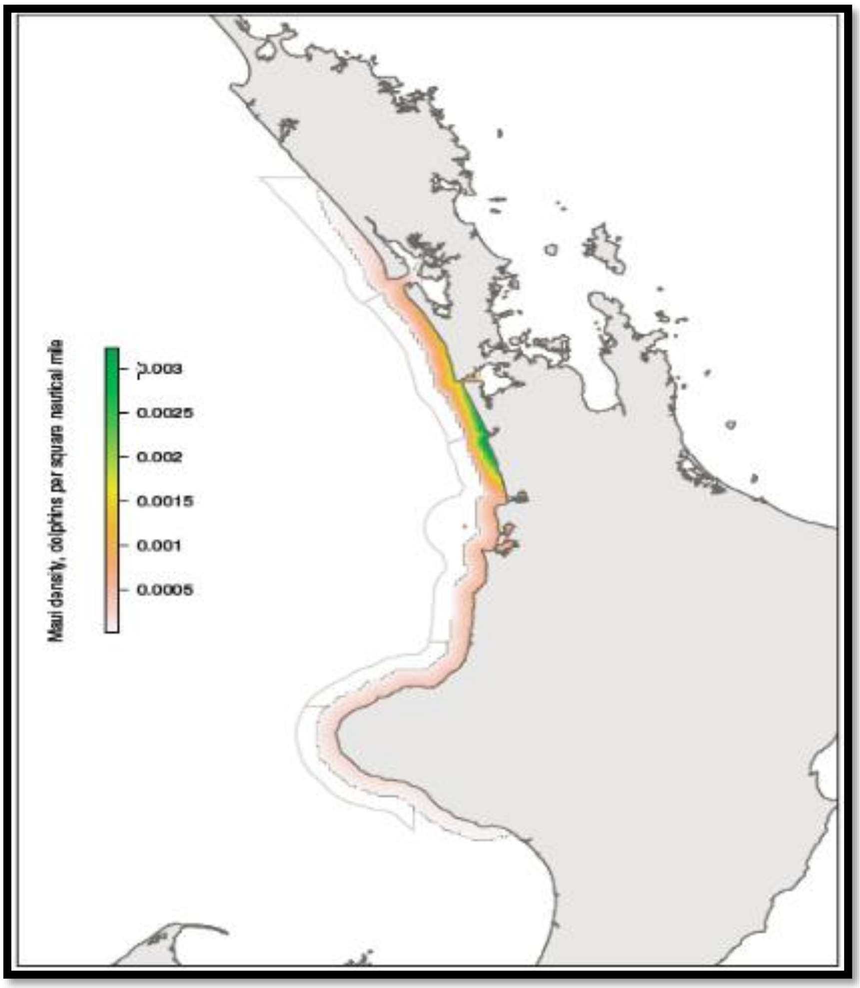


Figure 8 Maui's Dolphin distribution

Killer whales are classified as a nationally critical threatened species in New Zealand. Between 1980 and 2005 there were three sightings within the STB. The entire New Zealand population is less than 200, with broad distribution patterns across the North and South Islands. Killer whales may transition through the STB or use the area to forage for prey.

Southern right whales are considered nationally endangered due to whaling reducing population to an estimated 1,000. Southern right whales follow traditional annual migration routes between southern summer feeding areas and nearshore calving grounds in winter. They are mainly sighted in the waters around the Auckland and Campbell Islands, but there are occasional sightings around New Zealand, which may represent re-colonisation of breeding grounds largely unused since the 1830s. Two sightings have been recorded in the STB, a cow / calf pair in the spring of 1983 and the other a solitary animal in the winter of 2004.

NIWA was also commissioned to complete habitat modelling of the STB relating to the three endangered species (Torres et al. (2015)).The purpose of Torres et al. (2015) was to gain further understanding of the suitability of the STB as a marine habitat for these endangered species.

Habitat suitability for Hector's dolphin, and subsequently Maui's dolphin, in the project area is low;

Low habitat suitability for killer whales was predicted in the project area. A band of average to above average habitat suitability for killer whales, corresponding to an area of increased sea surface temperature gradient, begins approximately 8 km seaward of the project area; and

Low habitat suitability for southern right whales was predicted at and adjacent to the project area. A coastal strip within 5 km of the shoreline, had low to moderate suitability for this species suggesting that individuals may use this area as a migration corridor.

Cawthorn (2015) also undertook a survey of the marine mammals within the STB. A total survey time of 50 hours and 11 minutes was recorded, with a flight distance of 8,426 km. During this time a single pod of six to eight common dolphins and a total of seven fur seals and various other fauna (e.g. seabirds, fish and sharks) were observed.

Joint expert conferencing was held on 26 March 2014 as part of the previous marine consent application by TTR. The experts at the conferencing agreed on the following with regard to marine mammals:

- Killer whale pods are likely to be transitory through the project area and the STB;
- Blue whale sightings mainly occurred around the 100 m depth contour with very few sightings inshore. The project area may be on the edge of blue whale feeding grounds, but feeding may still extend into this area;
- Beaked whales are typically found in water depths of approximately 200 m. As such, they are unlikely to be found in the project area. Sperm whales are also found in deeper waters and are unlikely to be found in the project area;
- Humpback and southern right whales are likely to be present in the project area and the STB on a seasonal basis (during their migration between the summer feeding grounds in the Antarctic and the winter calving and breeding grounds in the tropics);
- Pilot and false killer whales may use the project area and the STB over the summer months; and
- Common dolphins and New Zealand fur seals are widespread in the project area and the STB, and are found year-round.

15. Seabirds

NIWA was commissioned by TTR to assess the presence of seabirds in the STB. The assessment identified that the majority of the seabird species present in the STB are relatively coastal in their distribution. This included blue penguins, shags, gulls and terns. However, the latter two taxa can extend into more offshore areas.
By contrast, and although some species have been observed from, and relatively close to the coast, albatross and petrel species tend to be more pelagic and wide-ranging in their distributions and will likely occur at times throughout the STB and the project area.

The project area does not support large breeding colonies of any avifauna species. The nearest offshore islands are the Nga Motu / Sugar Loaf Islands near New Plymouth, which support perhaps a few tens of thousands of breeding pairs of seabirds. However, a number of coastal estuarine sites are of significant value to coastal, shore, wading and migratory bird species. These include the Waikirikiri Lagoon and the Whanganui, Whangaehu, Turakina, Manawatu and Rangitikei River estuaries. These are, however, located a significant distance from the project area.

Of the seabird species present within the STB, five species have been examined in further detail with regard to migration, habitat and diet, and to illustrate the scale of distribution and movement within the EEZ and beyond. These species, and their Union for the Conservation of Nature Red List classification and a New Zealand Conservation status is identified in the table below. Overall, there is considered to be a very low presence of seabirds within the project area.

Seabird Species	**Union for the Conservation of Nature Red List Classification**	**New Zealand Conservation Status**
Gibson's albatross	Vulnerable	Threatened – nationally critical
Westland petrel	Vulnerable	At risk – naturally uncommon
Sooty shearwater	Near threatened	At risk – declining
Red billed gull	Least concern	Threatened – nationally vulnerable
Little blue penguin	Least concern	At risk – declining

Table 5 Seabird Species and Conservation Classification.

16. Seascape and Visual Character

Boffa Miskell Limited (Boffa (2015)) was commissioned by TTR to assess the natural character, landscape, seascape, and visual amenity values of the project area and the STB.

16.1. Seascape Character Types

The seascape of the STB was classified into the following three broad regional seascape character types based on the nature of the coastal margin and their associated beach sediment characteristics.

16.2. Dunes and Low Cliffs

The two coastal areas where this occurs within the STB are located between the mouth of the Whanganui River and the mouth of the Patea River. The larger of the areas occurs at Waiinu Beach and extends north to the mouth of the Patea River, with the smaller area being to the south along the foreshore of Castlecliff (refer to Appendix 3.5).

16.3. Fossil Sea Cliffs

This relatively small area extends for approximately 1.5 km to the north of Castlecliff, near the mouth of the Whanganui River and is characterised by stable hard rock cliffs backing sandy beaches (refer to Appendix 3.6).

16.4. Eroding Sea Cliffs

These extensive areas extend from north of the fossil cliffs near Castlecliff to a point south of Waiinu Beach, and from the mouth of the Patea River to Ohawe and beyond. These actively eroding steep sea cliffs, which extend along 70% of the STB coastline, contain narrow beaches where the sediment material comprises a mixture of sand and gravel with areas of soil deposited from the actively eroding escarpment face (refer to Appendix 3.7).

The defining elements and features for the regional seascape types have been primarily influenced by the nature and character of the visually prominent coastal margin. The coastal escarpment, dune systems and associated beaches which have been sculptured and shaped by past and ongoing erosion processes, clearly display very high levels of coastal natural character throughout most of the coastal environment of the STB.

16.5. Seascape Character Areas

Twenty seascape character areas have been identified in the coastal environment between Mania and Whanganui. The spatial relationship between the national, regional and district seascape scales defined for this assessment are illustrated in Appendix 3.8.

17. Natural Sediment Plumes

In addition to the distinctive coastline features that define and characterise the seascape, a particularly distinctive feature of the nearshore seascape (up to 5 km offshore) is the appearance of naturally occurring suspended sediment plumes.

While the appearance, extent and pattern of these plumes vary considerably, they are a characteristic feature of the STB. As noted in the sections above, the sediment plumes are largely derived from river and stream deposited material, active shoreline erosion processes and the re-suspension of bottom sediments as a consequence of sea current and wave action.

These plume patterns generally relate to natural processes such as would be expected at river mouths, in the vicinity of eroding sea cliffs and the patterns associated with tides, currents, and wave and weather conditions. Notwithstanding these variations, the natural sediment plumes are distinctive features that contribute to the high visual, recreational and amenity values of the seascape of the STB.

18. Archaeological Sites

Clough & Associates Limited was commissioned by TTR to identify the potential for the discovery of historic shipwreck sites within the project area, which included the identification of any existing archaeological sites of significance within the project area (Clough (2015)).

Clough (2015) identifies that there are at least 126 documented shipwrecks in the Taranaki Region, of which 64 pre-date 1900. The remains of the majority of the shipwrecks are in unconfirmed locations, and only 11 of these wrecks have been successfully relocated in recent times. Twenty-three vessels have been recorded as lost along the coastline of South Taranaki at or near Patea, and 28 along the coast at or near Wanganui.

19. Maritime and Navigation

Marico Marino NZ Limited was commissioned by TTR to assess vessels movements in the STB and to assess the impact the project will have on commercial shipping vessels.

The report analysed 12 months of automatic identification system data in the area encompassed by Cook Strait, Kahurangi Point and Cape Egmont, including Tasman Bay.

A total of 926 movements were detected over the 12-month period. By way of summary, 40.5% of vessels identified during the study period were dry cargo ships. The second highest vessel type were tankers, making up 9.4%. A detailed breakdown of the types of vessels recorded is included in the table below.

Vessel Type	Unique Stations	Percentage (%)
Anchor Handlers	4	0.4
Buoys / Navigational Markers	6	0.6
Dry Cargo Ships	375	40.5
Dredges	3	0.3
Fishing	37	4.0
Naval	6	0.6
Passenger / Cruise Ship	35	3.8
Pilot Vessel	5	0.5

Recreational Craft	39	4.2
Research / Survey	13	1.4
Tankers	87	9.4
Tugs / Towing	20	2.2
Other	296	32.0
Totals	926	100

Table 6 Total Numbers of Ship Stations in STB for April 2012 – March 2013.

A minimal amount of marine traffic travelled through, or near, the project area during the study period and this is considered to be a realistic reflection of the annual marine traffic volumes that will be expected while iron sand extraction activities are occurring. Marine traffic recorded during the study period is shown in the figure below.

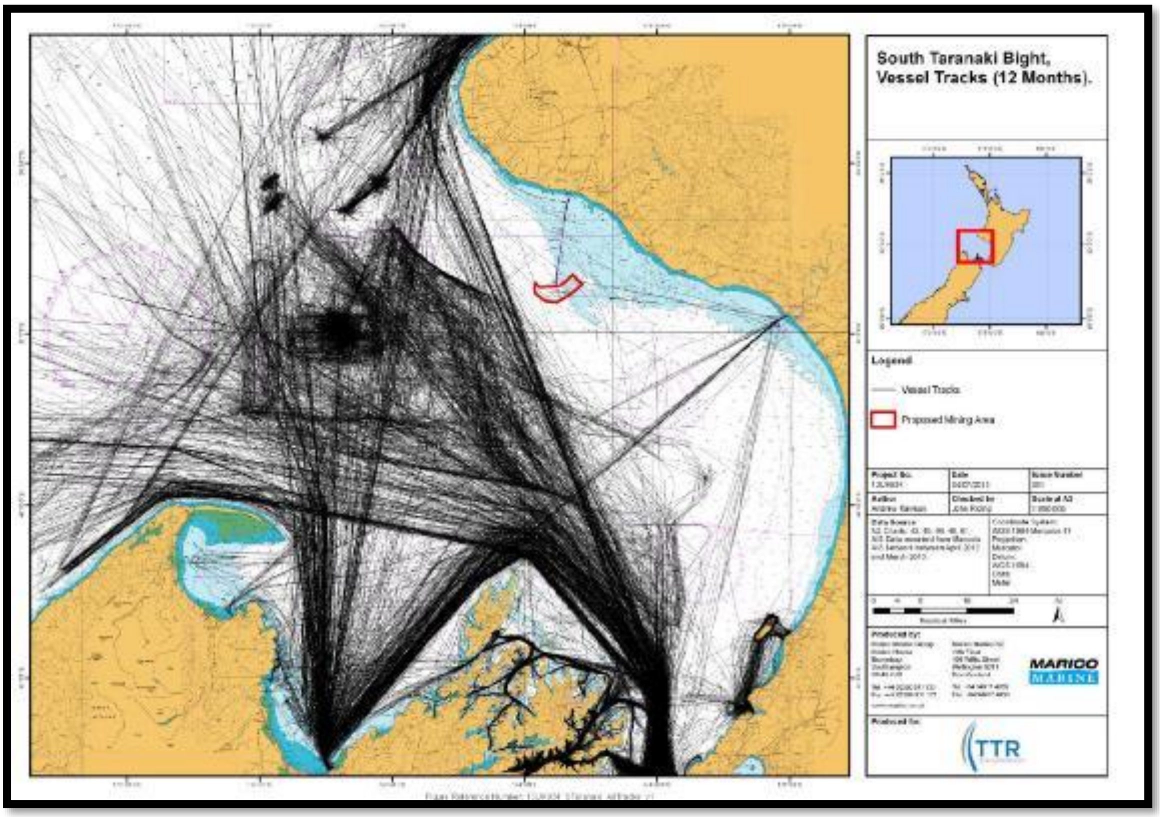


Figure 9 Marine Traffic through the STB: April 2012 – March 2013.

Marico concluded that the project area is well separated from the regular shipping routes and commercial fishing grounds.

The marine traffic in and around the project area is scarce. The main marine traffic consists of smaller recreational fishing vessels and vessels carrying out exploration activities for TTR. It is on this basis that TTR does not consider that marine traffic constitute an existing interest that may be affected by the project.

20. Commercial Fishing and Aquaculture

20.1. Commercial Fishing

Fathom Consulting Ltd was commissioned by TTR to assess the commercial fisheries in the STB. Further, and following consultation by TTR with the commercial fishing sector, an additional report was prepared by NIWA looking at commercial fishing within the STB, with a specific focus on the effort and catch for each fishing method over a period from 2006 to 2015.

The STB is part of the Central (West) Fisheries Management Area ("**FMA**") known as FMA 8, which runs from Tirua Point in Taranaki to a point north of Titahi Bay near Wellington (refer to the figure below). Despite the weather limitations, the area is considered to support a productive and diverse range of valuable inshore commercial fisheries.

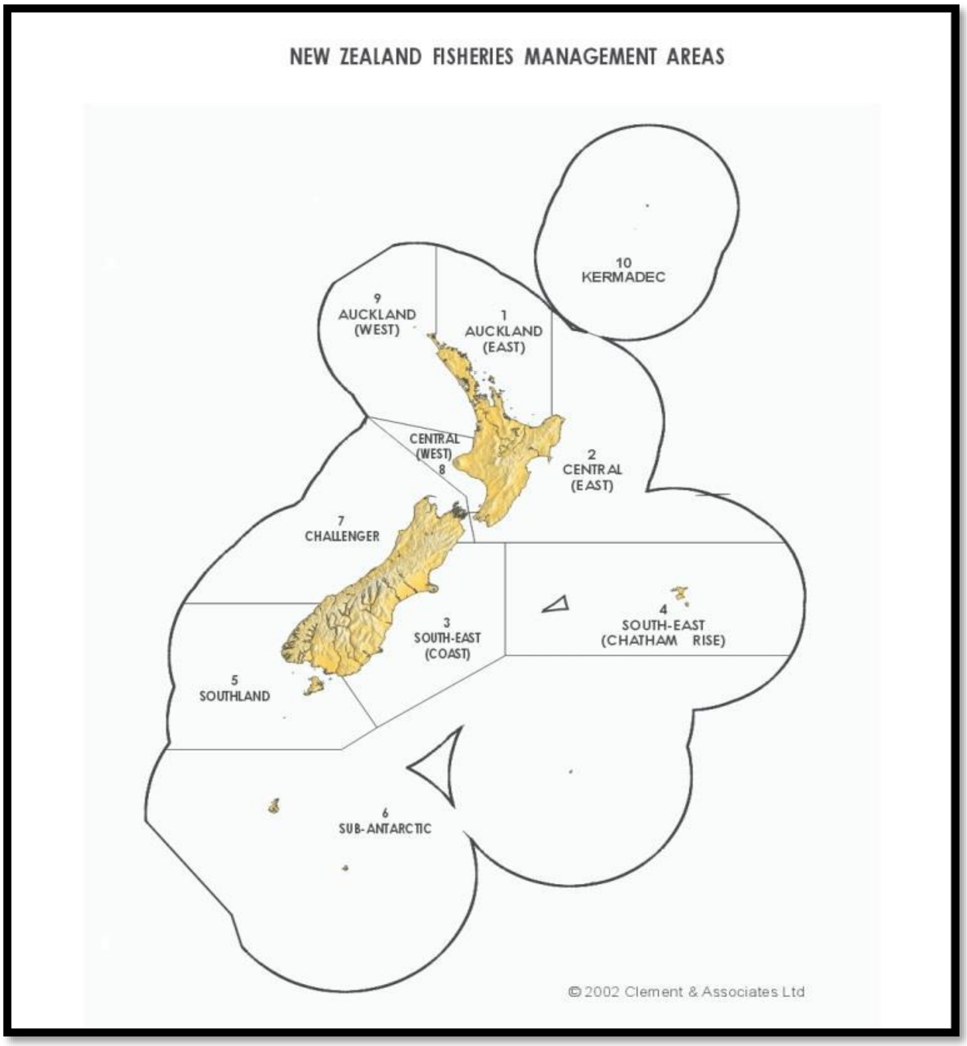


Figure 10 New Zealand Fisheries Management Areas.

Commercial fishers in the STB use a variety of fishing methods, including bottom trawling, mid-water trawling, set-netting, bottom long-lining, squid jigging, purse seining, trolling, potting or trapping, and drop lining. The main commercial fishing methods are bottom trawling (for trevally, leatherjacket, gurnard and snapper), midwater trawling (mainly for jack mackerel) and set-netting (mainly for school shark, rig and blue warehou). These methods account for 98% of the commercial fishing over the nine-year period assessed by NIWA.

Trawling occurs year-round with no obvious seasonality when viewed as a whole. However, the catch rates of key species are highly seasonal. In this regard, snapper and John Dory catch rates peak during October - March, while catch rates of trevally are highest in January - February. Catch rates of barracoota also tend to be highest during the summer months, while the catch rate of red gurnard tends to remain relatively constant throughout the year.

Mid-water trawling targets jack mackerel, with barracoota taken mainly as bycatch. The fishery occurs year-round, but there is a concentration of effort in December and January. A secondary peak occurs in July to August and is characterised by a greater proportion of tows targeting barracoota.

With regard to set lining, rig is mostly caught during spring and summer when the fish aggregate close to the shore. The main rig catches occur from September to March, with a peak in January. School shark is caught year-round, but the highest catch rates occur in April and May.

NIWA also identifies that rock lobster potting and crab potting were both common commercial fishing activities in the STB over the last nine years. The majority of the catch in the study area is caught in Area 935, which runs from just south of New Plymouth to Bulls, a distance along the coast of approximately 240 km.

Some fishing methods are excluded from parts of the STB. In this regard, trawling by vessels larger than 46 m was prohibited from an area in the STB just outside the territorial sea boundary in 1986. Set-netting from the coast out to 2 NM offshore in the area from Pariokariwa Point to Hawera was prohibited in 2012. Set-netting was also prohibited on vessels operating out to 7 NM offshore unless a Ministry for Primary Industries ("**MPI**") fisheries observer was on board.

Quota ownership in both the trawl and set-net fisheries is dominated by Talleys and Sanford. Te Ohu Kaimoana Trustee is also a major quota owner on behalf of Maori, and several other iwi-owned companies feature in the top 10 quota owners for stocks in the STB.

The lowest levels of overall fishing effort in the STB were in the central south sector, offshore of Whanganui and also close to the shore north of Opunake. The highest level of fishing effort is off the coastline between New Plymouth and Cape Egmont, and between Hawera and Whanganui (near the 50 m contour).

The project area has minimal overlap with the trawler fishing industry, which is mainly concentrated seaward of the 50 m contour. In contrast, the project area is located in water depths of between 20 and 42 m. The proportion of trawl catch taken within the project area is, therefore, likely to be minimal and can be provided for at other fishing locations within the STB. However, the commercial fisheries with the greatest overlap with the project area are the bottom trawl fisheries for leatherjackets and trevally, and the set-net fisheries for rig, carpet sharks, trevally, school shark, snapper and spiny dogfish.

20.2. Aquaculture

If adverse weather conditions are present within the project area, there is the potential that some of TTRs project related vessels may seek shelter in Admiralty Bay. Admiralty Bay has been identified due to the relatively deep waters and the greatest likelihood of experiencing sheltered sea conditions compared to the STB in the event of a large storm.

Admiralty Bay lies approximately 100 km south of the project area within Te Tau Ihu (top of the South Island) region, where eight iwi groups are represented under the Te Tau Ihu Settlement Bill, currently hosts longline mussel farming and is part of the $276 million aquaculture export industry within the Marlborough Sounds.

TTR project-related vessels would not undertake any activities within Admiralty Bay other than sheltering and therefore, will present no additional risks compared to any other vessel sheltering in Admiralty Bay at that time. TTR has assessed the proposed sheltering activities in Admiralty Bay against the Marlborough Sounds Resource Management Plan and consider that the anchoring of any project-related vessel within Admiralty Bay will not breach any of the Rules in the Plan.

If disturbance to the seabed was greater than 20 m^3, the activity would be considered as discretionary under the Marlborough Sounds Resource Management Plan and a coastal permit would be required. However, due to the size of the vessels being used, the anchoring of any TTR project-related vessels will not disturb an area of seabed greater than 20 m^3; hence, no coastal permit will be required.

As vessels will only be using Admiralty Bay for safe harbouring in adverse weather events, and no resource consents or marine consents required for such activities, TTR does not consider that this activity constitutes an ‘effect’ any on party that may have any existing interest within this area. TTR also note there is no aquaculture activities undertaken within the STB.

21. Kupe Joint Venture Parties

Kupe Joint Venture Parties New Zealand (“**Kupe JVP**”) are the holders of Petroleum Mining Licence #38146, with Origin Energy as the operator, which gives Kupe JVP the rights and interests to the Kupe natural gas field, which is located approximately 30 km off the coast of Manaia. The production facility comprises an unmanned offshore platform, a 30 km single three phase pipeline to shore and an onshore production station (refer to the figure below).

Approximately half of the project area is located within the mining licence area held by the Kupe JVP licenced area. The unmanned platform, pipeline and umbilicals are located approximately 1.2 km northwest of the project area.

Based on the above, Kupe JVP are considered a party who has a lawfully established ‘existing interest’ that may be affected by the project.

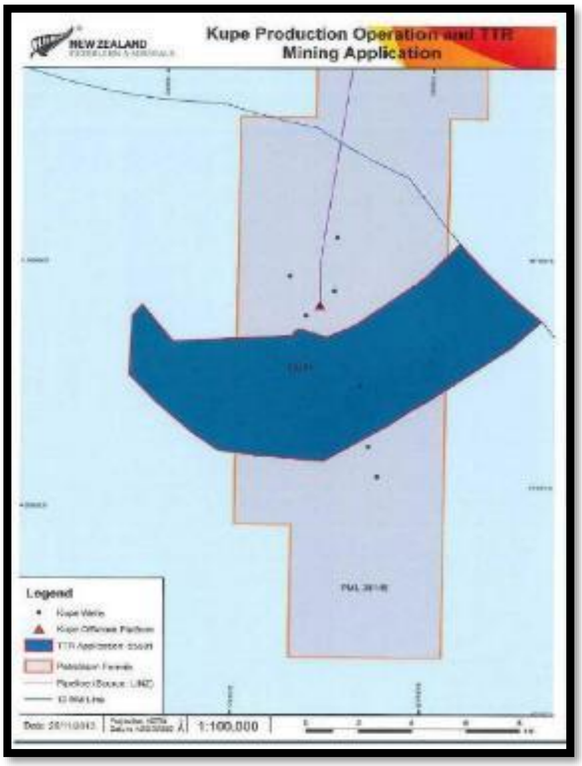


Figure 11 The extent of the Kupe Production area and project area.

Appendix 19.22 - Trans-Tasman Resources Discounted Cash Flow Model

STB Vanadium Titanomagnetite Iron Sands Project

20 YEAR LIFE OF MINE

High Level DCF **x US$1,000,000** **OPEX/US$t** **27.20**

		US$M		Yr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
NOTE: PRICE IS CURRENT SPOT PRICE		Conc m/t avg sales					4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
90.0	US$/t North China	***Revenue (FeX Earnings)***	***(58% disc to 62%CFR)***				380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6	380.6
13.7%	62% Fines Discount 57%Fe																									
5.45	US$/lb V_2O_5 less 50% costs	0.50%		0.77	50.00%		113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3	113.3
2,080.00	US$/$TiO_2$	8.50%		0.77	0%		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100.79	***Revenue/tonne US$/t***	***Total Revenue***					***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***	***493.9***
-	US$/t	V_2O_5 & TiO_2 Roast 50% revenue (cost 50% revenue row 10)					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27.2	Fixed	Direct and GA costs avg	***(IFO $500/t US$75/bbl)***				133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3	133.3
10.0	US$/t	Freight					49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0
37.2	***Cost/tonne US$/t***	***Total Costs***					***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***	***182.3***
63.59	***EBITDA/tonne US$/t***	**EBITDA**					***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***	***311.6***
		Interest					17.5	15.4	13.1	10.7	8.2	5.6	2.9	-	-	-	-	-	-	-	-	-	-	-	-	-
602.18		Depn / Amort (DA)	EOL 7yrs. SL Depn				86.0	86.0	86.0	86.0	86.0	86.0	86.0													
		Fe, V_2O_5 & TiO_2 Royalties	2% AVR / 10% APR				20.8	21.0	21.2	21.5	21.7	22.0	22.3	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2
		NPBT					***187.3***	***189.2***	***191.2***	***193.4***	***195.6***	***198.0***	***200.4***	***280.4***	***280.4***	***280.4***	***280.4***	***280.4***	***280.4***	***280.4***	***280.4***	***280.4***	***280.4***	***280.4***	***280.4***	***280.4***
28%		Tax	Corporate tax rate. No loss C/fwd				-	5.4	53.5	54.1	54.8	55.4	56.1	78.5	78.5	78.5	78.5	78.5	78.5	78.5	78.5	78.5	78.5	78.5	78.5	78.5
		NPAT					***187.3***	***183.8***	***137.7***	***139.2***	***140.8***	***142.5***	***144.3***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***
		Cash Flows																								
		NIAT-DA					273.3	269.8	223.7	225.3	226.9	228.6	230.3	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9
602.18	Capex	Asset			125.0	477.2																				
		Financing Principal repayments				421.5	(43.0)	(45.1)	(47.4)	(49.8)	(52.3)	(54.9)	(57.6)	(60.5)	-	-	-	-	-	-	-	-	-	-	-	-
		CF		**1,204.3**	(125.0)	(55.7)	230.3	224.7	176.3	175.5	174.6	173.7	172.7	141.4	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9	201.9
		Disc % /yr			1.0	0.9	0.8	0.7	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1
0.1	Discount factor excl inflation	**DCF**		**1,263.0**	***(119.2)***	***(48.2)***	***181.5***	***161.0***	***114.8***	***103.9***	***94.0***	***85.0***	***76.8***	***57.2***	***74.2***	***67.5***	***61.3***	***55.8***	***50.7***	***46.1***	***41.9***	***38.1***	***34.6***	***31.5***	***28.6***	***26.0***
		IRR		**37.7%**	***(125.0)***	***(477.2)***	***273.3***	***269.8***	***223.7***	***225.3***	***226.9***	***228.6***	***230.3***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***	***201.9***

Appendix 19.23 - DRA Process Plant Review

TRANS-TASMAN RESOURCES LTD

SOUTH TARANAKI BIGHT IRON SANDS PROJECT

PROCESS REVIEW

STRICTLY CONFIDENTIAL

DRA PROJECT NUMBER: C8381

DOCUMENT NUMBER: C8381-RPT-001

REVISION: 0

DATE: 11-JUNE-2014

RECORD OF REVISIONS

Revision	Description	Date
A	Issued for Internal Review	07 Mar 2014
B	Issued for Client Review	24 Mar 2014
0	Final Report Issued with Client Input	11 Jun 2014

DISCLAIMER

This document has been prepared by DRA Mineral Projects (Pty) Ltd (hereinafter referred to as "DRA"), utilising professional and thorough guidelines within its scope of work and terms of reference. However, it is based largely and materially on assumptions as identified throughout the text and upon information, data and conclusions supplied by others. DRA is not in a position to, nor does it verify the accuracy of, or adopt as its own, the information and data supplied by others.

DRA, or any other person acting for and/or on behalf of DRA, assumes no responsibility, duty of care or liability to any person with respect to the contents of this document or with respect to any inaccuracy, absence of suitable qualification, unreasonableness, error, omission or other defect of any kind or nature in or with respect to this document.

The conclusions and recommendations contained in this document are believed to be prudent and reasonable in the context in which they are expressed and founded on experience, preliminary calculations and information provided by others. The opinions expressed herein are given in good faith, but are not a substitute for the evaluation and analysis of the information available, by others.

No representation or warranty with respect to the contents of this document is given or implied and DRA accepts no liability whatsoever for any loss or damage, howsoever arising, which may directly or indirectly result from the use or misuse of this document.

This document and the information contained herein is proprietary to DRA, and as such, will be held in confidence and treated as secret ("the Confidential Information").

The Confidential Information shall not be used, published or reproduced in whole or in part for any purpose other than in connection with the purpose for which it was requested, nor shall the Confidential Information be disclosed to any third parties whomsoever, without the prior written consent of DRA, which consent shall not be unreasonably withheld or delayed.

This document is a "work in progress" document and is still subject to DRA's internal review and, as such, is subject to change. Only the final version of this document, may be utilised and not this or any other version of this document. DRA accepts no responsibility or liability for any version of this document or the utilisation thereof.

EXECUTIVE SUMMARY

Trans-Tasman Resources Limited (TTR) has appointed DRA Mineral Projects (Pty) Ltd to carry out a high level review of the process design for their South Taranaki Bight Iron Sands Project off the west coast of New Zealand's North Island. TTR propose to extract up to 50 million tonnes of seabed sediment and process the sediment aboard a mining vessel producing approximately 5 million tons of iron ore concentrate per annum.

In addition, a 20 kg sample of LIMS 1 concentrate, produced by TTR's pilot plant, was supplied to Metso Minerals in York PA USA for Vertimill milling testwork.

DRA sent a delegation to TTR's offices in Wellington NZ to review the process design in conjunction with TTR's design team.

This report documents DRA's findings and recommendations and presents an order of magnitude (± 40%) capex estimate for the process plant within the battery limits described herein.

Process and Plant Layout Recommendations

During the review process, a number of opportunities were identified in terms of installed power savings as well as alternate concepts and recommendations for consideration by TTR:

- The TTR flowsheet allowed for the dredge pump feed to be discharged over a static grizzley and into a boil box. The material is then pumped from the boil box by four centrifugal pumps to the trommel screens on the main deck.
  An alternative solution would be to pump this feed into a pressure splitter (4 ways), thereby splitting the material into four streams and removing the static grizzly, boil box and pumps. This arrangement may however necessitate an in-line booster pump on the 900 mm ROM feed line.

- The TTR flowsheet allowed for four trommel screens to remove the oversize material (+3.5 mm). This oversize material discharged onto a static screen, discharging the +25 mm material into a waste bin.

  An alternative solution would be to investigate the use of double deck vibrating screens. The primary deck replaces the static grizzley above the boil box whilst the secondary deck removes +3.5 mm oversize material. Although additional height may be required to gravity feed the combined oversize material to the tailings disposal system, this would eliminate the need to manually remove oversize material from the static grizzley above the boil box and from the oversize waste bins.
- DRA carried out a milling simulation based on the Metso Minerals milling testwork results. The simulation indicates that two 3000HP Vertimills can be installed as opposed to the larger 4500HP model currently shown on the TTR flowsheets. It is however recommended that grind variability testwork be carried out prior to detailed design as only a single sample of 20 kg was tested. Additional testwork is also required to determine mill charge and optimal grinding media sizing.
- The TTR flowsheet allowed for all the coarse tails (trommel screen oversize, MIMS as well as LIMS 1 tails) to be collected in a common sump, from where it is pumped to the coarse tails cyclone clusters for dewatering.

  An alternative layout would be to gravity feed the MIMS and LIMS 1 tails directly to dewatering cyclones thereby eliminating the need for the common coarse collection tanks and pumping systems to the tails cyclones.

The potential power savings associated with the above recommendations is summarised in Table 1.

Table 1: Potential Power Savings

Description	Installed Power as per TTR Basis of Design	Installed Power as per Alternative Flowsheet	Delta Installed Power
Dredge Feed (Boil Box vs Splitter)	2,400 kW	1,200 kW	-1,200 kW
Oversize Screening	4,500 kW	300 kW	-4,200 kW
Milling Circuit	6,750 kW	4,500 kW	-2,250 kW
Coarse Tailings Disposal System	6,000 kW	0 kW	-6,000 kW
Total	19,610 kW	5,970 kW	-13,650 kW
De-rate to allow for additional pumping heights, process requirements and layout allowances			-25%
Total Potential Saving in Installed Power			**-10,250 kW**

In addition to the potential power savings, the following process design and layout enhancements have been identified:

- A separate motive water tank should be installed to capture the overflow from the surge tanks and re-introduce this water (and solids) into the surge tanks as motive / agitation water. It is further recommended that an elutriator type design be incorporated into the surge tanks to minimise the solids overflow to the motive water tank.
- The MIMS and LIMS 1 machines should be arranged in a paired configuration. The benefits of this arrangement is a reduced footprint as well as allowing the rejects from these paired machines to be collected in a common underpan.
- Buffer tanks should be introduced between the primary magnetic separation circuits and the milling and classification circuits. This buffer would be sized through a dynamic simulation of the process with a view to optimise overall plant utilisation and availability.
- Ten Derrick screens (2 banks of 5) should be installed as opposed to the eight units (2 banks of 4) indicated on the TTR classification flowsheet. A total of nine Derrick screens are required based on the volumetric throughput limitation

of the screens - this has been rounded up to 10 to keep the process streams symmetrical.

- The feed to the LIMS 2 and 3 circuits should be combined thus minimising mass fluctuations to this combined circuit as the classification circuit feed is mass controlled. In the TTR flowsheet, LIMS 2 treats the Derrick screen underflow and LIMS 3 treats the milled material. This configuration would require additional LIMS units (in both circuits) to cater for tonnage fluctuations reporting to each circuit resulting from PSD envelope variations.
- An additional dewatering stage operating in closed circuit with LIMS 2 should be introduced to capture maximum material and ensure the less than 10% material moisture content in the product bins is achieved. The TTR flowsheet indicates dewatering magnets delivering a 90% solids by mass product to the storage bins. The dewatering magnet vendor has indicated this technology is relatively new and is currently in a patenting phase. DRA recommends that that the dewatering magnet be observed in a similar production environment as well as testwork on TTR's product be conducted to quantify its' performance.
- Due to the nature of magnetite the material carries residual magnetic charge after exposure to a magnetic field. DRA recommends that the inclusion of de-mag coils be investigated in order to minimise the lock-up of gangue in the feed to the LIMS and prevent adherence of material to underpans and storage bins.

Capital Estimate

An order of magnitude estimate (OME) for the capital costs of the process plant incorporating the abovementioned recommendations has been prepared in New Zealand Dollars (NZD).

The estimate is subject to the qualifications, assumptions and exclusions contained in this report and is within the accuracy range required (- 40% + 40%).

Table 2: Order of Magnitude Capital Estimate (Accuracy: - 40% + 40%)

Item	Amount (NZD)
Direct Costs	**194 592 336**
Structural Steel	29 466 929
Platework & Liners	37 022 382
Mechanical Equipment Supply	58 814 501
Mechanical Equipment Erect	11 954 116
Piping & Valves	19 630 859
Electrical, Instrumentation & Control	32 602 605
Spares & Consumables	5 100 944
Indirect Costs	**38 381 021**
EPCM	Incl
External Services	Incl
Total Excl Contingency	**232 973 357**

Process Testwork Recommendations

DRA has reviewed the process testwork carried out to date by TTR. In order to confirm certain critical design parameters, it is recommended that additional process testwork is carried out prior to detailed design:

- Conduct additional pilot testwork with an Fe head grade range of 7 to 10% in order to understand the metallurgical response, as it appears that 60% of the resource is in this grade range and is being represented by only 3 of the 9 pilot samples taken;
- Conduct additional pilot testwork based on the current TTR flowsheet whereby mill undersize reports to LIMS 2 and oversize to milling followed by LIMS 3 at the abovementioned head grades. Although DRA proposes to combine these circuits, it is imperative to test LIMS 2 and LIMS 3 separately in order to quantify the liberation impact of the milling circuit;

- Although a single Vertimill test was carried out during the review, it must however be noted that a variability assessment of the ore has not been conducted and is recommended that this is done prior to detailed design as detailed testwork is required to confirm design parameters;
- Conduct dewatering testwork to determine if the dewatering magnet will obtain the requisite product moisture content or is another means of dewatering (or combination thereof) required;
- Conduct material flowability testwork on the "dry" product in order to determine the design parameters for the mining vessel product storage bins.
- Conduct rheological characterisation testwork to confirm the design parameters of high density slurry lines and gravity flow launders.

Recommendations for Subsequent Phases

Further layout work is required to develop the abovementioned process concepts to ensure that they are practically achievable within the constraints of the mining vessel.

It is recommended that a specialist be consulted to carry out a dynamic simulation of the process:

- Run a simulation on the proposed flowsheet to determine the overall mining vessel process plant availability and utilisation;
- Simulate the effect of various inter-process buffer storage capacities within the mining vessel plant to determine the impact on availability / utilization for final sizing of equipment;
- Simulate the overall operation to determine the supply chain availability / utilisation and possible impacts on annual production by coupling the mining vessel process plant to the mining operation, FSO and Cape Size Vessel.

GLOSSARY OF TERMS

BOD	Basis of Design
DTR	Davis Tube Recovery
FSO	Floating Storage and Offloading vessel
LIMS	Low Intensity Magnetic Separation
LOI	Loss of Ignition
MIMS	Medium Intensity Magnetic Separation
P80	Size fraction at which 80% of material with pass
PDC	Process Design Criteria
PFD	Process Flow Diagrams
PSD	Particle Size Distribution
ROM	Run of mine
TTR	Trans-Tasman Resources
XRF	X-Ray Fluorescence
% w/w	Fraction weight by weight

TABLE OF CONTENTS

1 INTRODUCTION.. 1
2 PROCESS DESIGN REVIEW.. 2
2.1 Screening and Surge Tanks.. 5
2.2 MIMS and LIMS 1.. 6
2.3 Classification and Milling.. 7
2.4 LIMS 2 and LIMS 3.. 8
2.5 Dewatering, Product Storage and Product Transfer.. 9
2.6 Coarse and Fines Tailings.. 11
2.7 Potential Power Saving Summary.. 12
2.8 Other Process Considerations.. 13
3 REVIEW OF METALLURGICAL TESTWORK CONDUCTED BY TTR.. 15
3.1 Screening Testwork.. 15
3.2 MIMS 1 and LIMS 1 Testwork.. 16
3.3 Classification Testwork.. 21
3.4 Milling Testwork.. 22
3.5 LIMS 2 and LIMS 3 Testwork.. 22
3.6 Dewatering Testwork.. 23
3.7 Hyperbaric Filtration Testwork.. 23
3.8 Slurry and Material Storage Testwork.. 23
3.9 Tailings Testwork.. 24
3.10 Desalinated Water Testwork.. 24
3.11 Rheological Characterisation Testwork.. 24
4 METALLURGICAL TESTWORK CONDUCTED DURING THE REVIEW.. 25

4.1 Milling Testwork 25
4.2 Dewatering Testwork 25
4.3 LIMS 3 Discard PSD Testwork 26
5 CAPITAL COST ESTIMATE 30
5.1 Estimate Summary 30
5.2 Basis of Estimate 30
5.3 Exclusions 32
6 RECOMMENDATIONS 34
7 APPENDICES I
7.1 Source Documents Received I
7.2 Process Design Criteria (PDC) VI
7.3 Process Flow Diagrams (PFD) VII
7.4 Mechanical Equipment List (MEL) VIII
7.5 Potential Power Savings IX
7.6 ROM PSD as Tested in TTR Pilot Plant X
7.7 ROM PSD Comparison XI
7.8 Recovery Data from Screening, MIMS and LIMS XII
7.9 LIMS 1 Conc PSD Data Source XIII
7.10 Metso Milling Testwork Report XIV
7.11 Metso Milling Recommendation Report XV
7.12 DRA Milling Simulation Report XVI
7.13 Mechanical Equipment List – Budget Prices XVII

1 INTRODUCTION

Trans-Tasman Resources Limited (TTR) is a private New Zealand company that was established in 2007 to explore the iron sands deposits off the west coast of New Zealand's North Island. TTR has explored a project area of approximately 65 km^2 between 22-36 km off the coast of Patea, in the South Taranaki Bight in water depths of 20-45 m. TTR propose to extract up to 50 million tonnes of seabed sediment per annum and process the sediment aboard a mining vessel producing approximately 5 Mtpa of iron ore concentrate for export whilst re-depositing the remaining sediment on the seafloor in a controlled manner.

DRA Mineral Projects (Pty) Ltd was appointed by TTR to carry out a review of the process design conducted by TTR.

DRA's scope included the review and analysis of:

- process testwork;
- process flow diagrams (PFDs);
- mass and water balances;
- process equipment selection and sizing.

This report documents DRA's findings and recommendations as well as an order of magnitude (±40 %) capex estimate for the process plant within the battery limits described herein.

Information was provided by TTR for the purposes of the review. The detailed list of information received is provided in appendix section 7.1.

2 PROCESS DESIGN REVIEW

DRA sent a delegation to visit TTR's offices in Wellington in order to carry out a series of technical review sessions in conjunction with TTR's design team.

The TTR flowsheet (TTRL-05-PFD-10002) was reviewed in conjunction with the PFD Basis of Design document TTRL-05-BOD-12000 Rev 2, dated 17 January 2014.

The sections that follow outline the opportunities that were identified in terms of installed power savings as well as alternate concepts and recommendations for consideration by TTR. DRA has generated a process design criteria (PDC), process flow diagrams (PFDs) and mechanical equipment list (refer to appendix sections 7.2, 7.3 and 7.4 respectively) that incorporate the opportunities and recommendations described herein.

Although these opportunities have been identified, further engineering design, including plant layouts is required in order to finalise the overall power requirements of the processing plant.

DRA's scope of review was limited to the process plant on the mining vessel. The battery limits as depicted in Figure 1 below.

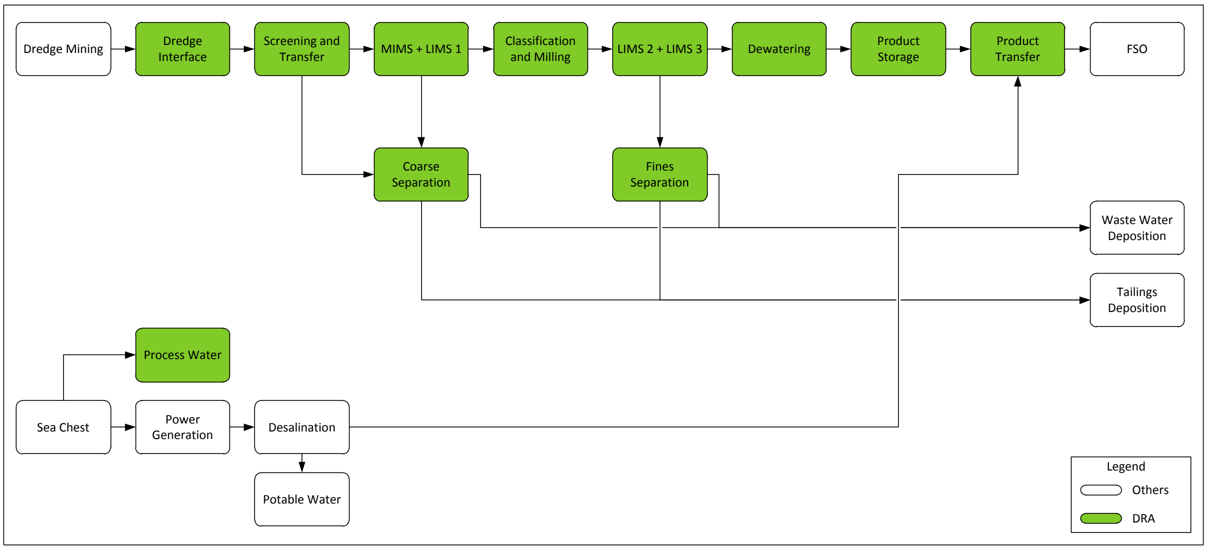


Figure 1: Study Scope Battery Limits

Inputs:

- ROM Feed: Dredge crawler discharge from 900mm ROM hose on main deck.
- Process Water: Suction flanges on sea chest/s.
- Desalinated Water: Suction flanges from desalinated water tank/s.
- Electrical Power: Tie-in to main switch room/s.

Outputs:

- Product: Discharge flange on slurry product transfer line to FSO vessel.
- Tailings: Inlet flange of tailings deposition system.
- Waste Water: Inlet flange of waste water disposal system.Dredge Operation Interface

The TTR flowsheet allowed for the dredge pump feed to be discharged over a static grizzley and into a boil box. The material is withdrawn from the boil box by 4 centrifugal pumps and pumped to 4 trommel screens.

An alternative solution would be to pump this feed into a pressure splitter (4 ways), thereby splitting the material into 4 streams and removing the static grizzly, boil box and pumps. A slurry design consultant with CFD capability and testwork facilities should be engaged, this could typically be Paterson and Cooke or similar. In operation, this splitter should attempt to limit material segregation and provide an even split to four streams, with flexibility to feed only 3 streams.

The advantages of a pressure splitter are:

- reduced overall mass (boil box and contents = 1,900 ton);
- reduced safety risk (regarding potential manual removal of oversize material);
- higher splitter efficiency (volume and mass);
- reduction in installed power.

The disadvantage of the pressure splitter being a higher overall static pumping head from the dredge pump. Additional layout work would be required to determine the pumping height to the splitter arrangement, which may necessitate the introduction of an in-line booster pump on the Dredge feed line.

The installation of a booster pump may however be able to reduce the power requirements of the dredge. Further design work would be required to determine the viability of this trade-off. Table 3 summarises the potential installed power reduction by utilising the pressure splitter feed arrangement.

Table 3: Potential Power Savings on Feed Distribution

Description	Existing Boil Box Arrangement	Alternative Pressure Splitter Arrangement	Comments
Dredge Booster Pump	0 kW	1,200 kW (TBC)	Based on adding an additional 6m static head to dredge pump
Boil Box Pumps	4 x 600 kW	0 kW	From Basis of Design Document
Total Installed Power	**2,400 kW**	**1,200 kW**	

2.1 Screening and Surge Tanks

The TTR flowsheet allowed for 4 trommel screens to remove the oversize material (+3.5mm). This oversize material is then passed over a static screen, discharging the +25 mm material into a waste bin.

An alternative solution would be to investigate the use of double deck vibrating screens. The primary deck would be to replace the duty of the static grizzly located on the boil box. The secondary deck would be to remove the +3.5mm material. Vibrating screen have been used in marine processing operations and have proven to be robust in the removal of various material types, including wood and rocks, as with all screens there is a limitation in the amount of clay that can be removed, however the addition of spray water should assist in breaking this up as well as panel selection.

The advantages of using vibrating screens are:

- reduced mass (30 tons per screen compared to 220 tons per trommel);
- reduced footprint;
- reduced capex;
- reduction in installed power.

The disadvantage of installing double deck vibrating screens are reduced operator visuals and maintenance access to the bottom deck.

Table 4 summarises the potential power saving by installing vibrating screens in lieu of trommel screens.

Table 4: Potential Power Savings on Screening

Description	Existing Trommel Screen Arrangement	Alternative Vibrating Screen Arrangement	Comments
Trommel Screen Installed Power	4 x 1,120 kW	0 kW	As per basis of design document
Vibrating Screen Installed Power	0 kW	4 x 75 kW	
Total Installed Power	**4,500 kW**	**300 kW**	

Due to the fine nature of the material and overflow entrainment, the overflow of the surge tanks directly to waste water, as indicated on TTR's flowsheet, may result in a significant loss of Fe from the process. DRA recommends that a separate (motive water) tank be installed to capture the overflow from the surge tanks and re-introduce this water (and solids) into the surge tanks as motive / agitation water. It is further recommended that an elutriator type design be incorporated into the surge tanks to minimise the solids overflow to the motive water tank.

2.2 MIMS and LIMS 1

The TTR flowsheet indicated that the MIMS and LIMS 1 magnetic separator units are individually fed. DRA recommends that these machines be arranged in a paired configuration. The benefits of this arrangement is a reduced footprint as well as allowing the rejects from these paired machines to be collected in a common underpan. The quantity and sizing of these units will be confirmed during detailed design.

DRA also recommends the introduction of a buffer tank between the primary magnetic separation circuit and the milling and classification circuit. This buffer should be sized through dynamic process simulation with a view to optimise overall plant utilisation and availability.

2.3 Classification and Milling

The TTR flowsheet proposes regulated pumped feed to cyclone 1 (open circuit primary cyclone), with the overflow reporting to a set of Derrick screens. The oversize from the derrick screens is combined with the cyclone 1 underflow and pumped in closed circuit to cyclone 2 (closed circuit, secondary cyclone) ahead of the mill.

DRA recommends that ten Derrick screens (2 banks of 5) be installed as opposed to the eight units (2 banks of 4) indicated on the TTR flowsheet. A total of nine Derrick screens are required based on the volumetric throughput limitation of the screens - this has been rounded up to 10 to keep the process streams symmetrical.

The TTR flowsheet indicates a 73 % w/w feed to cyclone 1. This is considered to be beyond what a normal pumping system operates at (closer to thickener underflow) the effect being that the cyclone will not classify efficiently. DRA recommends that is diluted to a 45 % w/w range to ensure efficient classification.

Further investigation should be conducted between the current cyclone / Derrick screen combination versus a Derrick only option. Preliminary vendor indication is that 16 screens (mass constrained) would be required as opposed to 10 screens (volume constrained) operating in conjunction with the cyclones.

Various mill options and configurations were investigated during the review, namely: ball mills, ISA Mills and Vertimills. The TTR flowsheet allowed for 2 x 4500HP Vertimills in parallel. A single mill test was conducted during the review to establish preliminary Vertimill design parameters (refer to section 4.1).

Based on this initial result, DRA's assessment of the milling circuit indicates that two smaller 3000HP Vertimills in parallel can be utilised. It must however be noted that a variability assessment of the ore has not been conducted and is recommended that this is done prior to detailed design as detailed testwork is required to confirm design parameters.

With reference to the appended report (refer appendix section 7.12) on milling investigations for the grinding duty; conventional milling required between 7.5~12kWh/t, and ISA Milling was found to be less efficient, and further investigative test-work for assessing Vertimills showed that their performance was 2~3 times better than conventional milling, requiring about 3.5kWh/t. However, a more scalable number of tests (and possibly piloting VTM) should be conducted as per the recommendations mentioned above.

A full-scale ‘seasoned media’ charge may affect and require allowances for differences in efficiency; which have not been taken into consideration at this stage. At the time of submitting this report, feedback from Metso was expected.

Table 5 below summarises the mill specifications.

Table 5: Potential Power Savings on the Milling Circuit, Based on Initial Testwork

Description	Mill Specifications as per TTR Basis of Design	Mill Specifications as per Mill Testwork
Mill Description	2 x VTM 4500	2 x VTM 3000
Installed Power	2 x 3,375 kW	2 x 2,250 kW

Given the mechanical constraints of the Vertimill, it is recommended that the impact of the ship’s pitch and roll be investigated by the mill supplier to determine the equipment availability for the expected sea conditions.

2.4 LIMS 2 and LIMS 3

In TTR flowsheet, LIMS 2 treats the Derrick screen underflow and LIMS 3 treats the milled material. This configuration would require additional LIMS units (in both circuits) to cater for tonnage fluctuations reporting to each circuit resulting from PSD envelope variations.

DRA recommends that the feed to the LIMS 2 and 3 circuits be combined (as they are similar size fractions) thus minimising mass fluctuations to this combined circuit as the classification circuit feed is mass controlled.

Although DRA proposes to combine these circuits, it is imperative to conduct additional testwork on LIMS 2 and LIMS 3 separately in order to quantify the liberation impact of the milling circuit and the recovery profile between the two may be different. Unlike MIMS and LIMS 1, it is not foreseen that these units can be run in a back to back arrangement as these are larger units and the rejects volumetric underflow will be significantly higher.

2.5 Dewatering, Product Storage and Product Transfer

The TTR flowsheet indicates dewatering magnets delivering a 90% solids by mass product are to be installed prior to the mining vessel product storage bins. The dewatering magnet vendor has indicated this technology is relatively new and is currently in a patenting phase. DRA recommends that an additional dewatering stage operating in closed circuit with LIMS 2 be introduced to capture maximum material and ensure the less than 10% material moisture content in the product bins is achieved.

Current dewatering techniques at this time include:

- Mechanical – Current Selection
- Thermal – does not cater for chloride removal
- Chemical – not desirable for environmental reasons

For purposes of this report, only mechanical separation was investigated. Mechanical separation equipment typically consists of:

- Stockpile
    - Not practical for this application, however the product storage bins could be considered as a form of stockpile
- Screens

- Due to fine nature of material, conventional dewatering screens, which typically dewater with a 500um aperture are not adequate. A derrick dewatering screen could be investigated further
    - Linear screens will not deliver the required moisture content
- Thickeners
    - Not applicable
- Centrifuges
    - Will not meet moisture requirements
- Filtration
    - Continuous Filters
        - Vacuum Disk
        - Vacuum Drum
        - Belt Filter
        - Hyperbaric
        - Of the continuous filters, the disk, drum and hyperbaric filter are the least susceptible to the ocean movement, the hyperbaric filter would perform better than the disk filter due to a higher pressure gradient, the disk filter would require less footprint than the drum filter due to the higher surface area.
    - Batch Filters
        - Due to the high tonnages, batch filters where not investigated further
- Other Separation
    - Dewatering Magnets – new technology, testing recommended

In a typical dewatering application, the material is required to spread across the surface of the dewatering unit and form a consolidated bed, allowing air to displace the liquid. Depending on the results from the dewatering magnet test, a dewatering stage in series may be applicable (Derrick Screen/ Drum Filter/ Disk Filter/ Hyperbaric filter), however this may be an alternative.

The TTR flowsheet and layout does not provide for flexibility in terms of depositing product material in a balanced manner into the mining vessel storage bins should a portion of the plant be offline. DRA recommends that an arrangement allowing for full flexibility between bins be investigated.

Further investigation is required to optimise the desalination water consumption as well as the amount of water removed in the dewatering stage and the pumping requirements to the FSO.

2.6 Coarse and Fines Tailings

The TTR flowsheet allowed for all the coarse tails (trommel screen oversize, MIMS as well as LIMS 1 tails) to be collected in a common sump, from where it is pumped to the coarse tails cyclone clusters for dewatering. The cyclone underflow reports to the tailings deposition pipe and the overflow to the waste water pipe.

DRA recommends that an alternative layout be investigated to allow the oversize from the vibrating screens to be discharged directly to the tailings deposition pipe. This will eliminate the need to manually handle the +25mm waste that currently reports to the waste bins on TTR's flowsheet, as well as eliminating the need to pump oversize material (nominally -25mm) to the coarse tails cyclone clusters.

Further opportunity exists to gravity feed the MIMS and LIMS 1 tails directly to dewatering cyclones dedicated to the magnetic units. This eliminates the need for the common coarse collection tanks and pumping systems to the tails cyclones. The layout for this option is critical as additional height will be required for the MIMS and LIMS 1 circuits as the cyclone underflow will discharge directly into tailings disposal pipe.

Table 6 summarises the potential power savings by optimising the coarse tails disposal system (note: the effects of the additional MIMS and LIMS plant heights have not been taken into account in this comparison).

Table 6: Potential Power Savings for Coarse Tailings

Description	Coarse Tails Disposal System as per Basis of Design	Alternative Coarse Tails Disposal System
Coarse Tails Cyclone Feed Pumps Installed Power	4 x 1,500 kW	0 kW

The TTR flowsheet allowed for all fines magnetics' tails (from LIMS 2 and LIMS 3) to be collected in a common sump, from where it is pumped to the fines tails cyclone cluster for dewatering. The cyclone underflow reports to the tailings disposal pipe and the overflow to the waste water deposition pipe.

Although the same design philosophy as proposed by DRA for the coarse tails disposal could be implemented on the fines tails circuit, initial layouts of the plant have indicated that this is not practically achievable.

2.7 Potential Power Saving Summary

The power requirements of the processing plant can only be confirmed during detailed design once the layout has been finalised. This report attempts to provide estimates of potential savings that that may be realised during the detail design phase.

The following factors, however, have not been taken into account:

- The variability of the feed material and the influence on the circuit design and therefore power requirements;
- Effects of changes in process plant layout on the power consumption;
- Additional unit processes required, for example the additional drying / dewatering requirements ahead of the dry storage on the mining vessel.

Table 7 summarizes the potential reduction in installed power for the processing plant based on the opportunities identified by DRA during this review.

Table 7: Overall Potential Power Savings

Description	Installed Power as per TTR Basis of Design	Installed Power as per Alternative Flowsheet	Delta Installed Power
Dredge Feed + Splitter	2,400 kW	1,200 kW	-1,200 kW
Oversize Screening	4,500 kW	300 kW	-4,200 kW
Milling Circuit	6,750 kW	4,500 kW	-2,250 kW
Coarse Tailings Disposal System	6,000 kW	0 kW	-6,000 kW
Total	19,610 kW	5,970 kW	-13,650 kW
De-rate to allow for additional pumping heights, process requirements and layout allowances			-25%
Total Potential Saving in Installed Power			**-10,250 kW**

2.8 Other Process Considerations

2.8.1 Inter-Stage Demagnetisation

Due to the nature of magnetite the material carries residual magnetic charge after exposure to a magnetic field. DRA recommends that the inclusion of de-mag coils be investigated in order to minimise the lock-up of gangue in the feed to the LIMS and prevent adherence of material to underpans and storage bins.

2.8.2 Quality and Sampling

In terms of sampling, in-line slurry samples will be taken throughout the process. The handling system for this material requires careful consideration in the design phase as it will have an effect on piping layouts.

Of particular importance is the final product sampling system. This can either be situated on the mining vessel or the FSO, but is typically required to operate in accordance with ISO standards (ISO 3082 for Iron Ore Sampling and Preparation).

There would be a requirement for a sample analysis laboratory, either on board or on land. This has been excluded from this review, however items for consideration are typically XRF, chemical assay, PSDs (dry and/or wet), moisture content, LOI measurement etc.

3 REVIEW OF METALLURGICAL TESTWORK CONDUCTED BY TTR

DRA has reviewed the following documentation pertaining to testwork carried out to date by TTR:

- LIMS 1 Concentrate Sizing.xlsx
- LIMS1 Con Fe_P_Analaysis V2 MW.XLSX
- TTRL02_SchedA_MEM_001_PilotResults_P3.pdf
- TTRL02_SchedA_MEM_002_PilotResults_B456_P1.pdf
- TTRL02_SchedA_MEM_004_PilotResults_LowGrade_Rev0.pdf
- TTRL02_SchedA_MEM_005_PilotResults_Bulk501.pdf
- TTRL02_SchedA_MEM_006_PilotResults_X4001_Rev1.pdf
- TTRL-05-BOD-12000-R2 Basis of Design PFD.pdf

3.1 Screening Testwork

ROM sizing / grading has been conducted on the -2 mm material. The oversize material comprises mainly of shell and debris as can be seen in Figure 2. The top-size was limited to the opening of the sample pipe.

Figure 2: Photograph of Oversize Material

TTR's basis of design document used a nominal curve, however it is recommended for design purposes that a coarse, nominal and fines set of curves be prepared to establish a design envelope.

The coarse, nominal and fines curves shown in Figure 3 were collated from the data provided by TTR (refer to appendix section 7.6). The material was however screened at 2 mm as such the following estimates were made:

- fines curve – 100% passing 2mm
- nominal curve – 96% passing 2mm
- coarse curve – 94% passing 2mm.

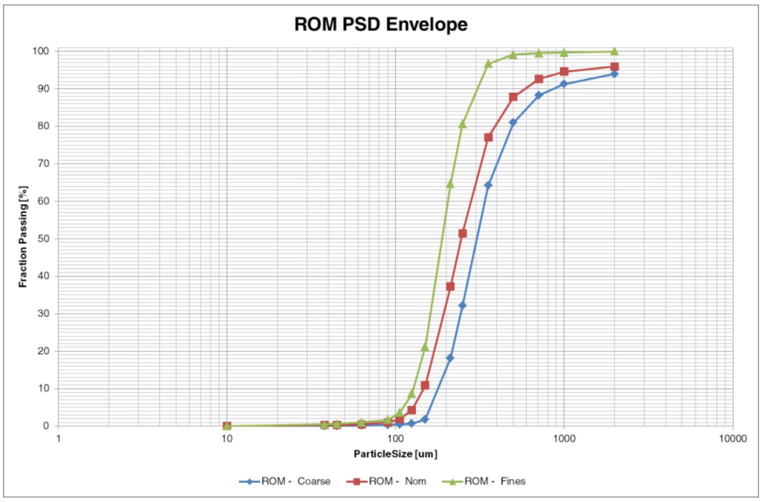


Figure 3: Estimated ROM PSD Envelope

A comparison was made between the PSD measured by laser on the bulk sample and sieve for the pilot plant ROM material. The laser PSD shows an additional 3 to 4% material in the -100um fraction as compared to the sieved material (refer to appendix section 7.7). This variance could be due to the nature of the two different sizing methods or due to the loss of fines in the sampling methods. The latter may however imply a variation to the head grade.

3.2 MIMS 1 and LIMS 1 Testwork

Pilot runs were conducted for MIMS and LIMS 1 by TTR. The dataset provided (up to the LIMS 1) consisted of 9 pilot run samples. Sample “Bulk501” was excluded by DRA as its’ recoveries were significantly lower than all of the samples taken and thus considered an outlier. Figure 4 illustrates the head grade frequency provided in the TTR BOD along with the number of pilot runs conducted at that head grade range.

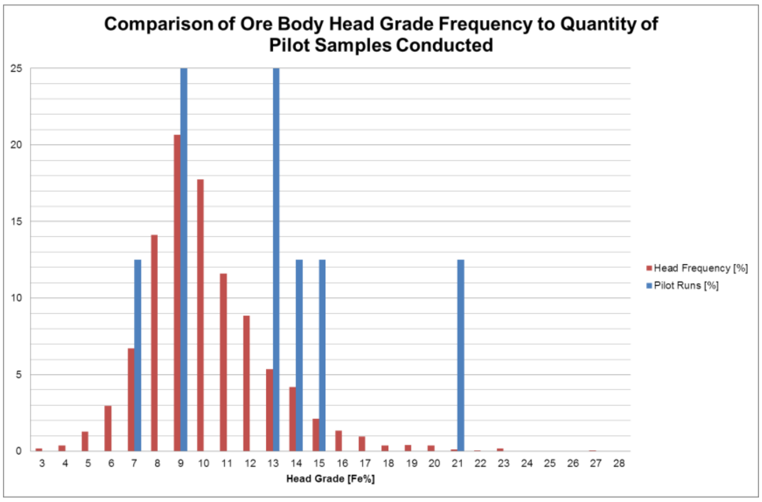


Figure 4: Head Grade Frequency vs. No. of Pilot Runs

Based on the mining schedule head grade frequency, it is recommended that additional pilot runs be conducted between the head grade range of 7-10% as approximately 60% of the feed material lies within this range. Presently there are only 3 of the remaining 8 pilot samples situated within this head grade range.

The pilot runs on the MIMS circuit were initially tested at 3,000 G, this was increased to 4,500 G in the latter runs. The magnetic strength for LIMS 1 was kept consistent at 1,250 G and the LIMS configuration was varied between double stage and triple stage.

The testwork carried out to date is consistent with TTR's proposed flowsheet (single stage MIMS at 4,500G and a two-stage LIMS 1 at 1,250G). Although the two-stage LIMS 1 configuration results in an increased mass yield as compared to the thee-stage configuration, this fraction would still be rejected in the LIMS 2 and 3 circuits and thus should not impact the overall recovery.

In order to establish mass and Fe recovery correlations as a function of head grade, DRA back calculated the recoveries from the data provided as the TTR BOD only indicates nominal recoveries. Table 8 contains a summary of data selected from the samples provided. The full data set and calculations are contained in appendix section 7.8.

Table 8: Selected MIMS and LIMS 1 Detailed Stage Recoveries

	Mass Recovery					Fe - Conc					Fe Recovery			Overall	
RUN	-2mm	MIMS	LIMS 1 - 1	LIMS 1 - 2	LIMS 1 - 3	Head Fe	MIMS Fe	LIMS 1 - 1	LIMS 1 - 2	LIMS 1 - 3	MIMS Fe	LIMS 1 - 1	LIMS 1 - 2 Fe	Mass	Fe
X038	96.80%	58.03%		40.89%		15.75%	22.27%		40.62%		82.06%		74.59%	22.97%	61.20%
X438	97.60%	66.78%	66.85%	85.12%		21.10%	28.10%	37.05%	42.00%		88.93%	88.14%	96.50%	37.09%	75.64%
B456	98.40%	44.42%	71.91%	91.86%		14.20%	29.00%	37.48%	40.10%		90.73%	92.93%	98.28%	28.87%	82.86%
X450	96.30%	34.21%	74.27%	95.19%		7.82%	20.22%	24.82%	25.70%		88.44%	91.17%	98.57%	23.29%	79.48%
X039	97.10%	50.00%	51.48%	81.85%	88.57%	9.82%	15.92%	24.54%	28.25%	30.80%	81.08%	79.34%	94.22%	20.45%	60.61%
X439	95.00%	44.58%	55.90%	84.81%	91.50%	9.62%	19.56%	30.06%	34.17%	36.60%	90.66%	85.89%	96.41%	20.08%	75.07%
X4001Y	96.20%	60.95%	56.83%	85.67%	91.13%	13.82%	21.41%	32.44%	36.51%	39.20%	94.41%	86.13%	96.42%	28.55%	78.40%
X4001Z	96.20%	58.55%	52.79%	86.80%	93.62%	13.80%	21.96%	34.63%	38.58%	40.60%	93.17%	83.25%	96.71%	25.81%	75.02%

Legend: Data Selected; Data Rejected; Data - Back Calculated via mass balance

The expected mass and Fe recovery ranges for the MIMS and LIMS 1 circuits are indicated in Table 9. Although the DRA mass recoveries for the individual process stages compare favourably to those contained in the TTR BOD, the overall mass recovery calculated for the MIMS + LIMS 1 circuit is higher than that in the TTR BOD (21.9% vs 18.1%). This variation may be due to the mass recovery being head grade and sample specific and the overall recovery not being necessarily obtained by multiplying the stage recoveries.

Table 9: MIMS and LIMS 1 Mass and Fe Recovery

			Mass Recovery					Fe Recovery				
		Fe Head Grade	Screen	MIMS	LIMS 1 - S1	LIMS 1 - S2	Overall	Screen	MIMS	LIMS 1 - S1	LIMS 1 - S2	Overall
Testwork Data	Min	7.8%	95.0%	34.2%	51.5%	81.8%	20.1%	100% (TBC)	81.1%	79.3%	74.6%	60.6%
	Nom	13.2%	96.7%	52.2%	61.4%	87.3%	25.9%	100% (TBC)	88.7%	86.7%	94.0%	73.5%
	Max	21.1%	98.4%	66.8%	74.3%	95.2%	37.1%	100% (TBC)	94.4%	92.9%	98.6%	82.9%
Comparison	TTR BOD	9.6%	96.0%	41.8%	45.2%		**18.1%**	100% (TBC)	75.0%	76.2%		**57.2%**
	DRA Calc	9.6%	95.6%	40.3%	54.8%	83.6%	**21.9%**	100% (TBC)	83.7%	81.8%	81.4%	**65.0%**
					45.8%					66.6%		

The Fe recoveries calculated by DRA for the individual process stages do not correspond to those contained in the TTR BOD. As such, the overall Fe recovery calculated for the MIMS + LIMS 1 circuit is significantly higher than that contained in the BOD (65.0% vs 57.2%).

Figure 5 illustrates the stage recoveries for MIMS, LIMS 1-stage 1 and LIMS 1-stage 2. Care needs to be taken when compounding stage recoveries to create an overall recovery correlation and is illustrated in Figure 6.

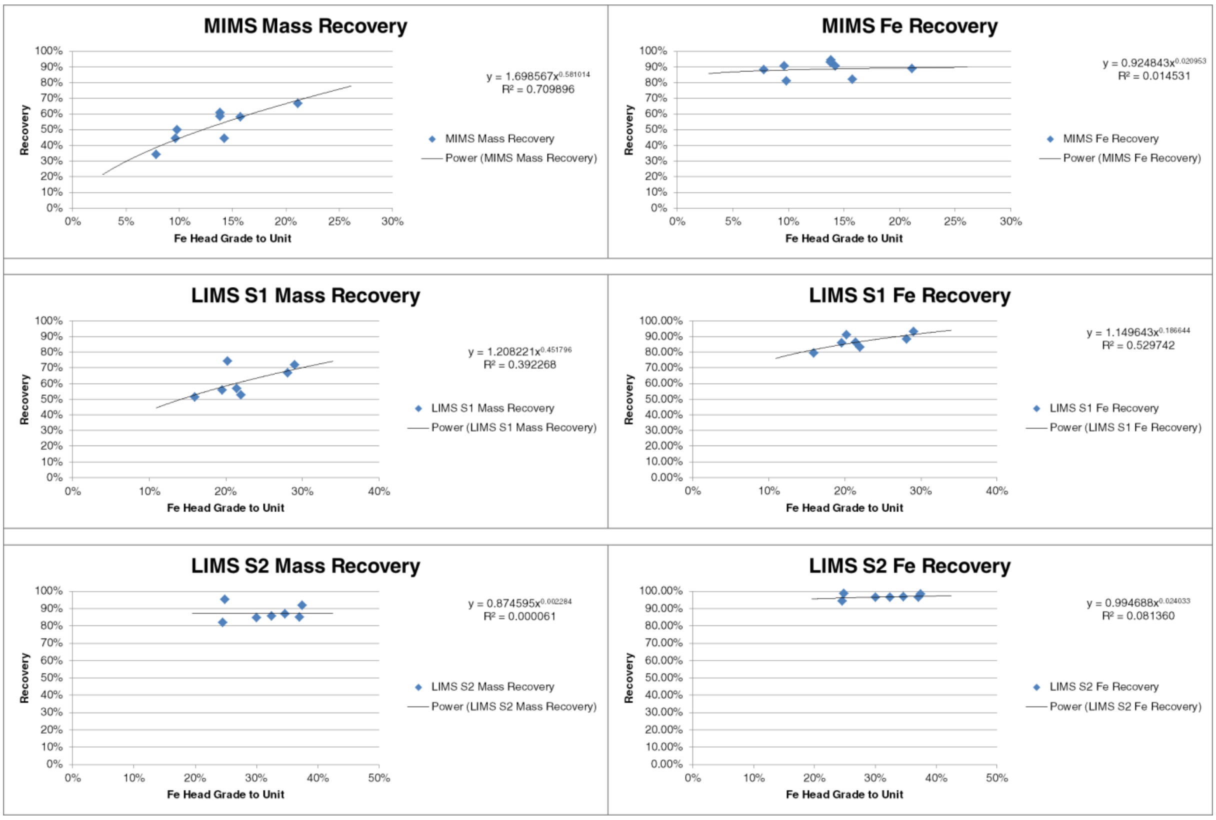


Figure 5: Stage Mass and Fe Yield Trends for MIMS and LIMS 1

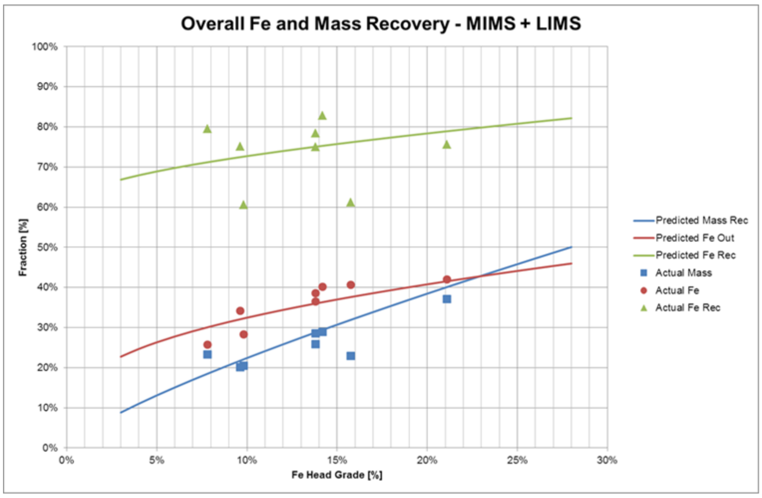


Figure 6: Overall Mass and Fe Yield Trends for MIMS and LIMS 1

Sizing analysis was conducted for the LIMS 1 concentrate - this is the material feeding the milling circuit.

Figure 7 below summarises the coarse, nominal and fines curves for LIMS 1 concentrate. The data source PSDs are illustrated in appendix section 7.9.

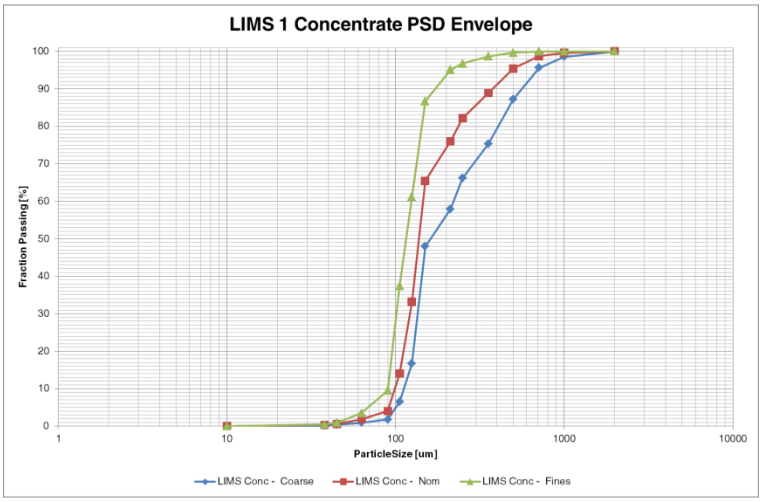


Figure 7: LIMS 1 Concentrate PSD

3.3 Classification Testwork

Additional classification testwork is not required as classification processes are well understood and it is difficult to pilot due to large volumes being required.

The TTR BOD uses a single nominal truncated PSD curve. The PSD comparison of LIMS 1 concentrate (cyclone 1 feed), data measured in the Metso testwork (refer to section 4.1) and the TTR BOD is shown in Figure 8.

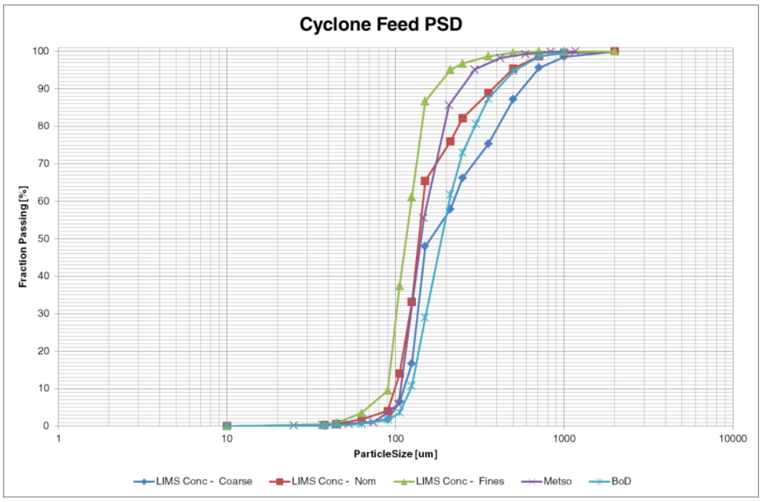


Figure 8: Cyclone Feed PSD Comparison

The PSD in the TTR basis of design indicates a coarser feed to the milling circuit than the measured data. As such, the LIMS 1 concentrate data was used in the simulation of the classification and milling circuit as opposed to the PSD supplied in the TTR BOD. A simulated PSD from cyclone and derrick underflow was thus generated. These size fractions reporting to the milling section are illustrated in Figure 9.

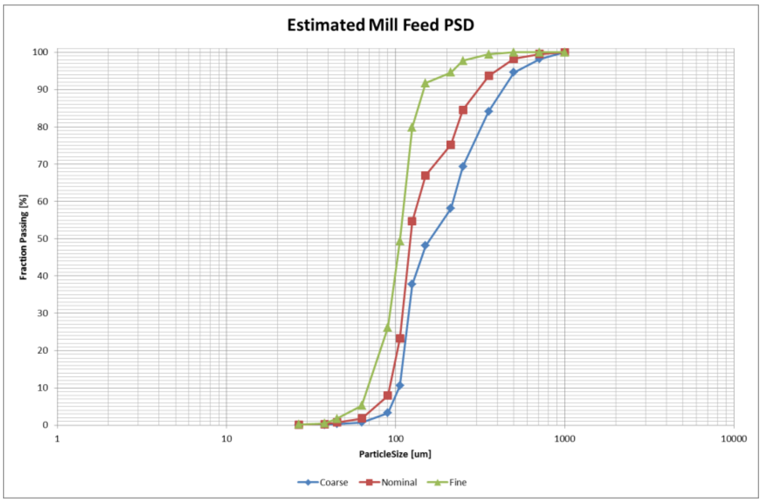


Figure 9: Estimated Mill Feed PSD

The TTR PFD indicates that 83% [(651 + 557) / 1447] of the LIMS concentrate reports to the milling circuit. Using the data obtained from the LIMS 1 concentrate PSDs mill circuit feed is estimated as a fraction of cyclone 1 feed to be:

- Min – 58.9%
- Nom – 72.0%
- Max – 80.6%.

3.4 Milling Testwork

Milling for the pilot samples to date was typically conducted to 80% passing 60um on the full sample feeding LIMS 2. This is not representative of the current process design described in the TTR BOD and flowsheet.

Further testwork conducted should be aligned with the current design philosophy. A single mill test was carried out by Metso Minerals during the review, refer section 4.1.

3.5 LIMS 2 and LIMS 3 Testwork

The TTR testwork on the LIMS 2 circuit has been on a full stream that was typically milled to 80% passing 60um. Furthermore, the testwork conducted to date with LIMS 3 was not on the split circuit configuration as currently indicated on the flowsheet, but rather as a cleaner / scavenger to LIMS 2. The current TTR flowsheet indicates a material split prior to the milling circuit, with dedicated LIMS 2 and LIMS 3 processes treating screen underflow and milled product respectively.

Although it has been proposed by DRA to combine these two LIMS processes, it is recommended that testwork be conducted on the LIMS 2 and LIMS 3 processes separately to gain insight into the liberation derived from the milling circuit.

3.6 Dewatering Testwork

No dewatering testwork was issued to DRA for review. DRA has reservations regarding the continuous sustainability of achieving the required 10% moisture content through the proposed single stage dewatering magnet as indicated on the TTR flowsheet.

DRA recommends that that the dewatering magnet be observed in a similar production environment as well as testwork on TTR's product be conducted to quantify its' performance.

3.7 Hyperbaric Filtration Testwork

No filtration testwork was issued to DRA for review. Although this is outside of DRA's scope of review, it is important that testwork be conducted to verify the moisture content of the product storage on the FSO vessel.

3.8 Slurry and Material Storage Testwork

For the slurry tanks where material is being buffered, DRA recommends that a specialist is consulted during the design phase of these tanks.

DRA recommends that material flowability tests be conducted on the product reporting to the mining vessel product bins. This will determine the design parameters for the product storage bins.

3.9 Tailings Testwork

The tailings deposition system was outside of DRA's scope of review.

3.10 Desalinated Water Testwork

Although the desalination system was outside of DRA's scope of review, it is however important to quantify the mineral content in the desalinated water (chlorine, potassium and sodium, etc) as these could have an impact on the final product specification.

3.11 Rheological Characterisation Testwork

No rheological characterisation testwork was to DRA for review.

The material being processed may run close to 50% passing 500-600um, which can be considered to be the worst case material for pumping. This needs to be taken into consideration for pumping design.

DRA recommends that rheological characterisation testwork be conducted to confirm the design parameters of high density slurry lines and gravity flow launders.

4 METALLURGICAL TESTWORK CONDUCTED DURING THE REVIEW

A 20 kg sample of LIMS 1 concentrate, produced by TTR's pilot plant, was supplied for the purposes of milling testwork as well as DTR and PSD testwork to be carried out by Mesto Minerals and Mintek respectively under the co-ordination of DRA.

4.1 Milling Testwork

During the review, Vertimill testwork was conducted by Metso Minerals in York PA USA. The Metso testwork report is attached in appendix section 7.10. Metso's testwork recommended that two 3000HP Vertimills are required (refer appendix section 7.11) and this was confirmed through milling simulation as detailed in DRA's report attached in appendix section 7.12.

The DRA milling simulation was based on a mass feed rate of 1,447 tph (as indicated on the TTR flowsheet) with the PSD as estimated by DRA - nominal 72.0% and maximum 80.6% of cyclone and screen underflow (refer to section 3.3). The 1,447 tph mill feed equates to 18.1 % overall MIMS + LIMS 1 mass recovery, however the measured recovery based on testwork can increase to 37.1% depending on head grade (refer to section 3.2).

DRA therefore recommends to decouple the front end and the feed to the milling circuit with a buffer as the variation in mass recovery can double the mill capacity requirements. This buffer would be sized through a dynamic simulation of the process with a view to optimise overall plant utilisation and availability.

DRA recommends that grind variability testwork be conducted to verify these findings as only a single sample of 20kg was tested. Additional testwork is also required to determine mill charge and optimal grinding media sizing.

4.2 Dewatering Testwork

A small milled sample from the Vertimill testwork was sent to the Derrick labs in Buffalo USA to test the indicative percentage moisture attainable on a dewatering screen arrangement. Derrick have subsequently indicated that they require a 1 ton milled sample in order to quantify the performance of their dewatering equipment.

4.3 LIMS 3 Discard PSD Testwork

Material was sent to Mintek for Size by Assay (SBA) and Davis Tube Recovery (DTR) by size testwork. The mill feed was assayed by size. For this sample, the results in Table 10 indicate that the selected 150um split prior to milling is correct, as this -150um material is already on product spec:

Table 10: Mill Feed SBA

Screen size (µm)	Mass (%)	Fe Conc (%)	SiO2 Conc (%)
+212	14.5	16.5	44.8
-212+150	32.5	34.7	24.1
-150+125	36.3	56.5	2.7
-125+106	12.3	58.4	1.1
-106	4.4	56.4	3.4
Total	**100.0**	**43.9**	**15.6**

This breakdown of size also indicates that it may be prudent to investigate a sharper cut than the cyclone and Derrick screen combination. A DTR at 0.5A (940G) yielded recoveries shown in Table 11 and Fe grades per size fraction. Recoveries were calculated using a re-constituted head grade from the mag and non-mag assay data.

Table 11: DTR by Size Results for Mill Feed

Screen size (µm)	Mags mass split (%)	Fe Recovery (%)	Fe Conc (%)	SiO_2 Conc (%)
+212	33.6	53.2	26.3	35.0
-212+150	79.4	93.7	42.8	17.6
-150+125	98.3	99.2	57.2	2.0
-125+106	96.8	97.2	58.7	0.9
-106	95.7	97.7	57.6	2.0
Total	**82.5**	**94.8**	**51.1**	**8.7**

This confirms that liberation is required, as the +150um material does not make the required 55% Fe product specification and would also cause the full product to be out of specification.

The Mill Product was assayed by size and are shown in Table 12, compared to the mill feed, this shows a reduction in Fe in the lower size fractions, indicating a deportment of gangue to the finer fractions. This is confirmed in the Mintek report, whereby the SiO_2 levels are high in the lower fraction. This is the opposite of what was anticipated.

Table 12: Mill Product SBA

Screen size (µm)	Mass (%)	Fe Conc (%)	SiO_2 Conc (%)
+125	21.6	40.8	19.3
-125+106	20.4	47.6	11.8
-106+75	26.2	46.5	11.8
-75+53	12.2	46.1	14.5
-53+38	6.3	43.4	16.4
-38	13.3	39.2	21.2
Total	**100.0**	**44.3**	**15.3**

A DTR at 0.5A (940G) yielded the recoveries and Fe grades per size fraction shown in Table 13.

Table 13: DTR by Size Results for Mill Product

Screen size (µm)	Mags mass split (%)	Fe Recovery (%)	Fe Conc (%)	SiO_2 Conc (%)
+125	30.5	84.9	54.4	6.1
-125+106	86.0	97.8	57.0	3.4
-106+75	82.3	97.0	57.3	2.5
-75+53	79.7	95.5	56.9	2.4
-53+38	76.5	95.5	57.4	2.4
-38	40.8	58.7	58.2	1.9
Total	**65.7**	**96.2**	**56.9**	**3.0**

This confirms that for this sample there is liberation at -125um and that the attainable Fe grade will be above the minimum product specification of 55% Fe. The implication of the higher deportment of gangue to the fines is that the LIMS 2/3 tailings PSD will be finer than anticipated.

The material run through the liberation test was a combined feed to the mill, thus for simulation purposes a partition curve was generated for the mill product PSD based on the magnetic mass recovery per size fraction and applied to the simulated mill product PSD (ideally this would be tested on a representative mill sample), shown in Figure 10.

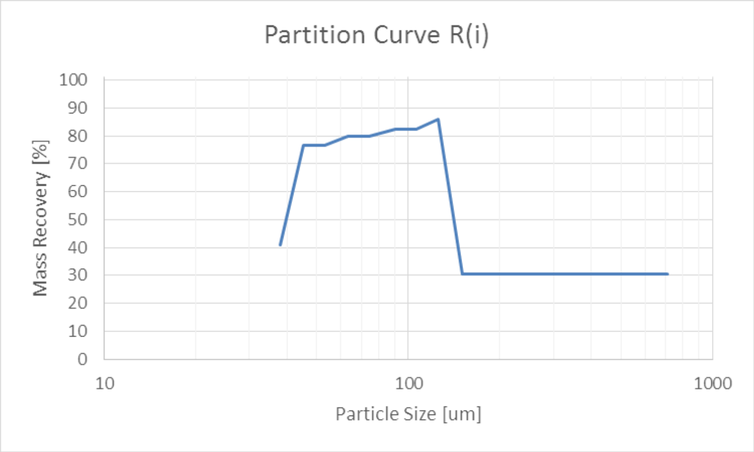


Figure 10: Partition Curve Applied to Determine Approximate PSD

This is illustrated in the approximated PSDs shown in Figure 11.

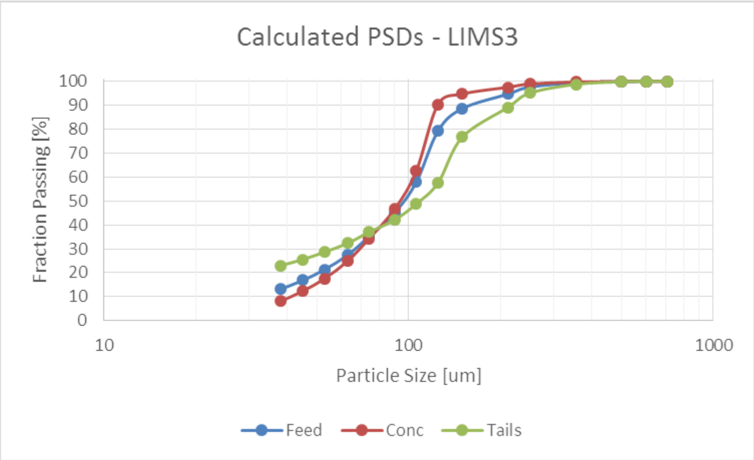


Figure 11: Calculated PSDs for LIMS 3

The Mintek report elaborates on other mineral content. DRA has not reviewed the other minerals as the TTR has not provided these in their product specification.

The Mintek report is attached in appendix section 7.14.

5 CAPITAL COST ESTIMATE

5.1 Estimate Summary

An order of magnitude estimate (OME) for the capital costs of the process plant has been prepared in New Zealand Dollars (NZD).

The estimate is subject to the qualifications, assumptions and exclusions contained in this report and is within the accuracy range required (-40% +40%).

Table 14: Order of Magnitude Capital Estimate (Accuracy: -40% + 40%)

Item	Amount (NZD)
Direct Costs	**194 592 336**
Structural Steel	29 466 929
Platework & Liners	37 022 382
Mechanical Equipment Supply	58 814 501
Mechanical Equipment Erect	11 954 116
Piping & Valves	19 630 859
Electrical, Instrumentation & Control	32 602 605
Spares & Consumables	5 100 944
Indirect Costs	**38 381 021**
EPCM	Incl
External Services	Incl
Total Excl Contingency	**232 973 357**

5.2 Basis of Estimate

The proposed DRA mechanical equipment list was costed using budget quotations received from the following vendors (refer to appendix section 7.13):

Derrick	Classification and Dewatering Screens
Metso	Vertimill
FLSmidth (Krebbs)/ Multotec	Cyclones
Vibramech	Primary Screens
Weir Warman	Pumps
Steinert	Magnetic Separators

The remaining disciplines where factorised from the DRA database for a similar marine project as well as a fines iron ore recovery project.

Adjustments were then made to the factorised costs to account for variances in scope between the projects.

DRA have assumed a modular construction approach and have made provision for the assembly of the modules (complete with mechanical, piping and electrical installation as far as practically possible) alongside the shipyard. The construction / installation costs of these pre-assembled modules onto the mining vessel has however been excluded as it is assumed that this will be carried out by the shipyard company.

5.2.1 General Qualifications

The capital cost estimate is subject to the following provisos:

- All costs are in present day terms in New Zealand Dollars (NZD) with a base date of 21 February 2014. The OME excludes all escalation, including that between the estimate base date and the project start.
- The accuracy of this estimate is deemed to be within ±40% for the scope of work and battery limits as contained in this document.
- The estimate is based on assumption of continuous engineering, procurement and construction effort, with no interruptions to this effort for whatever reason.

5.2.2 Foreign Exchange Exposure

This estimate is based on the exchange rates between the NZD and base currencies (mainly the AUD, USD and ZAR), as at 21 February 2014, as shown in Table 15 below.

No allowance has been made for foreign exchange variation, nor for forward cover costs.

Table 15: Foreign Exchange Rates (Base date: 21-February 2014)

	1 AUD =	1 USD =	1 ZAR =
NZD	1.0842	1.2079	0.1093
% Mech Equip	35.0%	7.7%	57.3%

5.2.3 Escalation

The base date for the OME is February 2014. No provision has been made for escalation beyond this date.

5.2.4 Contingency and Management Reserves

As this is a factorised OME, a contingency in the order of 40% has been applied to the estimate. This contingency is specific allowance required to cover inaccuracies in the estimate and does not cover scope changes or risks related to factors outside the control of DRA. A separate allowance should be provided in the project's management reserves for these items.

5.3 Exclusions

The capital costs are based strictly on the process plant as described in this report. The following items are excluded from this estimate:

- All costs relating to items outside of DRA's battery limits:
  - mining vessel including:
    - Power generation aboard the mining vessel;
    - Desalination system aboard the mining vessel;
    - Compressed air system aboard the mining vessel;
  - Tailings and waste water disposal systems;
  - Dredge and other mining related equipment;
  - Maintenance and workshop facilities aboard the mining vessel;

- Sample preparation and laboratory facilities aboard the mining vessel;
- Shipyard construction costs including those pertaining to the erection / installation of the process plant;
- FSO vessel including all process related equipment aboard;

- VAT, GST, import duties, levies and/or any other statutory taxation;
- Royalties, commissions, lease payments, rentals and other payments to landowners, title holders, mineral rights holders, surface right holders and/ or any other third parties.
- Environmental permitting activities, EIA / EMPR contributions to rehabilitation and/or closure funds, environmental monitoring and conformance to environmental requirements.
- Contributions to RDP, Health and Social Welfare programmes.
- Owners' budget costs: head office, infrastructure, administration charges, insurance premiums, interest payments, payroll, etc.
- Working capital, bridging finance and costs associated with finance raising.
- Escalation beyond the estimate base date;
- Forward cover on foreign exchange;
- Operating costs;
- Additional studies or testwork prior to project implementation;
- Management reserve provision for scope changes or project risks outside of those related to the design and estimating confidence levels.

6 RECOMMENDATIONS

DRA's recommendations following the testwork review are summarised as follows:

- Conduct additional pilot testwork with head grade between 7-10% to understand the metallurgical response. Approximately 60% of the resource is in this grade range and represented by only 3 of the 9 pilot samples taken.
- Conduct additional pilot testwork based on the current TTR flowsheet, whereby classification undersize reports to LIMS 2 and oversize to milling and then LIMS 3 at the abovementioned head grades. Although DRA proposes to combine these circuits, it is imperative to test LIMS 2 and LIMS 3 separately in order to quantify the liberation impact of the milling circuit.
- Although a single Vertimill test was carried out during the review, it must however be noted that a variability assessment of the ore has not been conducted and is recommended that this is done prior to detailed design as detailed testwork is required to confirm design parameters;
- Conduct dewatering testwork to determine if the dewatering magnet will obtain the requisite product moisture content or is another means of dewatering (or combination thereof) required;
- Conduct material flowability testwork on the "dry" product in order to determine the design parameters for the mining vessel product storage bins.
- Conduct rheological characterisation testwork to confirm the design parameters of high density slurry lines and gravity flow launders.

Further layout work is required to develop the abovementioned process concepts to ensure that they are practically achievable within the constraints of the mining vessel.

It is recommended that a specialist consultant is engaged to carry out a dynamic simulation of the process:

- Run a simulation on the proposed flowsheet to determine the overall mining vessel process plant availability and utilisation;

- Simulate the effect of various inter-process buffer storage capacities within the mining vessel plant to determine the impact on availability / utilization for final sizing of equipment;
- Simulate the overall operation to determine the supply chain availability / utilisation and possible impacts on annual production by coupling the mining vessel process plant to the mining operation, FSO and Cape Size Vessel.

7 APPENDICES

7.1 Source Documents Received

Filename	Document Name	Comment	Source	Author	Revision	Document Date
131101 Breaching tests full report - Draft.pdf	Report breaching tests	Not Covered	TTRL	MTI	Draft	Nov-2013
2013-09-24 Factual Report 1.pdf	Ironsand Laboratory Testing Factual Report	Not Covered	TTRL	Tonkin & Taylor Ltd		Sep-2013
64151 TTRL - Addendum Initial pump selection report rev_1.1.pdf	Addendum Initial Pump Selection Report	Volumetric interface to the mining vessel from Dredge	TTRL	IHC Merwede	1.1	Oct-2013
64151 TTRL - Initial pump selection report rev_2.0 Final.pdf	Initial Pump Selection	Volumetric interface to the mining vessel from Dredge	TTRL	IHC Merwede	2	Nov-2013
64151-MEM-783 Tailings Disposal Concept.pdf	Tailings Disposal Concept	IHC Scope to deposit the tailings on the Seabed	TTRL	IHC Merwede	Preliminary	Jan-2014
A14595 Part A.pdf	Metallurgical Testwork conducted upon A Number of Titaniferrous Magnetite Pilot Plant Samples for Trans-Tasman Resources Limited	Analysis of samples from TTRL only	TTRL	ALS Metallurgy		Nov-2013
Bene Overview of Bulk Processing.xlsx	Bene Overview of Bulk Processing Spreadsheet	Summary document of the testwork and processes used by TTRL	TTRL	TTRL		Jan-2013

Filename	Document Name	Comment	Source	Author	Revision	Document Date
Chemical and Physical Assessment of Product Final.pdf	Chemical and Physical Assessment of Products for In Situ Tank Testing	Bulk density tests, underwater angle of repose tests, permeability tests, porosity tests	TTRL	TTRL	1.3	Sep-2013
LIMS 1 Concentrate Sizing.xlsx	LIMS 1 Concentrate Sizing Spreadsheet	Summary document of LIMS Conc PSDS generated by TTRL, used for Mill sizing	TTRL	TTRL		Jan-2014
LIMS1 Con Fe_P_Analaysis V2 MW.XLSX	LIMS1 Con Fe_P_Analaysis spreadheet	Summary document of LIMS Conc contaminants generated by TTRL	TTRL	TTRL	2	Jan-2014
TTRL02_SchedA_MEM_001_PilotResults_P3.pdf	TTRL PILOT PLANT –TEST WORK PROGRESS	Internal memo of Run #1 & 2	TTRL	TTRL		Oct-2012
TTRL02_SchedA_MEM_002_PilotResults_B456_P1.pdf	TTRL PILOT PLANT TEST WORK : RUN #3 – MEDIUM GRADE SEDIMENT EX DIANNE	Internal memo of Run #3	TTRL	TTRL		Dec-2012
TTRL02_SchedA_MEM_004_PilotResults_LowGrade_Rev0.pdf	TTRL PILOT PLANT TEST WORK : RUN #4 TO 6 – LOW GRADE SEDIMENT	Internal memo of Run #4,5 &6	TTRL	TTRL	0	Mar-2013
TTRL02_SchedA_MEM_005_PilotResults_Bulk501.pdf	TTRL PILOT PLANT TEST WORK RESULTS SUMMARY: RUN #9 – BULK501 (LOW GRADE SEDIMENT)	Internal memo of Run #9	TTRL	TTRL		May-2013
TTRL02_SchedA_MEM_006_PilotResults_X4001_Rev1.pdf	TTRL PILOT PLANT TEST WORK : X4001 SEAWATER TRIAL	Internal memo of comparative sea water trials	TTRL	TTRL		Sep-2013
TTRL-05-BOD-12000-R2 Basis of Design PFD.pdf	BASIS OF DESIGN - PFD	Summary design document generated by TTRL, used as input into PDC	TTRL	TTRL	2	Jan-2014

Filename	Document Name	Comment	Source	Author	Revision	Document Date
TTRL-05-DWG-00001-01_R0C.PDF	Vessel GA	GA 1 of 8	TTRL	TTRL	C	Jan-2014
TTRL-05-DWG-00001-02_R0C.PDF	Vessel GA Main Deck	GA 2 of 8	TTRL	TTRL	C	Jan-2014
TTRL-05-DWG-00001-03_R0C.PDF	Vessel GA Work Decks No. 1 & No. 2	GA 3 of 8	TTRL	TTRL	C	Jan-2014
TTRL-05-DWG-00001-04_R0C.PDF	Vessel GA sections Below Main Deck Views	GA 4 of 8	TTRL	TTRL	C	Jan-2014
TTRL-05-DWG-00001-05_R0C.PDF	Vessel GA Vertimill & Generation Decks	GA 5 of 8	TTRL	TTRL	C	Jan-2014
TTRL-05-DWG-00001-06_R0C.PDF	Vessel GA sections A & B	GA 6 of 8	TTRL	TTRL	C	Jan-2014
TTRL-05-DWG-00001-07_R0C.PDF	Vessel GA sections C & D	GA 7 of 8	TTRL	TTRL	C	Jan-2014
TTRL-05-DWG-00001-08_R0C.PDF	Vessel GA section E	GA 8 of 8	TTRL	TTRL	C	Jan-2014
TTRL-05-DWG-11001_Legend Sheet 1.pdf	P&ID Legend Sheet	P&ID Legends	TTRL	TTRL	A	Dec-2013
TTRL-05-DWG-11002_Legend Sheet 1.pdf	P&ID Legend Sheet	P&ID Legends	TTRL	TTRL	A	Dec-2013
TTRL-05-DWG-11003_Legend Sheet 1.pdf	P&ID Legend Sheet	P&ID Legends	TTRL	TTRL	A	Dec-2013
TTRL-05-DWG-52000-R0C.pdf	Ironsand Wet Processing Plant Schematic	Process schematic	TTRL	TTRL	C	Dec-2013
TTRL-05-PFD-10002_R0E.pdf	Ironsand Wet Processing Plant PFD - Average Flow	Block flow diagram with preliminary mass balance	TTRL	TTRL	E	Dec-2013
TTRL-05-PID-11005-01-R0A.pdf	P&ID Boil Box	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11006-01-R0A.pdf	P&ID Trommel No. 1	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11016-01-R0A.pdf	P&ID MIMS GROUP No. 1 - Stream A	Preliminary P&ID	TTRL	TTRL	A	Dec-2013

Filename	Document Name	Comment	Source	Author	Revision	Document Date
TTRL-05-PID-11024-01-R0A.pdf	P&ID LIMS Stage 1 Feed Tank No. 1	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11028-01-R0A.pdf	P&ID LIMS 1 - Group No. 1	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11032-01-R0A.pdf	P&ID Cyclone 1 Feed Tank No. 1 & Cyclone No. 1	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11034-01-R0A.pdf	P&ID Cyclone 2 Feed Tank No. 1 & Cylone 2	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11038-01-R0A.pdf	P&ID Screen Stage No. 1 - Five Stage Group No. 1	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11040-01-R0A.pdf	P&ID Vertimill 4500 No. 1	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11044-01-R0A.pdf	P&ID LIMS 2 Feed Tank and LIMS 2 Group 1	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11046-01-R0A.pdf	P&ID LIMS 3 Feed Tank and LIMS 3 Group 1	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11050-01-R0A.pdf	P&ID Dewatering mag and Dry Conc Storage	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11054-01_R0A.pdf	P&ID Concentrate Slurry Tank	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11060-01_R0A.pdf	P&ID Coarse Tailings Tank No. 1	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11062-01_R0A.pdf	P&ID Fine Tails Tank	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-PID-11082-01_R0A.pdf	P&ID Tailings & Waste Water Deposition Pipe	Preliminary P&ID	TTRL	TTRL	A	Dec-2013
TTRL-05-SCH-13000-R5 Tab 2 - Pump List.pdf	Pump List	Preliminary Pump Schedule for power estimate	TTRL	TTRL	5	Jan-2014

Filename	Document Name	Comment	Source	Author	Revision	Document Date
TTRL-13-MEM-12000 Memo on ROM grade variation.docx	Run of Mine Head Feed Grade	Internal document reviewing the ROM head grade	TTRL	TTRL		Nov-2013
TTRL-MEM-001-Fe Yield.pdf	Offshore Titanomagnetite Resource Fe Yield and Process Flow Sheet	Internal document indicating DTR results for a number of samples	TTRL	TTRL		Mar-2013

7.2 Process Design Criteria (PDC)

TRANS - TASMAN RESOURCES LTD

Iron Sands

South Taranaki Bight Project

C8381

Process Design Criteria Summary

Strictly Confidential

Document Number: C8381-PRO-PDC-002

Revision: B

Issued for: Discussion

Process Design Criteria

Disclaimer

This document has been prepared by DRA Mineral Projects (Pty) Ltd (hereinafter referred to as "DRA"), utilising professional and thorough guidelines within its scope of work and terms of reference. However, it is based largely and materially on assumptions as identified throughout the text and upon information, data and conclusions supplied by others. DRA is not in a position to, nor does it verify the accuracy of, or adopt as its own, the information and data supplied by others.

DRA, or any other person acting for and/or on behalf of DRA, assumes no responsibility, duty of care or liability to any person with respect to the contents of this document or with respect to any inaccuracy, absence of suitable qualification, unreasonableness, error, omission or other defect of any kind or nature in or with respect to this document.

The conclusions and recommendations contained in this document are believed to be prudent and reasonable in the context in which they are expressed and founded on experience, preliminary calculations and information provided by others. The opinions expressed herein are given in good faith, but are not a substitute for the evaluation and analysis of the information available, by others.

No representation or warranty with respect to the contents of this document is given or implied and DRA accepts no liability whatsoever for any loss or damage, howsoever arising, which may directly or indirectly result from the use or misuse of this document.

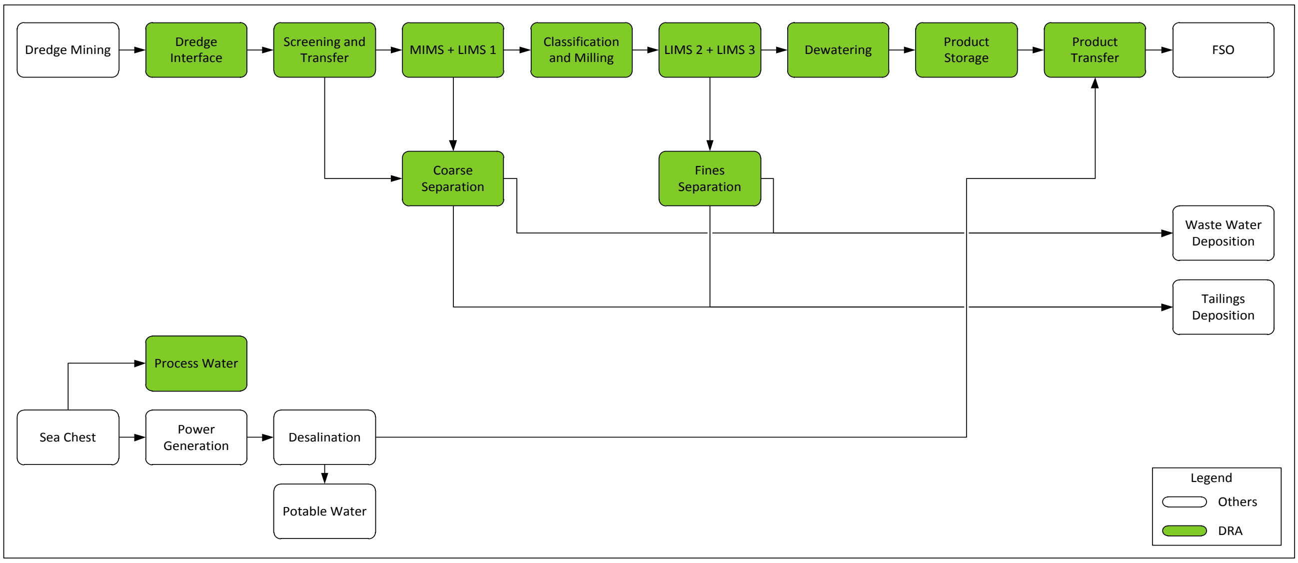
This document and the information contained herein is proprietary to DRA, and as such, will be held in confidence and treated as secret ("the Confidential Information").

The Confidential Information shall not be used, published or reproduced in whole or in part for any purpose other than in connection with the purpose for which it was requested, nor shall the Confidential Information be disclosed to any third parties whomsoever, without the prior written consent of DRA, which consent shall not be unreasonably withheld or delayed.

This document is a "work in progress" document and is still subject to DRA's internal review and, as such, is subject to change. Only the final version of this document, may be utilised and not this or any other version of this document. DRA accepts no responsibility or liability for any version of this document or the utilisation thereof.

Process Design Criteria

Process Description



Seabed material containing magnetite is dredged from the seabed at a rate of 8000tph. This material is screened for oversize and beneficiated using magnetic separation technology.

The Process Steps are summarised as:

- Screening
- MIMS (Magnetic Separation at 4500G)
- LIMS 1 (Magnetic Separation at 1250G)
- Classification (+150um to milling)
- Milling (+150um milled to -125um)
- LIMS 2 + 3 (Final Magnetic Separation of -150um and Milled Material at 950G)
- Dewatering
- Product Storage
- Product Transfer to FSO

Source Codes

A	Assumed
C	Calculated
D	DRA
E	Expert/ Consultant Recommendation
I	IHC
O	Operating Practice/ Industry Norm
T	TTRL
V	Vendor Requirement

Process Design Criteria

General Information

Criteria	Units	Value			Source	Rev
General						
Project Number			C8381			
Project Name			Offshore Iron Sands Project			
Client Name			Trans-Tasman Resources LTD			
Location			New Zealand			
Region			South Taranaki Bight			
Aproximate Elevation/ Altitude	mASL		0			
Temperature						
Air Temperature	°C	TBC	TBC	TBC		A
Water Temperature	°C	TBC	TBC	TBC		A
Rainfall						
Annual Average	mm	TBC	TBC	TBC		A
Units of Measurement						
All units are metric, tons per hour are expressed as dry metric tons unless otherwise specified						

Battery Limits

Criteria	Units	Value	Source	Rev
Incoming				
Ore		Dredge Connector Flange on deck	T	B
Water - Desalinated Water		Sea Chest into RO Plant, Pump From RO Plant	T	B
Water - Potable		IHC to supply	T	B
Water - Sea Water		Flange tie-in to Sea Chest	T	B
Power		Tie in to Main Switch Room	T	B
Network/ Control		Process Control Room Equipment	T	B
Outgoing				
Ore		Flange on product transfer pipeline	T	B
Tailings Deposition		Flange to tailings deposition lines	T	B
Waste Water Deposition		Flange to waste water deposition lines	T	B

Process Design Criteria

General Processing Information

Criteria	Units	Value	Source	Rev
FSOP Availability				
Operational availability	hrs	6 340	C	A
De-Rate Factor for oceanic behaviour	%	0-20	D	A
Mining				
Extraction Method		Dredging Crawler	T	A
Footwall Material		Low Grade Magnetite Deposit	T	A
Pump GSW Source		Filtered Sea water	T	B
Power Supply		6.6 kV @ 50 Hz	T	B
LV to MV cutoff		500 kW	T	B
Small Power		415 V	T	B
Low voltage supply		690 V	T	B

Process Design Criteria

ROM Characteristics

Criteria	Units	Value			Source	Rev
ROM		Minimum	Average	Maximum		
ROM Slurry Feed Rate	m³/hr		14 500		I	B
ROM Feed Rate	tph	TBC	8 000	TBC	T	A
Annual Capacity	Mtpa	TBC	50.7	TBC	T	A
ROM Ore Characteristics						
Moisture	% w/w		60.6		T	A
Solids	%w/w		39.4		C	A
Maximum Feed Size	mm		300		I	B
ROM in-situ Density	t/m³		3.20		T	A
Sea Water Density	t/m³		1.03		O	A
Fresh Water Density	t/m³		1.00		O	A
ROM Elemental analysis						
Fe Cut off Grade for Mining Model	% w/w		7.00		T	B
Fe (Iron - Elemental)	% w/w	1.71	9.60	26.4	T	A
SiO2 (Silica)	% w/w	35.2	49.2	69.0	T	A
Al2O3 (Alumina)	% w/w	5.22	11.8	17.6	T	A
TiO2 (Titania)	% w/w	0.42	1.40	3.78	T	A
CaO (Lime)	% w/w	5.31	11.7	23.3	T	A
MgO (Magnesia)	% w/w	1.86	6.00	10.8	T	A
V (Vanadium - Elemental)	% w/w	TBC	0.10	TBC	T	A
P (Phosphorus - Elemental)	% w/w	TBC	TBC	TBC		A
ROM PSD (Cumulative Passing)		ROM - Coarse	ROM - Nominal	ROM - Fines		
38 um	% w/w	0.05	0.26	0.48	T	B
45 um	% w/w	0.05	0.29	0.57	T	B
63 um	% w/w	0.14	0.46	1.00	T	B
90 um	% w/w	0.33	0.99	1.72	T	B
106 um	% w/w	0.46	1.85	3.54	T	B
125 um	% w/w	0.70	4.31	8.62	T	B
150 um	% w/w	1.76	10.8	21.2	T	B
212 um	% w/w	18.2	37.3	64.6	T	B
250 um	% w/w	32.1	51.5	80.7	T	B
355 um	% w/w	64.2	77.1	96.7	T	B
500 um	% w/w	81.0	87.8	99.1	T	B
710 um	% w/w	88.3	92.7	99.5	T	B
1000 um	% w/w	91.3	94.6	99.7	T	B
2000 um	% w/w	94.0	96.0	100	A	B
D80	µm	477	398	260	C	A
D95	µm	NA	1 219	240	C	A

Process Design Criteria

Process Requirements

Criteria	Units	Value			Source	Rev
Product Requirements		Minimum	Average	Maximum		
Fe (Iron - Elemental)	% w/w	TBC	55.0	TBC	T	B
SiO2 (Silica)	% w/w	TBC	TBC	TBC		A
Al2O3 (Alumina)	% w/w	TBC	TBC	TBC		A
TiO2 (Titania)	% w/w	TBC	TBC	TBC		A
CaO (Lime)	% w/w	TBC	TBC	TBC		A
MgO (Magnesia)	% w/w	TBC	TBC	TBC		A
V (Vanadium - Elemental)	% w/w	TBC	TBC	TBC		A
P (Phosphorus - Elemental)	% w/w	TBC	TBC	TBC		A
Cl (Chloride)	ppm	TBC	350	450	T	B
Moisture	% w/w	6.50	-	10.0	T	B
Product PSD (Cumulative Passing)		Minimum	Average	Maximum		
38 um	% w/w	TBC	TBC	TBC		A
P95	µm	TBC	TBC	TBC		A
P99	µm	TBC	TBC	TBC		A
Production Target	tph		800		T	B
Annual Production Target	Mtpa		5.07		T	B
Process Technology						
Dredge			IHC Dredge Crawler		T	B
Screening			Trommels or Vibrating Screens		T	B
Primary Mag Separation			MIMS @ 4500G		T	B
Secondary Mag Separation			LIMS @ 1250G		T	B
Classification Circuit			Cyclones and Derrick Screens		T	B
Milling Circuit			Vertimills		T	B
Fines & Milled Fines Mag Seperation			LIMS @ 950G		T	B
Pre-Dewatering			Dewatering Magnet		T	B
Final Dewatering			TBC			B
Product Storage			"Dry" Material in bins		T	B
Grade Control			TBC			B
Product Grade Measurement			TBC			B
Product Transfer to FSO			Dry material pulping and slurry transfer		T	B
Low Pressure Water Reticulation			TBC			B
High Pressure Water Reticulation			TBC			B

7.3 Process Flow Diagrams (PFD)

TRANS-TASMAN RESOURCES LTD

OFFSHORE IRON SANDS PROJECT

PROCESS FLOW DIAGRAMS

C8381

REV No.: B

DATE : 1[illegible]/03/2014

INDEX

DRA DRAWING No.	AREA	DESCRIPTION	REV
	20-110 – ROM & SCALPING		
C8381-PFD-20-110	ROM	ROM & SCALPING	B
	20-200 – MIMS 1 (PRIMARY ROUGH MAGNETIC SEPARATION)		
C8381-PFD-20-210	MIMS 1	MIMS 1 – STREAM 1	B
C8381-PFD-20-220	MIMS 1	MIMS 1 – STREAM 2	B
C8381-PFD-20-230	MIMS 1	MIMS 1 – STREAM 3	B
C8381-PFD-20-240	MIMS 1	MIMS 1 – STREAM 4	B
C8381-PFD-20-250	MIMS 1	MIMS 1 – STREAM 5	
C8381-PFD-20-260	MIMS 1	MIMS 1 – STREAM 6	
C8381-PFD-20-270	MIMS 1	MIMS 1 – STREAM 7	
C8381-PFD-20-280	MIMS 1	MIMS 1 – STREAM 8	
	20-300 – LIMS 1 (SECONDARY ROUGH MAGNETIC SEPARATION)		
C8381-PFD-20-310	LIMS 1	LIMS 1 – STREAM 1	B
C8381-PFD-20-320	LIMS 1	LIMS 1 – STREAM 2	B
C8381-PFD-20-330	LIMS 1	LIMS 1 – STREAM 3	B
C8381-PFD-20-340	LIMS 1	LIMS 1 – STREAM 4	B
	20-400 – CLASSIFICATION & MILLING		
C8381-PFD-20-410	CLASSIFICATION & MILLING	CLASSIFICATION & MILLING – STREAM 1	B
C8381-PFD-20-420	CLASSIFICATION & MILLING	CLASSIFICATION & MILLING – STREAM 2	B
	20-500 – LIMS 2 (CLEANER MAGNETIC SEPARATION)		
C8381-PFD-20-510	LIMS 2	LIMS 2 – STREAM 1	B
C8381-PFD-20-520	LIMS 2	LIMS 2 – STREAM 2	B
	20-600 – PRODUCT HANDLING		
C8381-PFD-20-600	PRODUCT & TAILS HANDLING	PRODUCT HANDLING, PRODUCT STORAGE & TRANSFER	B

DRA DRAWING No.	AREA	DESCRIPTION	REV
	20-700 – PROCESS WATER DISTRIBUTION		
C8381-PFD-20-700	SERVICES & RETICULATION	SERVICES & RETICULATION – SEA CHEST	B
C8381-PFD-20-710	SERVICES & RETICULATION	SERVICES & RETICULATION – PROCESS WATER DISTRIBUTION	B
C8381-PFD-20-715	SERVICES & RETICULATION	SERVICES & RETICULATION – PROCESS WATER DISTRIBUTION	B
C8381-PFD-20-720	SERVICES & RETICULATION	SERVICES & RETICULATION – GSW DISTRIBUTION	B
	20-800 – WASTE WATER HANDLING		
C8381-PFD-20-800	WASTE WATER HANDLING	WASTE WATER DEPOSITION	B
	20-810 – TAILINGS HANDLING		
C8381-PFD-20-810	TAILS HANDLING	TAILINGS DEPOSITION	B
	20-010 – COMMON SERVICES		
C8381-PFD-20-010	COMMON SERVICES	COMPRESSED AIR	B
	30-100 – DESALINATION		
C8381-PFD-30-100	DESALINATION	SERVICES & RETICULATION	B
	40-100 – POWER GENERATION		
C8381-PFD-40-100	POWER GENERATION	SERVICES & RETICULATION	B

DATE	REV	DESCRIPTION	CHECK
06/03/2014	B	ISSUED FOR COMMENT	
28/02/2014	A	ISSUED FOR COMMENT	

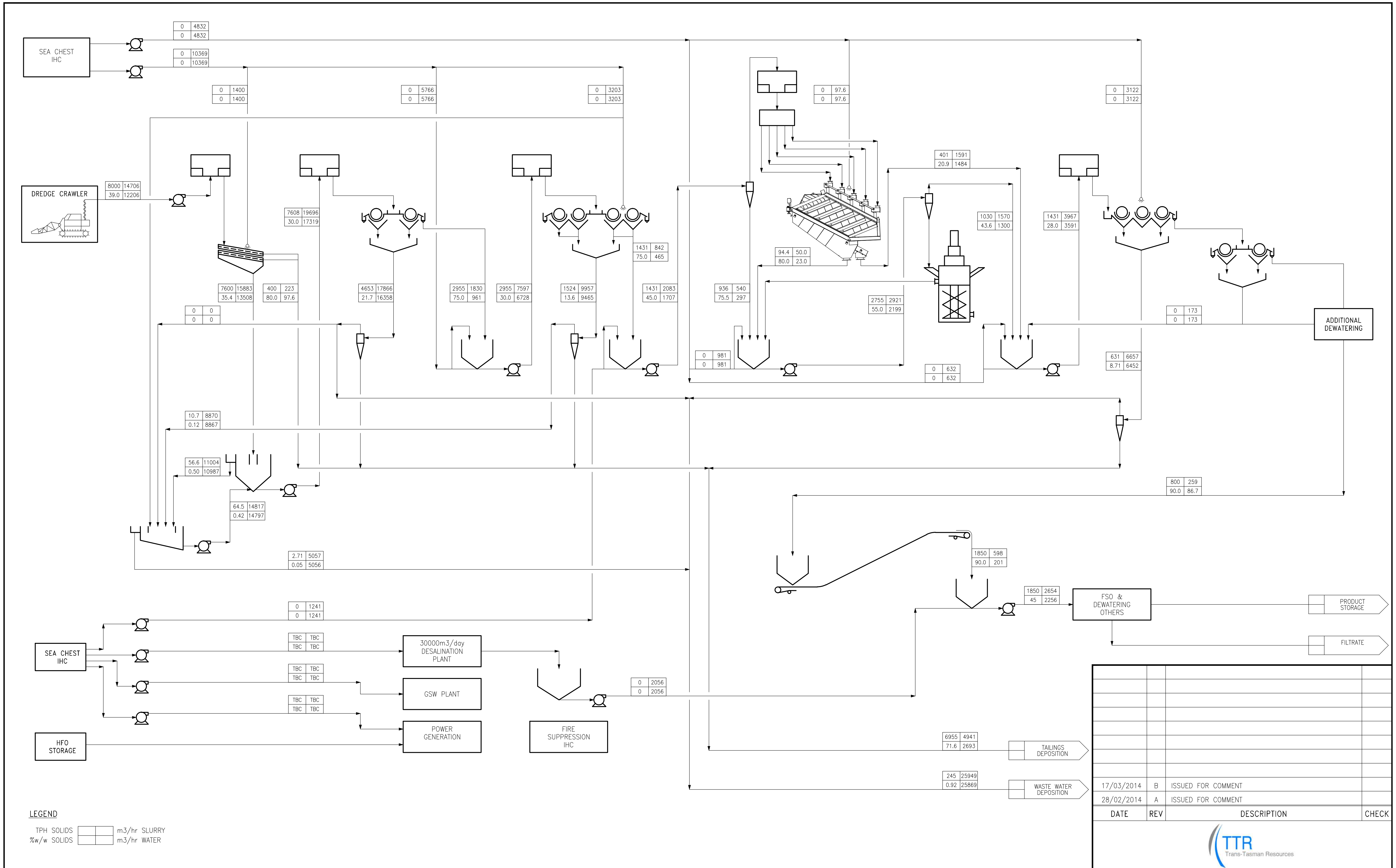
TTR Trans-Tasman Resources

DRA
DRA Minerals Park / Number 3 In anga Close / Sunninghill / 215
PO Box 356 / Rivonia / 2128 / South Africa
Tele hone: 2 11 202 8600
www.DRAglobal.com
DRA MINERAL PROJECTS

CLIENT		
PROCESS MAN.		
PROJECT MAN.		
PROCESS ENG.	D. MATTHEWS	FEB 2014
CHECKED		
DRAWN	MMK	19/02/14
APPROVAL	SIGNATURE	DATE

TITLE TRANS-TASMAN RESOURSES LRD
OFFSHORE IRON SANDS PROJECT
INDEX
PROCESS FLOW DIAGRAM

DRAWING No.	CAD REF		
C8381-PFD-INDEX	8381-PFD-index-1 06/03/14		
	REVISION B	SIZE A2	SCALE N.T.S.



DATE	REV	DESCRIPTION	CHECK
17/03/2014	B	ISSUED FOR COMMENT	
28/02/2014	A	ISSUED FOR COMMENT	

TTR Trans-Tasman Resources

DRA

DRA Minerals Park / Number 3 Inyanga Close / Sunninghill / 2157
PO Box 356 / Rivonia / 2128 / South Africa
Telephone: +27 11 202 8600
www.DRAglobal.com
DRA MINERAL PROJECTS

CLIENT		
PROCESS MAN.		
PROJECT MAN.		
PROCESS ENG.	D. MATTHEWS	FEB 2014
CHECKED		
DRAWN	MMK	19/02/14
APPROVAL	SIGNATURE	DATE

TITLE TRANS-TASMAN RESOURCES LTD
OFFSHORE IRON SANDS PROJECT
SERVICES & RETICULATION COMPRESSED AIR
PROCESS FLOW DIAGRAM

DRAWING No. C8381-PFD-000
CAD REF 8381-PFD-000-1 06/03/14
REVISION B | SIZE A2 | SCALE N.T.S.

7.5 Potential Power Savings

TRANS-TASMAN RESOURCES LTD

IRON SANDS

OFFSHORE IRONSANDS PROJECT

C8381

High Level Optimization of Processing Plant Power Requirements

STRICTLY CONFIDENTIAL

DOCUMENT NUMBER: C8381-PRO-003

REVISION: A

DATE: 04-February-2014

RECORD OF REVISIONS

Page	Revision	Description	Date
	A	Document issued for comment	04/02/2014

DISCLAIMER

This document has been prepared by DRA Mineral Projects (Pty) Ltd (hereinafter referred to as “DRA”), utilising professional and thorough guidelines within its scope of work and terms of reference. However, it is based largely and materially on assumptions as identified throughout the text and upon information, data and conclusions supplied by others. DRA is not in a position to, nor does it verify the accuracy of, or adopt as its own, the information and data supplied by others.

DRA, or any other person acting for and/or on behalf of DRA, assumes no responsibility, duty of care or liability to any person with respect to the contents of this document or with respect to any inaccuracy, absence of suitable qualification, unreasonableness, error, omission or other defect of any kind or nature in or with respect to this document.

The conclusions and recommendations contained in this document are believed to be prudent and reasonable in the context in which they are expressed and founded on experience, preliminary calculations and information provided by others. The opinions expressed herein are given in good faith, but are not a substitute for the evaluation and analysis of the information available, by others.

No representation or warranty with respect to the contents of this document is given or implied and DRA accepts no liability whatsoever for any loss or damage, howsoever arising, which may directly or indirectly result from the use or misuse of this document.

This document and the information contained herein is proprietary to DRA, and as such, will be held in confidence and treated as secret (“the Confidential Information”).

The Confidential Information shall not be used, published or reproduced in whole or in part for any purpose other than in connection with the purpose for which it was requested, nor shall the Confidential Information be disclosed to any third parties whomsoever, without the prior written consent of DRA, which consent shall not be unreasonably withheld or delayed.

This document is a “work in progress” document and is still subject to DRA’s internal review and, as such, is subject to change. Only the final version of this document, may be utilised and not this or any other version of this document. DRA accepts no responsibility or liability for any version of this document or the utilisation thereof.

TABLE OF CONTENTS

1 Introduction 1

2 Installed Power Saving Opportunities 2

2.1 Dredge Feed and Splitter Arrangement 2

2.2 Oversize Removal.. 4

2.3 Milling Circuit.. 5

2.4 Coarse Tailings Disposal 5

2.5 Fines Tails Disposal System 6

3 Summary.. 7

1 Introduction

The Trans Tasman Resources LTD flowsheet (TTRL-05-PFD-10002) was reviewed by DRA Mineral Projects for the purpose of identifying and conducting a preliminary estimation for potential reduction to installed power.

Various opportunities for power savings were identified, it must however be highlighted that in order to finalise the overall power requirements of the processing plant a detailed design including layout will be required. The installed power of process units for the existing flowsheet design were taken from the Basis of Design Document (TTRL-05-BOD-12000 BASIS OF DESIGN FOR PFD-R1) and at this stage were not verified by DRA Mineral projects for the purpose of this report.

In order to optimize the design, it is advised that a trade-off study for the various opportunities be conducted in terms of:

- Mass
- Lay-Out- Footprint/Height
- Maintainability
- Availability and Utilization
- Capex
- Opex
- Safety
- Efficiency

The sections that follow highlight some of the opportunities that were identified in terms of installed power savings.

2 Installed Power Saving Opportunities

2.1 Dredge Feed and Splitter Arrangement

The current flowsheet allows for the dredge pump feed to be discharged over a static screen and into a boil box. The material is withdrawn from the boil box by 4 centrifugal pumps and pumped to 4 trommel screens.

An alternative solution would be to pump this feed into a pressure splitter (4 ways), thereby splitting the material into 4 streams. The advantages of a pressure splitter are:

- lower overall mass (boil box and contents = 1900t),
- reduced safety risk (regarding potential manual removal of oversize material),
- higher splitter efficiency (volume and mass)
- lower overall installed power.

The disadvantage of the pressure splitter are:

- higher overall static pumping head from the dredge pump
- Depending on the additional height and lay-out requirements, a booster pump in line with the dredge pump may be required.

The following table summarises the potential installed power reduction by utilising a pressure splitter:

Description	Existing Boil Box Arrangement	Alternative Pressure Splitter Arrangement	Comments
Dredge Booster Pump	0Kw	1200kw (TBC)	Based on adding an additional 6m static head to dredge pump
Boil Box Pumps	4x600kw	0kw	From Basis of Design Document
Total Installed Power	2400kw	1200kw	

2.2 Oversize Removal

The current flowsheet allows for 4 trommel screens to remove the oversize material (+3.5mm).

An alternative solution would be to investigate the use of double deck vibrating screens. The primary deck would be to replace the duty of the Grizzly on the boil box. The secondary deck would be to remove the +3.5mm material. The advantages of using vibrating screens are:

- lower mass (30 tons per screen compared to 220t per trommel),
- smaller footprint,
- lower Capex
- lower installed power.

The following table summarises the potential power saving by installing screens:

Description	Existing Trommel Screen Arrangement	Alternative Vibrating Screen Arrangement	Comments
Trommel Screen Installed Power	4 x 1 120kw	0kw	As per basis of design document
Vibrating Screen Installed Power	0Kw	4x75kw	
Total Installed Power	4 500kw	300kw	

The influence of utilizing screens on the streaming requirements (in terms of maintenance allowance and equipment oversize) and therefore availability and utilization must be further investigated.

2.3 Milling Circuit

Various mill options were investigated, ball mills, ISA Mills and Vertimills. The current flowsheet allows for 2 Vertimills in parallel. Mill testwork was undertaken to determine the Vertimill design parameters.

Initial assessment of the milling circuit indicates that two smaller Vertimills in parallel can be utilised. It must however be noted that the variability of the ore has not been taken into account and that during the detail design phase additional milling capacity might be required.

The following tables summarises the mill specifications

Description	Mill Specifications as per Basis of Design	Mill Specifications as per Mill Testwork
Mill Description	2 x VTM 4500	2 x VTM 3000
Installed Power	2 x 3 375kw	2 x 2 250kw

2.4 Coarse Tailings Disposal

The current flowsheet allows for all the coarse tails (trommel screen oversize, MIMS as well as LIMS tails) to be collected in a common sump, from where it is pumped to the tails cyclone clusters for dewatering. The cyclone underflow reports to the tailings disposal pipe and the overflow to the waste water deposition pipe.

An alternative option to be investigated and traded off is to lay the processing plant out such that the sizing screen oversize is discharged directly to the tailings deposition pipe. This will minimise the need to pump oversize material (nominally -25mm) to the coarse tails cyclone clusters.

Further opportunity exists to gravity feed the MIMS and LIMS1 tails directly to dewatering cyclones dedicated to the magnetic units, thereby eliminating the need for separate coarse tails disposal pumps and a common collection tanks. This solution will however require additional height for the MIMS and LIMS1 circuits. The lay-out for this option is critical as the cyclone underflow is required to discharge directly into tailings disposal pipe.

The effects of the potential additional heights have not been taken into account in this comparison. The following table summarises the potential power savings by optimising the coarse tails disposal system:

Description	Coarse Tails Disposal System as per Basis of Design	Alternative Coarse Tails Disposal System
Coarse Tails Cyclone Feed Pumps Installed Power	4 x 1500kw	0 Kw

2.5 Fines Tails Disposal System

The current flow sheet allows for all fines magnetics tails (from LIMS 2 and LIMS 3) to be collected in a common sump, from where it is pumped to the tails cyclone cluster for dewatering. The cyclone underflow reports to the tailings disposal pipe and the overflow to the waste water deposition pipe.

The same design philosophy as the coarse tails disposal can be utilised by gravity feeding individual tails dewatering cyclones thereby eliminating the need for pump fed cyclones. It must be noted that from a lay-out point of view it will be problematic to launder the cyclone underflow from the LIMS 2 and LIMS 3 areas into the tails deposition pipe.

It was therefore felt that the potential power savings on the fines tails disposal system would not be included in the report

3 Summary

The final power requirements of the processing plant can only be verified and calculated once a final design and lay-out has been completed. The report only highlights potential savings that will still have to be traded off and finalised during the detail design phase.

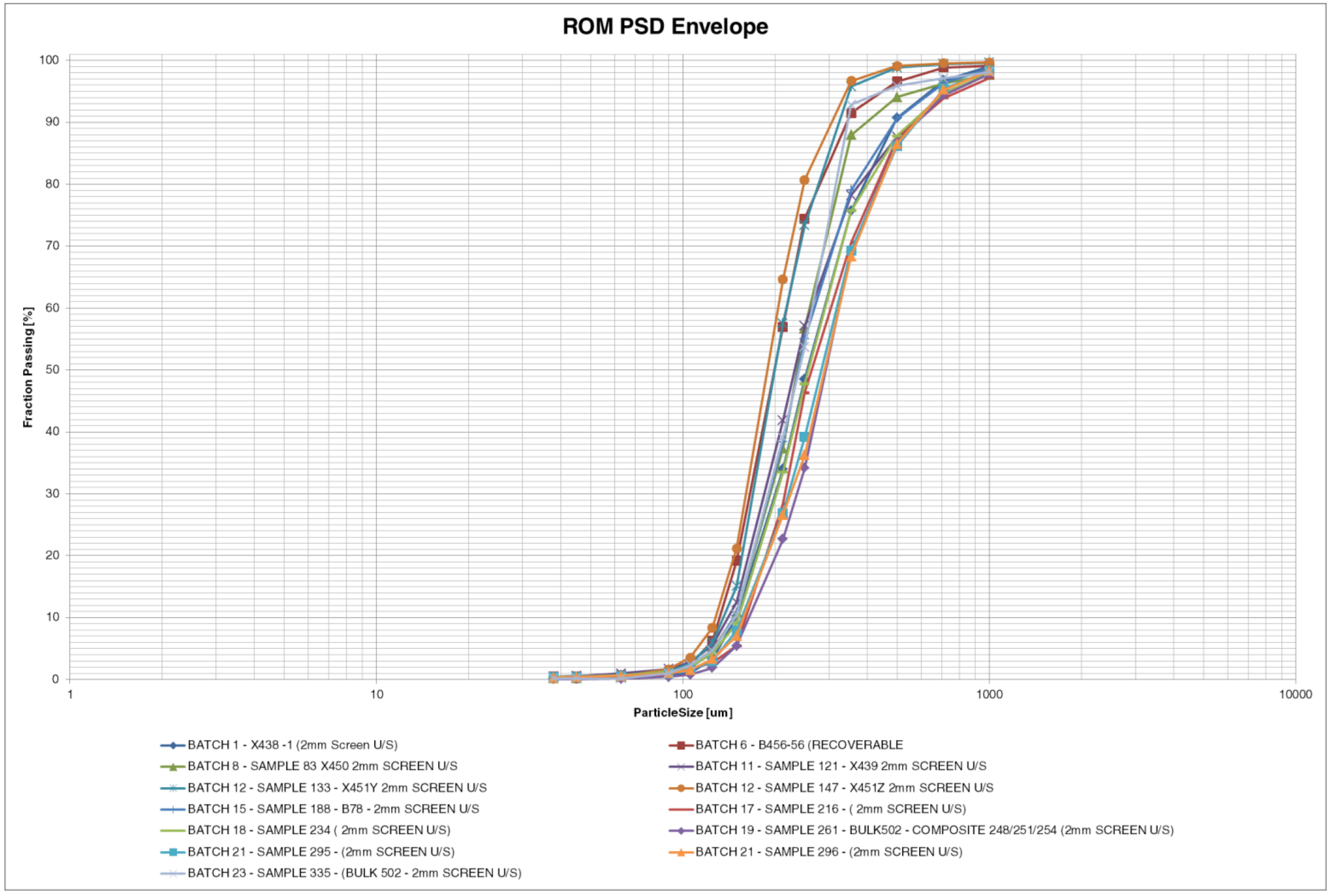
The following factors have not been taken into account:

- The variability of the feed material and the influence on the circuit design and therefore power requirements;
- Effects of changes in lay-out on the power consumption;
- Additional unit processes required, for example additional; drying/dewatering requirements ahead of the dry storage on the FPSO

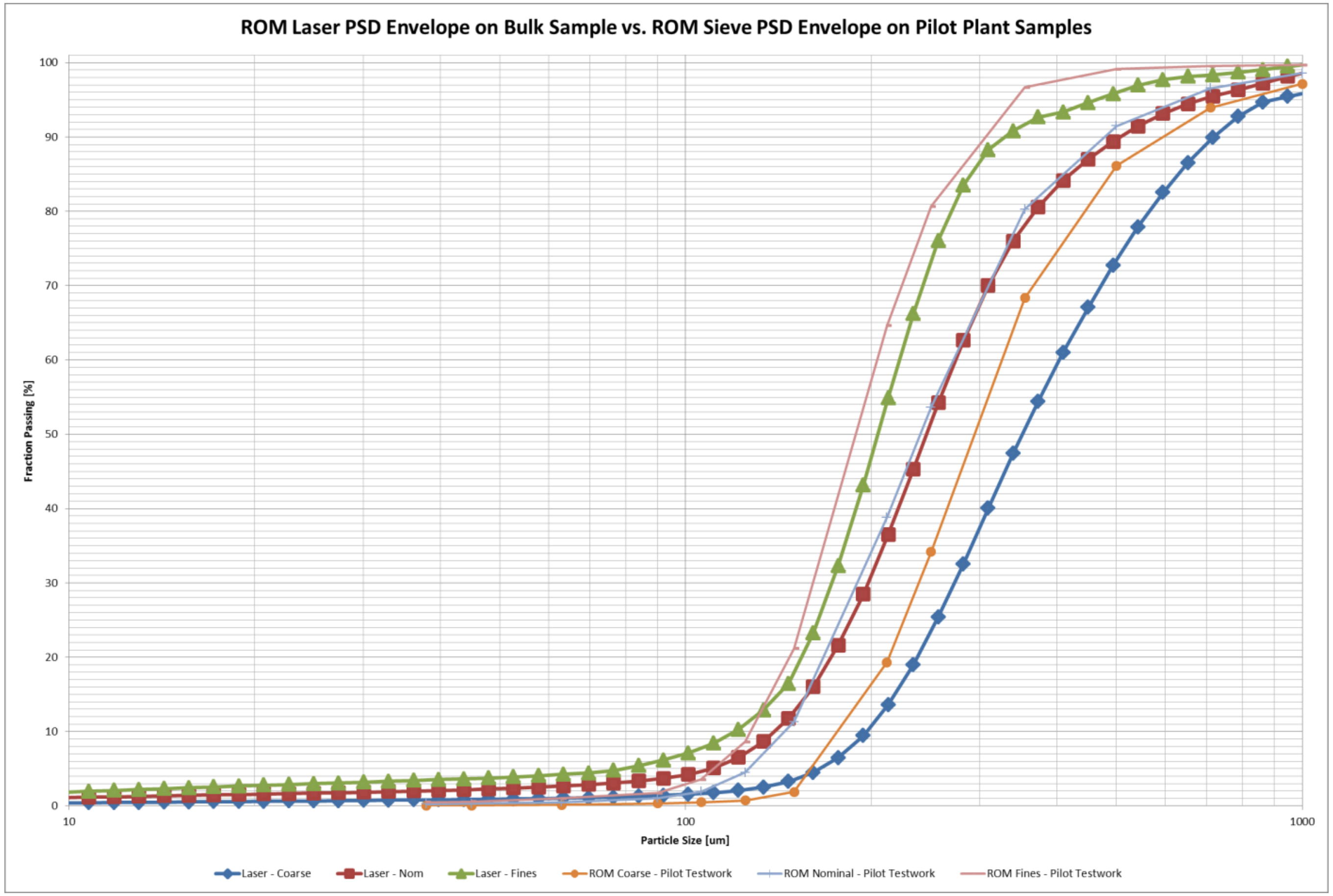
The following table summarizes the potential reduction in installed power for the processing plant based on the opportunities identified in the report above:

Description	Installed Power as per Basis of Design	Installed Power as per Alternative Flowsheet	Delta Installed Power
Dredge Feed + Splitter	2 400kw	1 200kw	-1 200kw
Oversize Screening	4 500kw	300kw	-4 200kw
Milling Circuit	6 750kw	4 500kw	-2 250kw
Coarse Tailings Disposal System	6 000kw	0 kw	-6 000kw
Total	19 610kw	5 970kw	13 650kw
Derate is to allow for additional pumping heights, process requirements and lay-out allowances			-25%
Total Potential Saving in Installed Power			-10 250kw

7.6 ROM PSD as Tested in TTR Pilot Plant



7.7 ROM PSD Comparison



TTR Trans-Tasman Resources

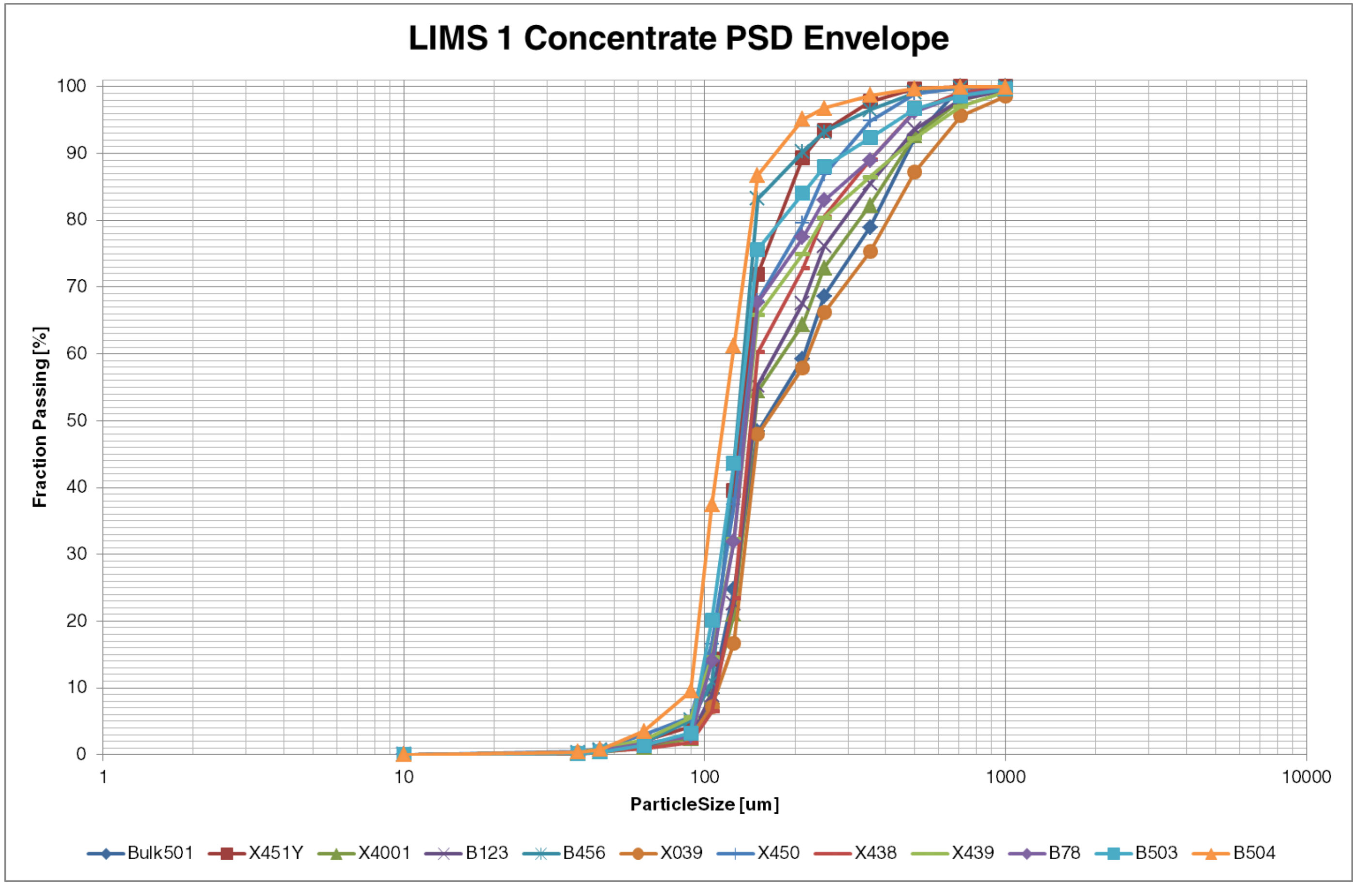
DRA

7.8 Recovery Data from Screening, MIMS and LIMS

	Mass Recovery					Fe - Conc					Fe - Rej				Fe Recovery			Overall	
RUN	-2mm	MIMS	LIMS 1 - 1	LIMS 1 - 2	LIMS 1 - 3	Head Fe	MIMS Fe	LIMS 1 - 1	LIMS 1 - 2	LIMS 1 - 3	MIMS Fe	LIMS 1 - 1	LIMS 1 - 2	LIMS 1 - 3	MIMS Fe	LIMS 1 - 1	LIMS 1 - 2 Fe	Mass	Fe
X038	96.80%	58.03%		40.89%		15.75%	22.27%		40.62%		6.19%		8.90%		82.06%		74.59%	22.97%	61.20%
X438	97.60%	66.78%	66.85%	85.12%		21.10%	28.10%	38.06%	42.00%		6.68%	8.01%	8.71%		88.93%	90.55%	93.93%	37.09%	75.64%
X438	97.60%	66.78%	66.85%	85.12%		21.10%	28.10%	37.05%	42.00%		6.68%	8.01%	8.71%		88.93%	88.14%	96.50%	37.09%	75.64%
B456	98.40%	44.42%	71.91%	91.86%		14.20%	25.40%	37.10%	40.10%		4.73%	7.30%	7.94%		79.46%	105.03%	99.29%	28.87%	82.86%
B456	98.40%	44.42%	71.91%	91.86%		14.20%	26.05%	33.37%	40.10%		4.73%	7.30%	7.94%		81.49%	92.13%	110.38%	28.87%	82.86%
B456	98.40%	44.42%	71.91%	91.86%		14.20%	26.05%	37.48%	40.10%		4.73%	7.30%	7.94%		81.49%	103.47%	98.28%	28.87%	82.86%
B456	98.40%	44.42%	71.91%	91.86%		14.20%	29.00%	37.48%	40.10%		4.73%	7.30%	7.94%		90.73%	92.93%	98.28%	28.87%	82.86%
X450	96.30%	34.21%	74.27%	95.19%		7.82%	20.22%	24.82%	25.70%		3.77%	6.94%	7.38%		88.44%	91.17%	98.57%	23.29%	79.48%
X039	97.10%	50.00%	51.48%	81.85%	91.71%	9.82%	16.22%	25.12%	28.95%	30.80%	4.33%	6.78%	7.82%	8.52%	82.58%	79.72%	94.35%	20.45%	62.11%
X039	97.10%	50.00%	51.48%	81.85%	88.57%	9.82%	15.92%	24.54%	28.25%	30.80%	4.33%	6.78%	7.82%	8.52%	81.08%	79.34%	94.22%	20.45%	60.61%
X439	95.00%	44.58%	55.90%	84.81%	93.25%	9.62%	19.80%	30.48%	34.67%	36.60%	3.70%	6.26%	7.10%	8.00%	91.76%	86.06%	96.46%	20.08%	76.17%
X439	95.00%	44.58%	55.90%	84.81%	91.50%	9.62%	19.56%	30.06%	34.17%	36.60%	3.70%	6.26%	7.10%	8.00%	90.66%	85.89%	96.41%	20.08%	75.07%
Bulk501	97.30%	49.30%	29.80%	53.90%		10.48%	15.3%	31.9%	53.2%		4.19%	12.57%	3.19%		71.90%	62.10%	90.00%	7.70%	40.18%
Bulk501	97.30%	49.30%	29.80%	53.90%		10.48%	14.3%	29.70%	49.40%		4.19%	11.77%	2.97%		71.90%	62.10%	90.00%	7.70%	40.18%
X4001Y	96.20%	60.95%	56.83%	85.67%	92.06%	13.82%	21.55%	32.69%	36.80%	39.20%	5.07%	6.88%	8.11%	8.92%	95.02%	86.22%	96.44%	28.55%	79.01%
X4001Y	96.20%	60.95%	56.83%	85.67%	91.13%	13.82%	21.41%	32.44%	36.51%	39.20%	5.07%	6.88%	8.11%	8.92%	94.41%	86.13%	96.42%	28.55%	78.40%
X4001Z	96.20%	58.55%	52.79%	86.80%	94.07%	13.80%	22.02%	34.75%	38.73%	40.60%	5.54%	7.79%	8.62%	9.03%	93.44%	83.30%	96.73%	25.81%	75.29%
X4001Z	96.20%	58.55%	52.79%	86.80%	93.62%	13.80%	21.96%	34.63%	38.58%	40.60%	5.54%	7.79%	8.62%	9.03%	93.17%	83.25%	96.71%	25.81%	75.02%

Legend: Data Selected; Data Rejected; Data - Back Calculated via mass balance

7.9 LIMS 1 Conc PSD Data Source



7.10 Metso Milling Testwork Report

DRA – Trans – Tasman Resources
Suite 502
80 Strand Street
Cape Town, RSA

Devan Matthews
Process Engineer
+27 82 921 6861
dmatthews@drasa.co.za

Test Plant Report – 20160216

January 31, 2014

Special Jar Mill Grindability Test

Iron Sands

Nick Mayfield

Material

One (1) sample of Iron Sands was received at the Metso York Test Plant on Wednesday, December 18, 2013. The as-received analysis is shown in the table below.

Table 1

Mesh	Microns	% Passing
14	1168	
20	833	99.9
28	589	99.5
35	417	98.6
48	295	95.8
65	208	87.2
100	147	57.4
150	104	6.5
200	74	1.2
270	53	0.7
325	44	0.6
400	37	0.5
500	25	0.4
D80 (µm)		193.6

Table 1: As received size analysis of material

Purpose

The Special Jar Mill Grindability Test was performed to determine the specific energy required to grind the as-received material to eighty percent passing 125µm using a Vertimill.

Equipment

Special Jar Mill Grindability Tester

The Jar Mill test rig consists of a 203 mm x 254 mm steel jar rotating at 76% critical speed. The Special Jar Mill Grindability Test was performed with 15.9kg of the selected diameter steel balls as media.

Special Jar Mill Grindability Procedure

Procedure

A representative sample was split from the as-received material and used to determine the bulk density and size distribution. The solids and water required for the desired solids concentration was calculated and respectively charged to the mill for each Jar Mill test. The material was milled for a predetermined period of time and then discharged. After dewatering and drying, the jar mill product was again split to determine the size distribution of the ground product. The process was repeated until the desired product size specification was achieved.

Remarks

Test data is shown in Table 3 as well as summarized in Table 2 below.

The Grind energy curve is shown in Figure 1.

Particle size distributions are shown in Figure 2.

Table 2

Test	F_{80} (µm)	P_{80} (µm)	Specific Energy (kWh/mt)
Jar Mill 1	193.6	125	3.10

Table 2: Summary of Tests

metso

Table 3 - Jar Mill Grindability Test Results

Service Order Number	20160216
Customer	DRA-Trans-Tasman Resources
Material	Iron Sands
Test	Jar Mill 1
Top Size Media	19 mm Steel Balls
Description of Media	15.9 kg of Monosize Balls
Ore Bulk Density	2541.8 g/L
Solids Charged	3501.3 g
Water Charged	1498.1 g
Solids Concentration	70% (by weight)
Net Power Draw	0.0451 kW
Product Size Specification	80% Passing 125 µm

Required Vertimill Specific Energy (kWhr/mt) 3.10

Tyler	Microns	Feed	1	2
6	3327			
8	2362			
10	1651			
14	1168			
20	833	99.9	99.9	
28	589	99.5	99.9	
35	417	98.6	99.9	
48	295	95.8	99.8	
65	208	87.2	99.2	99.8
100	147	57.4	88.9	96.7
150	104	6.5	46.3	70.0
200	74	1.2	22.5	35.8
270	53	0.7	13.3	21.9
325	44	0.6	10.2	16.9
400	37	0.5	8.6	14.0
500	25	0.4	6.2	9.7
d_{80} (µm)		193.6	139.0	120.0
Specific Energy (kWhr/mt)		0.0	2.1	3.5

Size Analyzes Reported as Cumulative Percent Passing

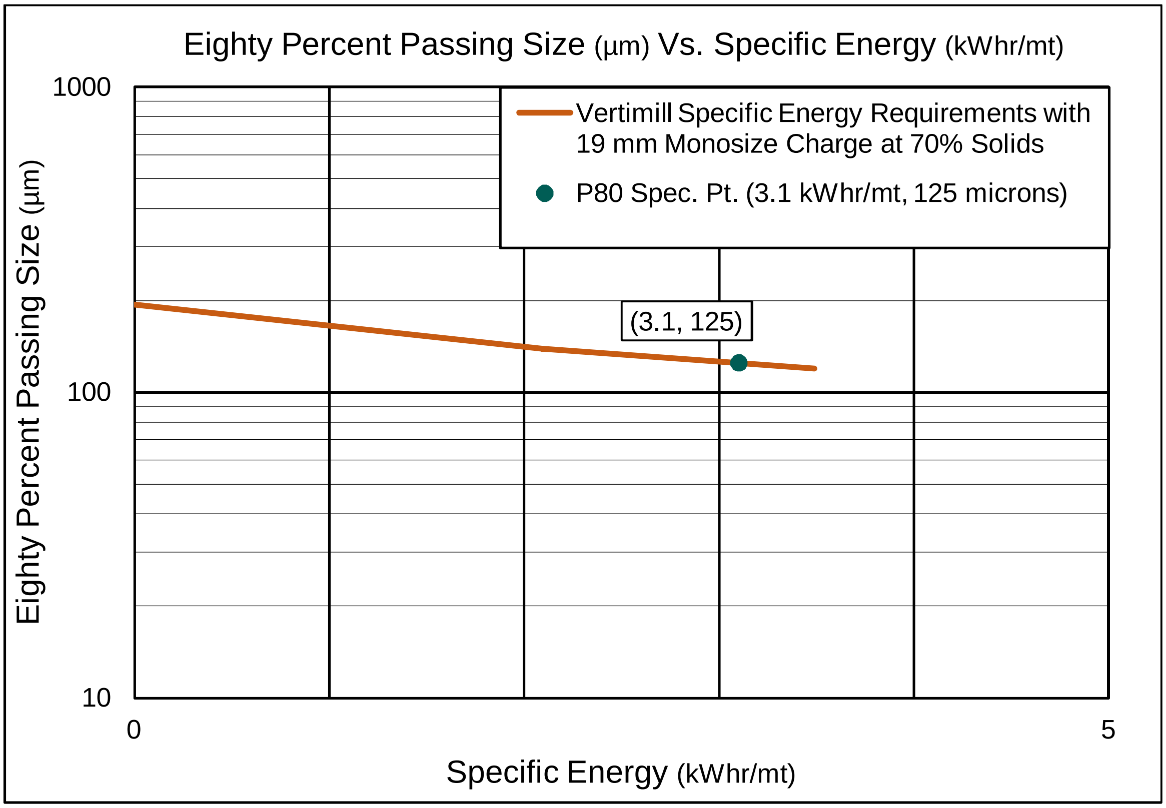


Figure 1 - Graph of Grind Energy Curve for Jar Mill 1

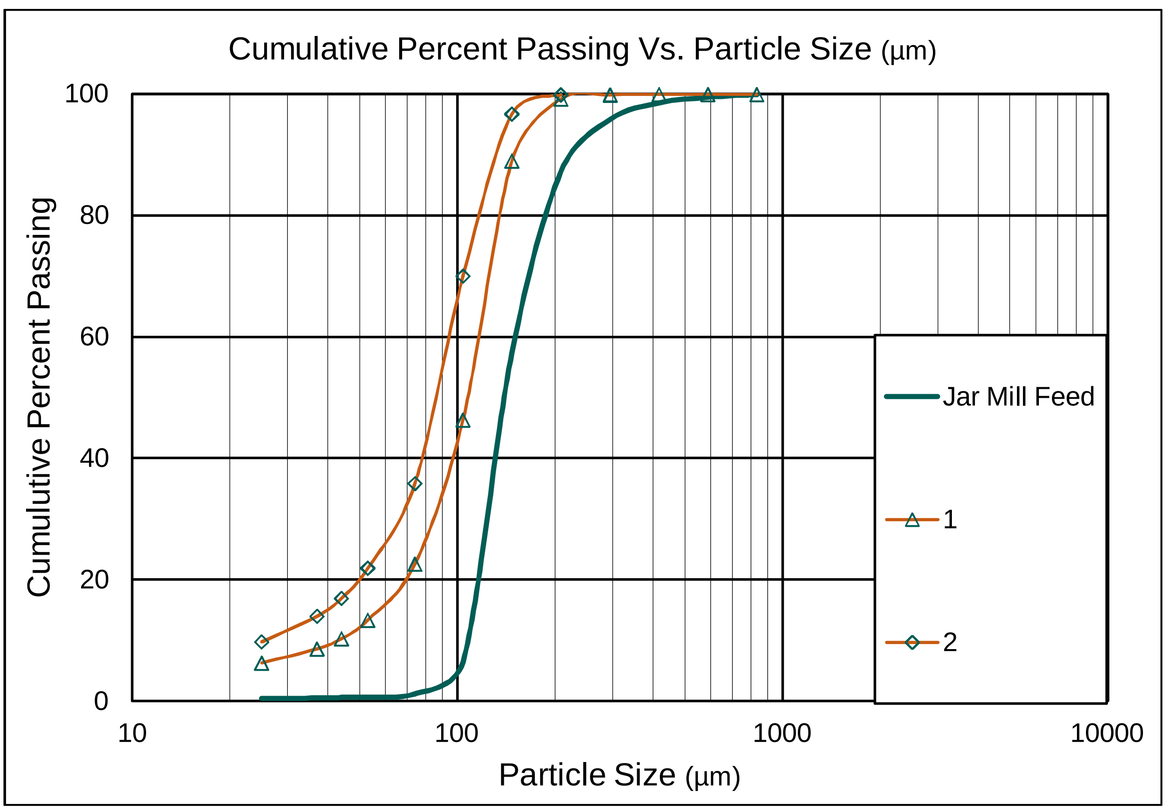


Figure 2 - Graph of Particle Size Distributions for Jar Mill 1

7.11 Metso Milling Recommendation Report

DRA - TTR

Offshore Iron Sands

VERTIMILL APPLICATION SHEET - POWER REQUIREMENT ESTIMATION

APPLICATION

Material Description	Iron Sands
Specific Gravity (gm/cc)	3.80
Fresh Feed - MTPH	1208.00
F80 (80% Passing Feed Size)	193.6 µm
P80 (80% Passing Product Size)	125 µm

POWER REQUIREMENT CALCULATIONS

Jar Mill Specific Energy - kW-hr/mt	3.1
Safety Factor	1.00
Special Mill Factor	1.00
Predicted Vertimill Specific Energy Requirement (kW-hr/mt)	3.1
Total Power Required @ Reducer Output (kW)	3745

MILL RECOMMENDATION

Recommended Mill Selection	Two (2) VTM-3000-WB
Standard Motor Power (kW)	2237
Mill Body Height (base to operating level, mm)	5835
Overall Mill Height (incl. Motor, mm)	17588
Mill Weight (kgs)	343000
Body Liner Type	Magnetic
Media Type	19-mm Steel
Standard Media Charge Weight (kgs)	278000

Information provided herein is preliminary and does not constitute a guarantee.
Prepared by Metso Minerals 2/10/2014

7.12 DRA Milling Simulation Report

TTR-Grinding Testwork and Mill Sizing

C8381: Simulations on fine milling Iron Sands

DRA Mineral Projects

Paul.Morgan

UFG Testwork & Simulations

Testwork

A number of milling tests have been conducted on several marine Iron Sands concentrates from Trans-Tasman Resources to establish the most appropriate and efficient comminution treatment route…

A limited amount of sample was provided to Metso for conducting standard Jar Mill testwork data to assess the milling requirements to achieve the target grind, and provide a Vertimill® sizing for the marine duty.

Several magnetic separation concentrates were progressively milled using the Levin-Method; which is effectively fine grinding in a standard Bond laboratory mill at known energy inputs. Milling tests were also conducted in laboratory scale UFG (ultrafine grinding) mills (Isa mill) on concentrates, and so a comparison between each technology and ball size effect can be made.

It has been possible to determine the grinding characteristics of the iron concentrate samples tested, and therefore establish the probable milling performance of various milling options.

Levin Progressive Milling

Population balance modelling was used to simulate the milling results obtained from the Levin testwork results supplied in the X038/X039 LIMS Magnetics Levin test document.

The subsequent milling rates are reportedly:

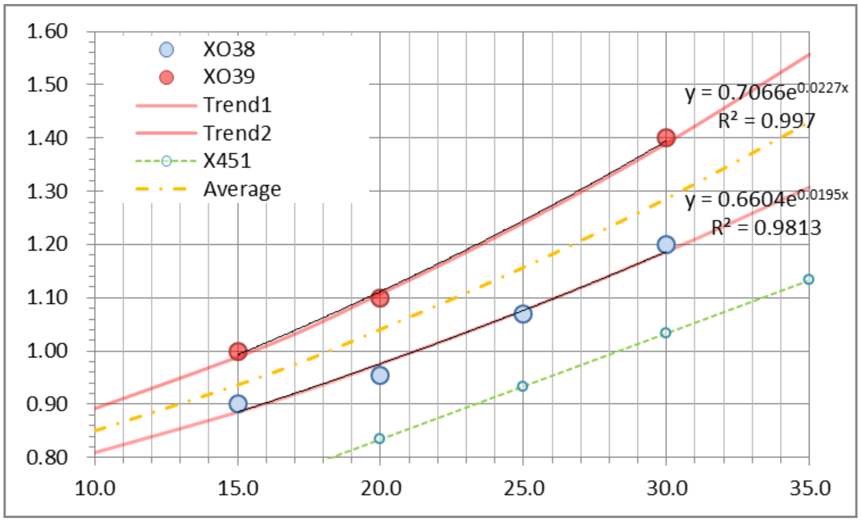


Figure 1-Levin Test Typical milling rates with applied power

The same breakage function was used throughout and the grinding rates were manipulated to ascertain the best fit. From low energy grinding simulations show that there is a gradual improvement in milling rates with applied power.

The following figures show the typical simulation results against actual results for the sample concentrate grinding.

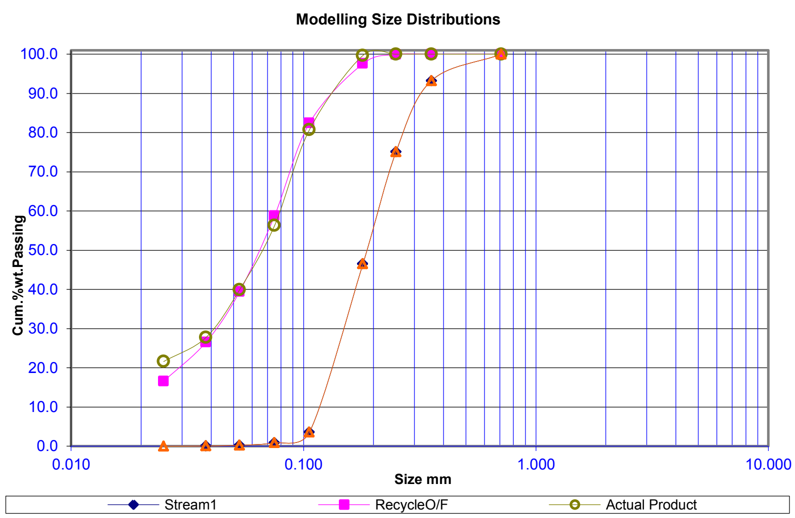


Figure 2 Applied 15kWh/t Concentrate Grind X039

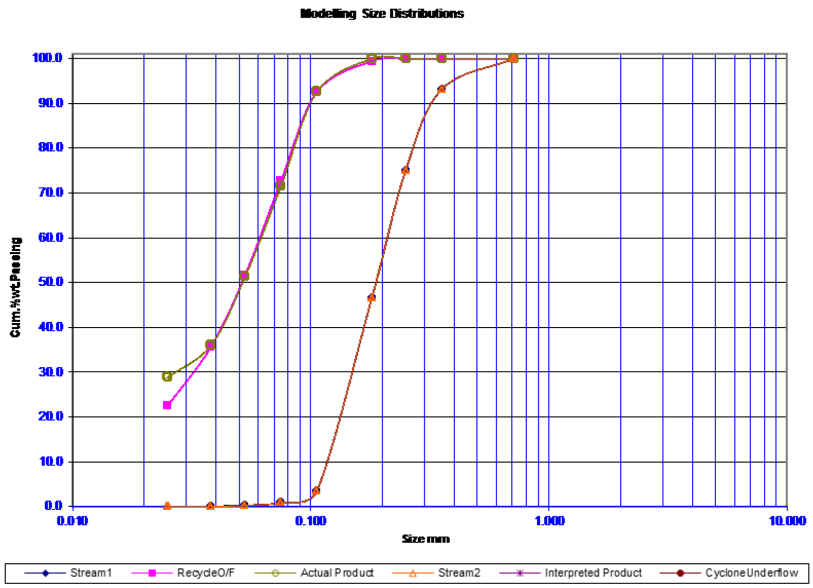


Figure 3 Applied 20kWh/t Concentrate Grind X039

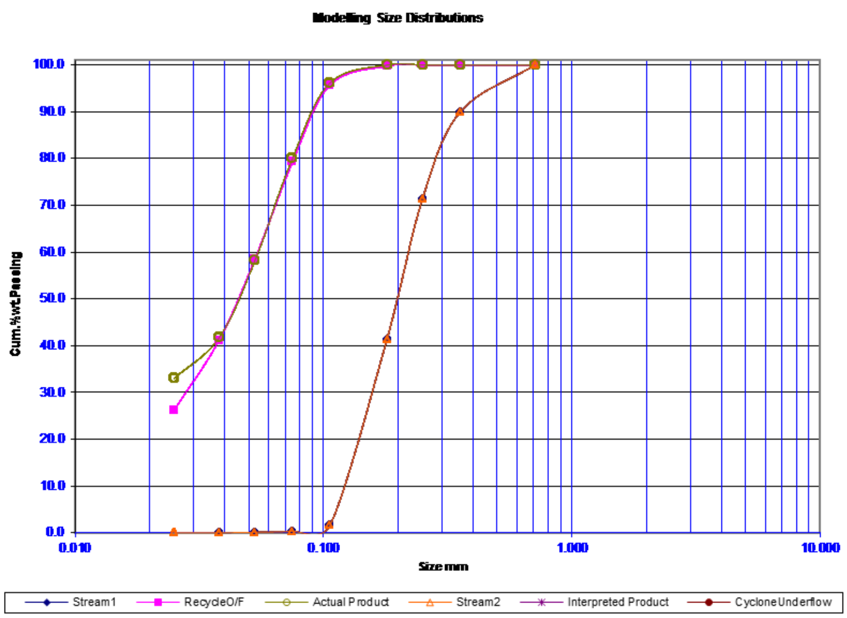


Figure 4 Applied 25kWh/t Concentrate Grind X038

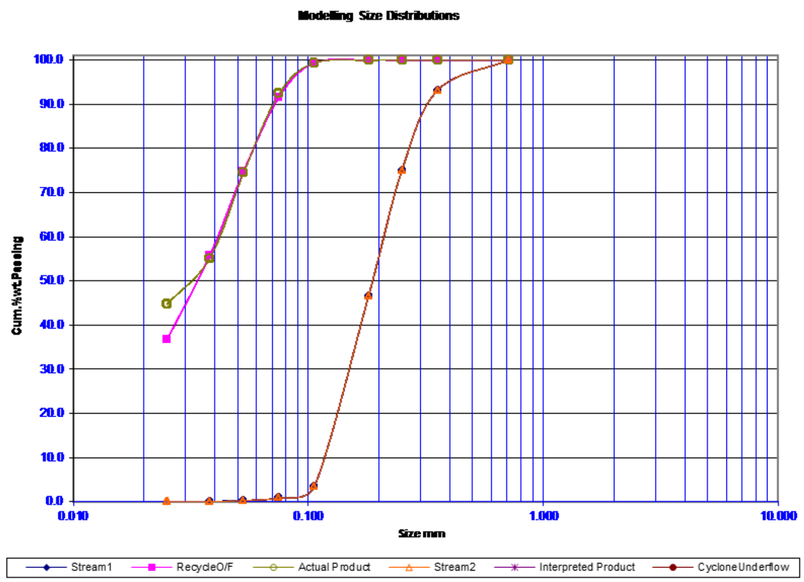


Figure 5 Applied 30kWh/t Concentrate Grind X039

It can be seen that the simulations give a good description of the milling response, suggesting that between 7.5~12kWh/t is required by conventional milling.

ISA Mill Signature Plot

[A14595 IsaMill Signature Plot.pdf]

ALS Metallurgy

IsaMill Grinding Test Report

Project Name	A14595 - NZ pilot plant	Date(s) Tested	15-Apr-13
Duty Description		Date Issued	23-Apr-13
Ore /Conc. Type	X461 - HIGH TIO2 MAGNETITE	Location	ALS Ammtec
Company	Trans Tasman Resources	IsaMill Type	M4
Contact Person	Andre Mouton	Media Spec.	5-6mm Cenotec
Contact Details	[illegible]	Contact Person	Ian Ladhams

Test Data

Solids SG (t/m3): 4.13 | Media Vol (L): 2.6 | Media g (Start): 6275 | Media g (End): 6259

Pass #	N (rpm)	NLP (kW)	Q (sec/L)	Pump %	kg/L (Marcy)	Temp C	E (Wh)	Time (h)	Comments
1	1514	0.74	14	100	1.75	29.5	168	0.075	
2	1515	0.74	15	100	1.82	40	200	0.077	
3	1515	0.74	15	100	1.76	41	187	0.081	
4	1515	0.74	17	85	1.75	45	249	0.109	
5	1516	0.74	19	70	1.74	50	277	0.124	
6	1516	0.74	20	70	1.76	51	250	0.123	
7	1517	0.74	21	70	1.75	52.5	176	0.107	
8	1516	0.74	20	70	1.76	52.5	176	0.098	
			>>>	Averaged	1.78	<<<			
				Calculated	1.77				

Calculated Data

Pass #	Gross kW	Net kW	Q (m3/h)	% Solids	M (t/h)	E (kWh/t)	Cumul. E	P80	P98	CSI
Feed								207.7	354.5	1.7
1	2.24	1.50	0.257	60.7%	0.275	5.5	5.5			
2	2.61	1.87	0.240	61.7%	0.261	7.2	12.6			
3	2.31	1.57	0.240	54.8%	0.232	6.8	19.4			
4	2.28	1.53	0.212	56.7%	0.211	7.3	26.6	87.9	189.1	2.2
5	2.24	1.49	0.189	55.1%	0.184	8.1	34.8	69.3	148.3	2.1
6	2.04	1.30	0.180	55.0%	0.174	7.4	42.2	50.4	109.0	2.2
7	1.64	0.90	0.171	53.9%	0.163	5.5	47.7	39.3	73.0	1.9
8	1.80	1.06	0.180	54.4%	0.173	6.2	53.9	28.6	55.7	1.9

Target P80 Size (if applic.): 63 | kWh/t @ Target: 38.7 | Media Consumption (g/kWh): 9

Signature Plot

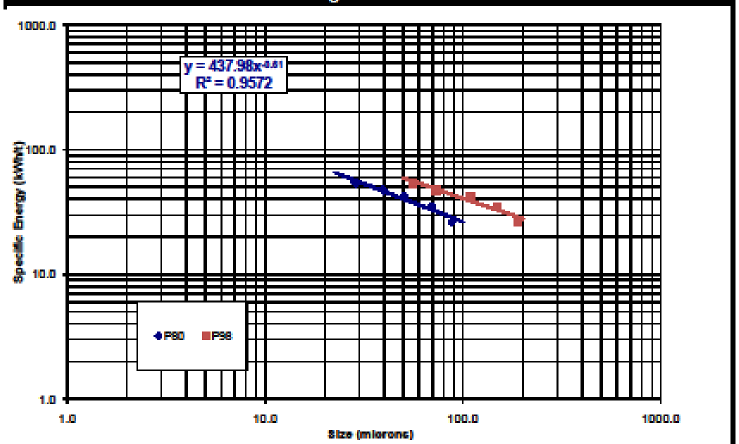


Figure 6-ISA Mill Spreadsheet

Sample X451 was submitted to Ammtec Laboratories for ISA Milling to obtain a signature plot, using 5~6mm beads.

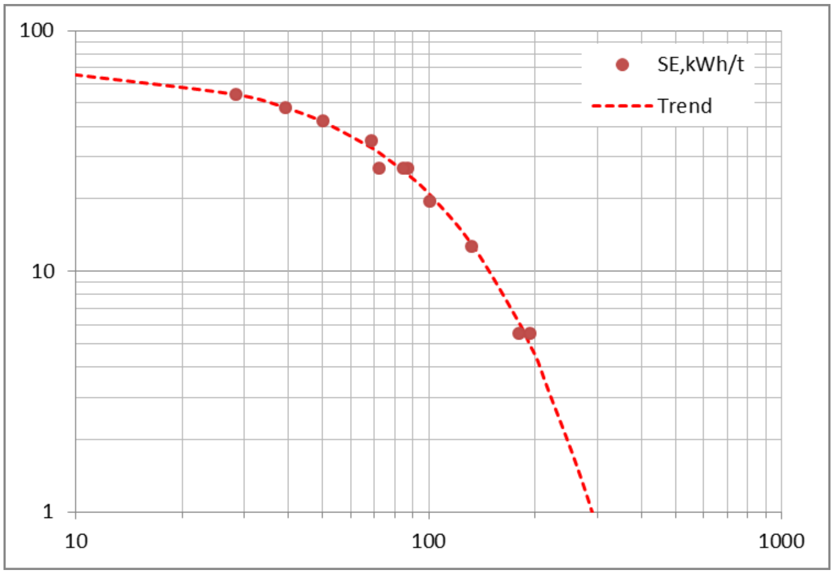


Figure 7 ISA Mill Specific Energy versus Product P80

Definition of the trend in breakage rates with applied energy was sufficient despite something peculiar occurring midway through the testwork during passes 3, 4 and 5. The rates are less than conventional milling, despite improved particle breakdown, suggesting the smaller media size is more inefficient.

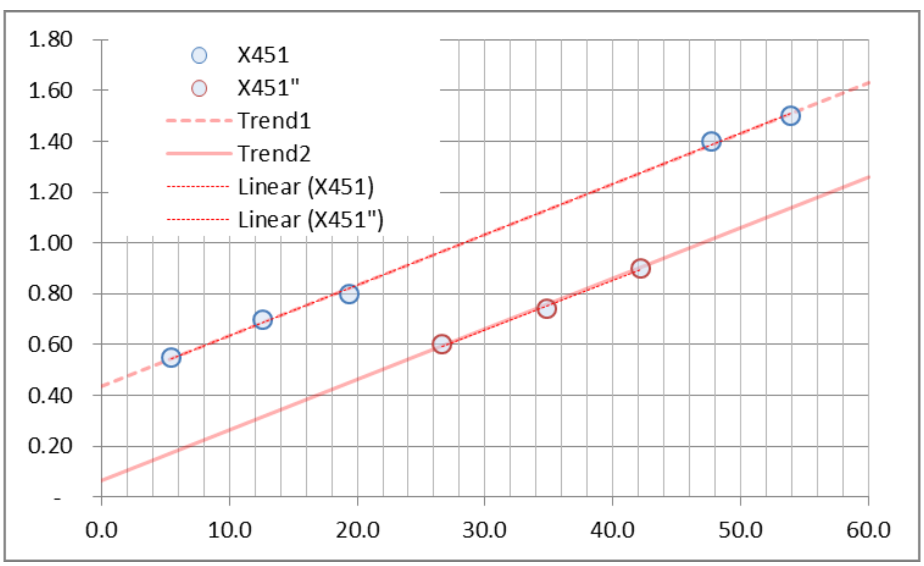


Figure 8-ISA mill Attributed Breakage Rates with Applied Power

Consequently, it was suggested to investigate the use of Tower Mills, which use slightly larger media than the ISA mill.

Jar Mill Testwork

Metso report – Appendix 9.11

The Jar mill test was conducted with 19mmØ mono-sized balls and was tested at two different energy levels, namely 2.1 and 3.5kWh/t. It may be significant that only mono-sized media was used, but subsequent full-scale simulations have been made without any de-rate taken into consideration.

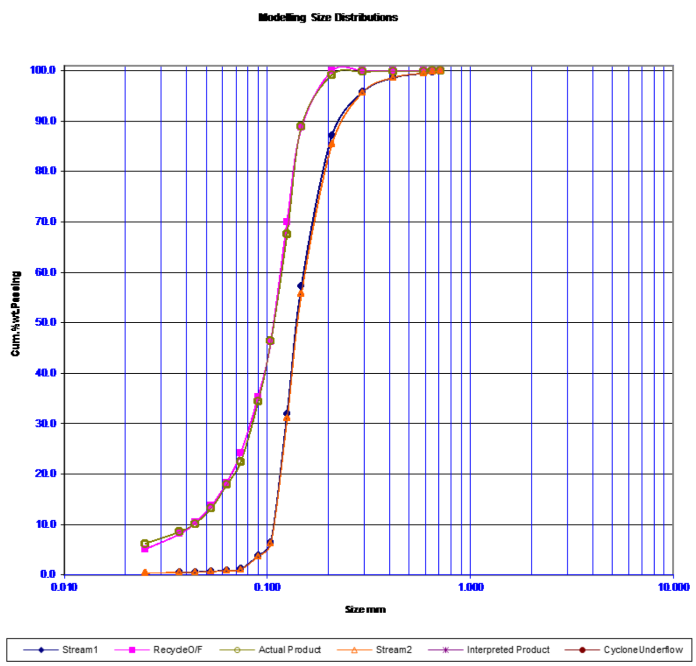


Figure 9-Jar Mill Simulation at 2.1kWh/t

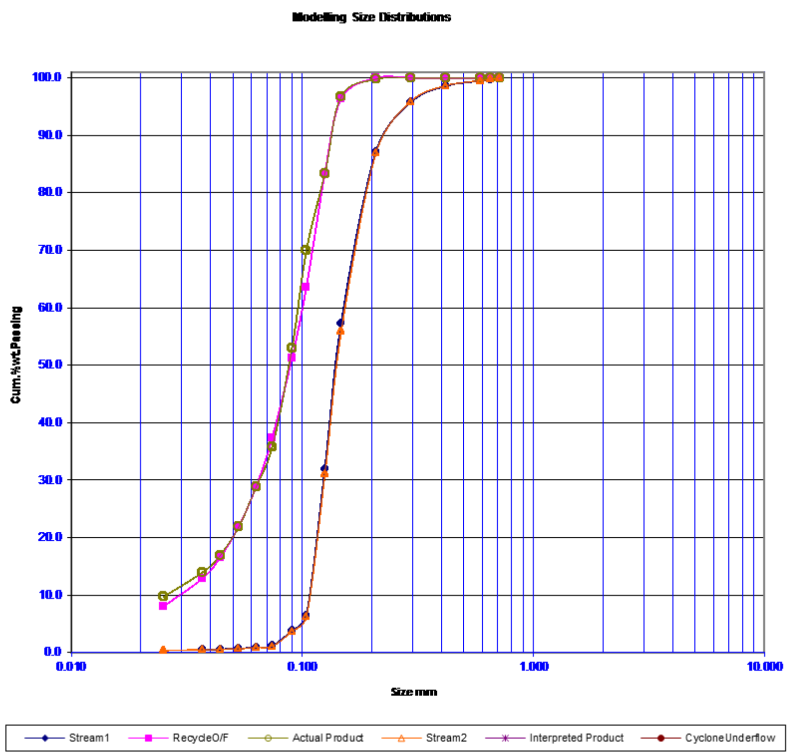


Figure 10-Jar Mill test Simulation 3.5kWh/t

The grinding rates obtained were similar at low energies, 3.465*t/kWh* and were significantly higher than both Levin and IsaMill, by *at least* a factor of two, and significantly more at the lower energy inputs.

These results were subsequently used for simulating a full-scale mill (*without any derate*).

Full-Scale Simulation

The milling circuit proposed is as follows:

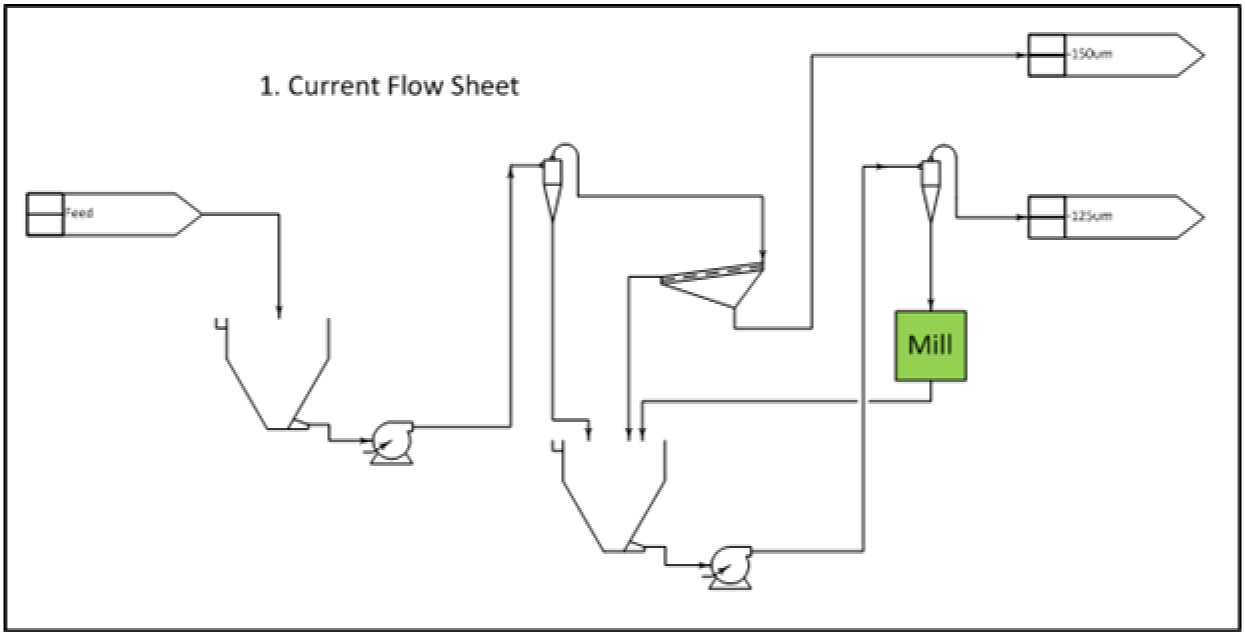


Figure 11-Proposed Milling Circuit Configuration

It has been suggested to use a cluster of 750mmØ separators ahead of Derrick Stacker screens (150µm) to achieve a sharp cut, and limiting the number of screens required. The following mill feed PSD range has been assumed from classification estimations on magnetic concentrate PSD variations provided:

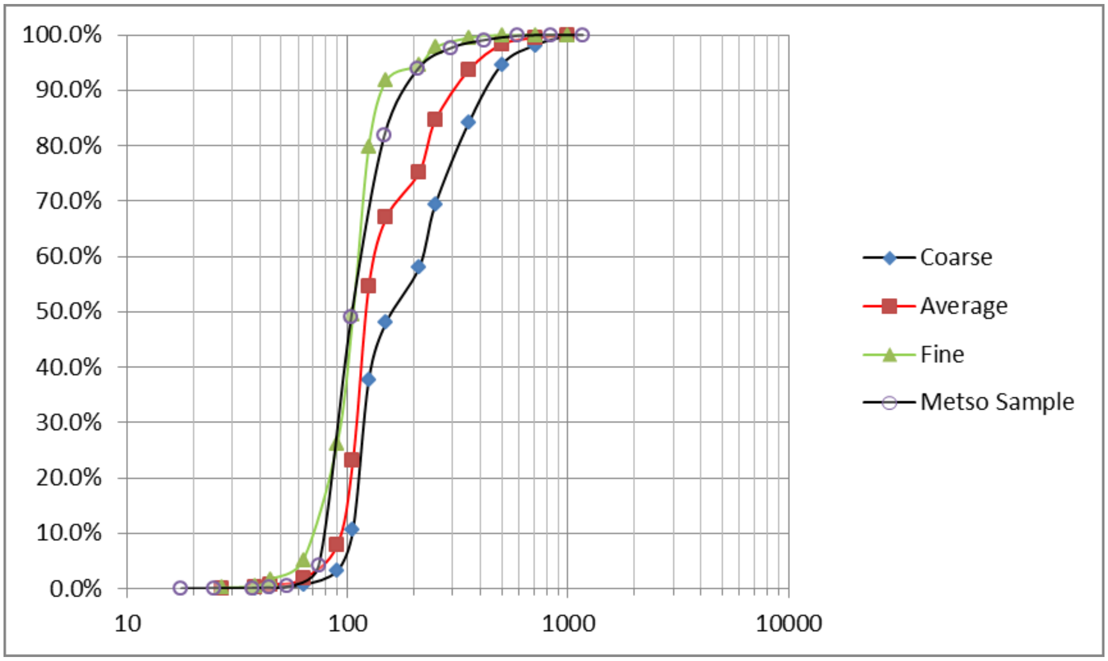
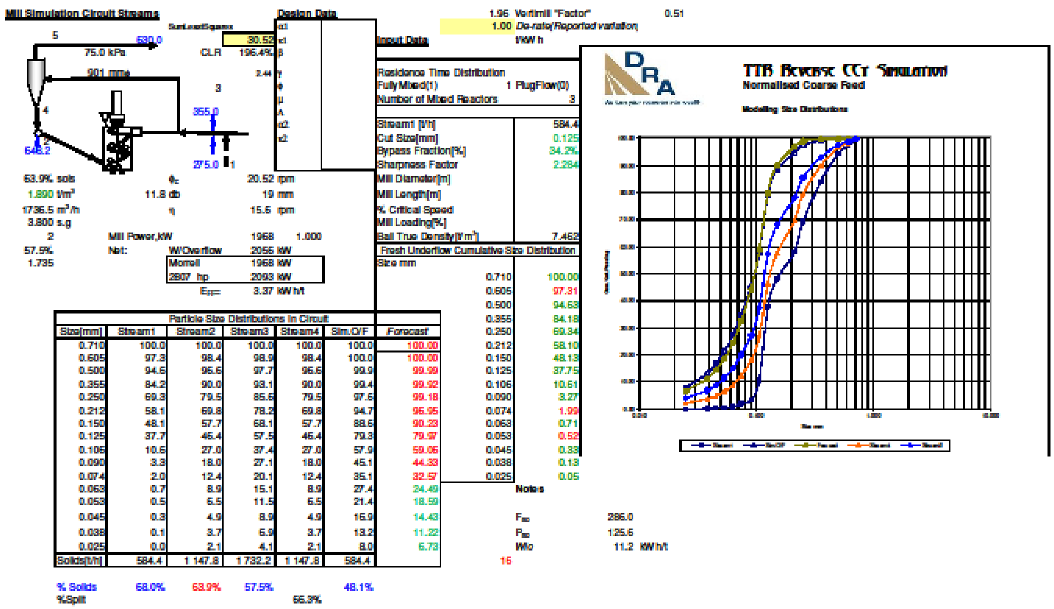


Figure 12-Typical Mill Feed PSD Variation (Size, um versus Cumulative %wt Passing)

VertiMill Simulation

Using the data from the Jar Mill test it was possible to estimate the performance of the full-scale unit, taking feed PSD and closed-circuit milling into consideration. The resultant simulations estimate that two VTM3000-WB units, in closed-circuit with two 33”Ø *gMax* or equivalent hydrocyclones, should cover the milling duty. However, it is strongly advised to consider a third standby unit, because the observed improvement in milling rates may not be fully realised with a seasoned charge on scale-up, and no derate factor has been used. It may be worth getting Metso’s opinion in this matter.

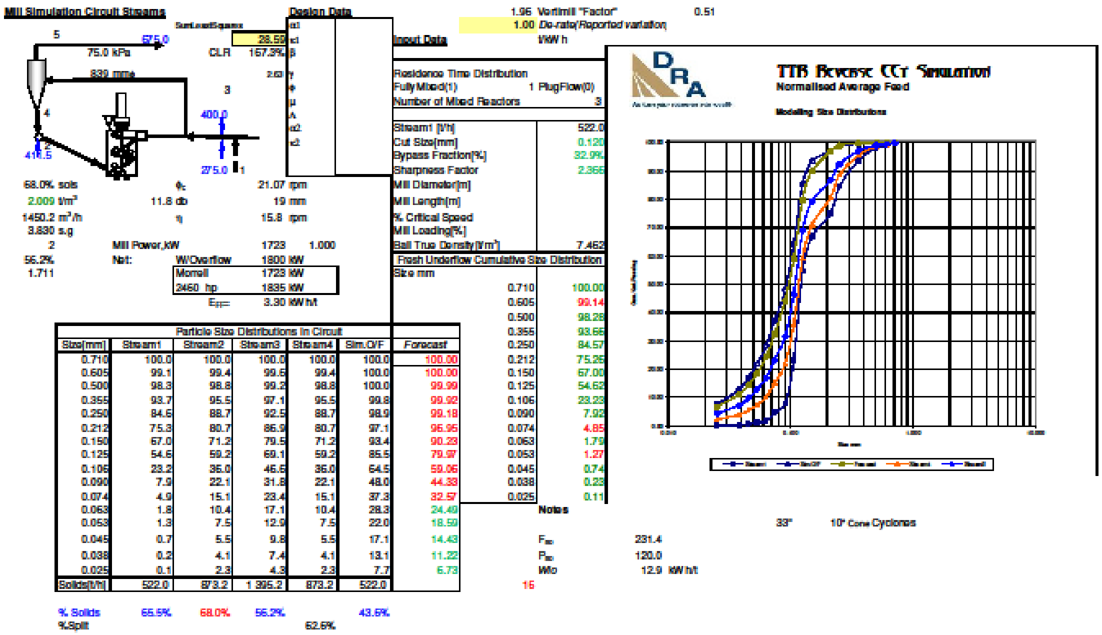
Currently the estimated power requirement is between 3.3~3.5kWh/t.



Fresh Underflow Cumulative Size Distribution Size mm	
0.710	100.00
0.605	97.31
0.500	94.63
0.355	84.18
0.250	69.34
0.212	58.10
0.150	48.13
0.125	37.75
0.106	10.61
0.090	3.27
0.074	1.99
0.063	0.71
0.053	0.52
0.045	0.33
0.038	0.13
0.025	0.05

Particle Size Distributions In Circuit						
Size(mm)	Stream1	Stream2	Stream3	Stream4	Sim.O/F	Forecast
0.710	100.0	100.0	100.0	100.0	100.0	100.00
0.605	97.3	98.4	98.9	98.4	100.0	100.00
0.500	94.6	96.6	97.7	96.6	99.9	99.99
0.355	84.2	90.0	93.1	90.0	99.4	99.92
0.250	69.3	79.5	85.6	79.5	97.6	99.18
0.212	58.1	69.8	78.2	69.8	94.7	96.95
0.150	48.1	57.7	68.1	57.7	88.6	90.23
0.125	37.7	46.4	57.5	46.4	79.3	79.97
0.106	10.6	27.0	37.4	27.0	57.9	59.06
0.090	3.3	18.0	27.1	18.0	45.1	44.33
0.074	2.0	12.4	20.1	12.4	35.1	32.57
0.063	0.7	8.9	15.1	8.9	27.4	24.49
0.053	0.5	6.5	11.5	6.5	21.4	18.59
0.045	0.3	4.9	8.9	4.9	16.9	14.43
0.038	0.1	3.7	6.9	3.7	13.2	11.22
0.025	0.0	2.1	4.1	2.1	8.0	6.73
Solids[t/h]	584.4	1 147.8	1 732.2	1 147.8	584.4	
% Solids	68.0%	63.9%	57.5%		48.1%	
%Split				66.3%		

Figure 13-Estimated performance on Coarse Feed



Size[mm]	Stream1	Stream2	Stream3	Stream4	Sim.O/F	Forecast
0.710	100.0	100.0	100.0	100.0	100.0	100.00
0.605	99.1	99.4	99.6	99.4	100.0	100.00
0.500	98.3	98.8	99.2	98.8	100.0	99.99
0.355	93.7	95.5	97.1	95.5	99.8	99.92
0.250	84.6	88.7	92.5	88.7	98.9	99.18
0.212	75.3	80.7	86.9	80.7	97.1	96.95
0.150	67.0	71.2	79.5	71.2	93.4	90.23
0.125	54.6	59.2	69.1	59.2	85.5	79.97
0.106	23.2	36.0	46.6	36.0	64.5	59.06
0.090	7.9	22.1	31.8	22.1	48.0	44.33
0.074	4.9	15.1	23.4	15.1	37.3	32.57
0.063	1.8	10.4	17.1	10.4	28.3	24.49
0.053	1.3	7.5	12.9	7.5	22.0	18.59
0.045	0.7	5.5	9.8	5.5	17.1	14.43
0.038	0.2	4.1	7.4	4.1	13.1	11.22
0.025	0.1	2.3	4.3	2.3	7.7	6.73
Solids[t/h]	522.0	873.2	1 395.2	873.2	522.0	
% Solids	65.5%	68.0%	56.2%		43.6%	
%Split				62.6%		

Fresh Underflow Cumulative Size Distribution

Size mm	
0.710	100.00
0.605	99.14
0.500	98.28
0.355	93.66
0.250	84.57
0.212	75.26
0.150	67.00
0.125	54.62
0.106	23.23
0.090	7.92
0.074	4.85
0.063	1.79
0.053	1.27
0.045	0.74
0.038	0.23
0.025	0.11

Notes

33" 10° Cone Cyclones

F_{80} 231.4
P_{80} 120.0
Wio 12.9 kW h/t

Figure 14-Estimated Performance on Averaged Feed

Conclusions

The Jar Mill test results (Tower Milling) have shown significant improvements in grinding rates compared to ISA milling, and conventional milling techniques. So much so, it might be prudent to apply some degree of conservatism, or design redundancy, to cover any risk.

Appendix 19.24 - NZIER - Economic Impact Study

Economic impact assessment of TTRL's Taranaki VTM Iron Sands Project

NZIER report to Trans-Tasman Resources Limited

12 March 2025

About NZIER

New Zealand Institute of Economic Research (NZIER) is an independent, not-for-profit economic consultancy that has been informing and encouraging debate on issues affecting Aotearoa New Zealand, for more than 65 years.

Our core values of independence and promoting better outcomes for all New Zealanders are the driving force behind why we exist and how we work today. Our purpose is to help our clients and members make better business and policy decisions and to provide valuable insights and leadership on important public issues affecting our future.

We are unique in that we reinvest our returns into public good research for the betterment of Aotearoa New Zealand.

Our expert team are based in Auckland and Wellington and operates across all sectors in the New Zealand economy and combine their sector knowledge with the application of robust economic logic, models and data and understanding of the linkages between government and business to help our clients and tackle complex issues.

Authorship

This report was prepared at NZIER by Christina Leung, Ting Huang, Daniel Hamill, Tom Dunn, and Philippa Miller-Moore.

It was quality approved by Peter Clough.

The assistance of Sarah Spring is gratefully acknowledged.

How to cite this document:

NZIER. 2025. Economic impact assessment of TTRL's Taranaki VTM Iron Sands Project. A report for Trans-Tasman Resources Limited.

Registered office: Level 13, Public Trust Tower, 22–28 Willeston St | PO Box 3479, Wellington 6140
Auckland office: Level 4, 70 Shortland St, Auckland
Tel +64 4 472 1880 | econ@nzier.org.nz | www.nzier.org.nz

What we are asked to do

You have commissioned NZIER to undertake an economic impact assessment (EIA) of TTRL's Taranaki VTM Iron Sands Project (the Project) to support your application for Fast-track consenting approval. In particular, you have asked us to estimate the direct and flow-on economic impacts of the Project on:

- The local economy – South Taranaki and Whanganui
- The regional economy – the Taranaki Region (South Taranaki, New Plymouth and Stratford) and Whanganui
- The New Zealand economy.

An EIA was undertaken by MartinJenkins in 2015 on the Trans-Tasman Resources Offshore Iron Sands project based on data inputs provided by TTRL. For this EIA, we use updated inputs from TTRL and NZIER's Input-Output multipliers model to estimate the direct and indirect impacts on economic activity, gross domestic product (GDP) and employment resulting from the Project's operation. We will also estimate the additional export earnings and contribution to royalties and taxation paid to the New Zealand Government based on the inputs you provided and more recent data on exchange rates and prices of the relevant commodities.

Our main findings are summarised below.

Summary of main findings

TTRL's VTM Iron Sands Project is a NZ$1 billion capital investment, with about $55 million to be spent in New Zealand across a range of activities involved in the initial setup of the Project

TTRL will make a one-off capital investment of approximately NZ$1 billion in setting up the Project, with more than NZ$55 million of this capital investment to be spent in New Zealand. Capital expenditure in New Zealand will cover costs associated with project management, consultancy, consenting and obtaining permits, and the setup of the TTR Charitable Trust, environmental initiatives, shipbuilding marine research and monitoring vessel and equipment, a vanadium recovery pilot plant and a training facility in Hāwera. Within the capital expenditure in New Zealand, NZ$30 million will be spent in the Taranaki Region and Whanganui District, and approximately NZ$10 million will be in the South Taranaki and Whanganui districts.

TTRL's VTM Iron Sands Project will directly create a total of 303 new full-time equivalent (FTE) jobs across the Taranaki Region and Whanganui District, with an annual direct expenditure of NZ$238 million on a range of industries in New Zealand

In the operational phase of the Project, TTRL will employ 173 crew members to operate the IMV and FSO vessels, with over 50 staff members required to support, engineer, perform environmental monitoring, and conduct fuel bunkering roles. There will also be 35 staff who will undertake general administration roles for the day-to-day operation of the Project.

In addition, TTRL plans to establish its New Zealand head office in New Plymouth, which will add 35 roles to provide marketing and corporate management.

TTRL plans to spend a total of NZ$238 million per annum in New Zealand across a range of industries, of which NZ$234 million of this direct operating expenditure will occur in the Taranaki Region and Whanganui District and within that, NZ$44 million in the South Taranaki and Whanganui districts. In total, the Project's operational activities will directly create 303 FTE jobs in the Taranaki Region and Whanganui, with 77 of those being in the South Taranaki and Whanganui districts.

We estimate the Project's capital investment in New Zealand will result in a NZ$62 million increase in New Zealand's GDP and create 459 new jobs. The Project is estimated to increase New Zealand's annual GDP by NZ$265 million and employment by 1,365 jobs, with about 83 percent of these economic impacts in the Taranaki and Whanganui economies

Based on published GDP data for the year ended March 2023 and Stats NZ's 2024 business demography data, the South Taranaki and Whanganui districts combined made up about 2.7 percent of the New Zealand economy in 2023[1], contributing a total GDP of about NZ$10,749 million. Meanwhile, the Taranaki Region and Whanganui District combined contributed a total GDP of NZ$25,558 million, making up 6.5 percent of the New Zealand economy. In terms of employment, a total number of 32,000 workers were in the combined area of South Taranaki and Whanganui districts. The Taranaki Region and Whanganui District combined had a total count of 74,400 workers, making up 3 percent of the total employment in New Zealand.

We estimate that the capital investment in the Project's setup phase will:

- Increase GDP by NZ$62 million and add 459 new jobs to the total New Zealand economy
- Make a GDP contribution of NZ$27 million and add about 211 new jobs to the regional economy of the Taranaki Region and Whanganui
- Contribute NZ$9 million of GDP and add about 86 new jobs to the local economy of the South Taranaki and Whanganui districts.

For each year of the Project's operation, we estimate:

- An annual GDP contribution of NZ$265 million and about 1,365 jobs to the total New Zealand economy
- Within that national impact, an annual GDP contribution of NZ$222 million and about 1,123 jobs to the regional economy of Taranaki and Whanganui
- Within that regional impact, an annual GDP contribution of NZ$37 million and about 224 jobs to the local economy of the South Taranaki and Whanganui districts.

Table 1 and Table 2 summarise the total economic impacts of the Project at the local, regional and national levels of its capital investment and operation activity in New Zealand, respectively. Note that the three sets of economic outcomes are not additive. That is, the New Zealand impact includes the regional impact, which includes the local impact.

[1] In nominal terms.

Table 1 Estimated economic impact of the VTM Project's capital investment

Study area	South Taranaki/ Whanganui	Taranaki Region/ Whanganui	New Zealand
Output ($million, NZD)	$17	$57	$128
GDP ($million, NZD)	$9	$27	$62
Employment	86	211	459

Source: NZIER

Table 2 Estimated economic impact of the VTM Project's operational activity

Study area	South Taranaki/ Whanganui	Taranaki Region/ Whanganui	New Zealand
Output ($million, NZD)	$81	$479	$568
GDP ($million, NZD)	$37	$222	$265
Employment	224	1,123	1,365

Source: NZIER

To the extent that our approach to estimating the economic impacts reflects the expenditure to carry out the activities for the Project, fluctuations in the exchange rate, prices of the commodities produced from the Project's iron sand mining and the price of Intermediate Fuel Oil (IFO) used for bunkering will not materially affect our economic impact estimates. We recognise the impacts through revenue and, in turn, tax paid to the Crown.

It is important to note that our economic impact analysis captures the benefits from the level of operational and economic activities by overlaying the current structure of the local, regional and national economies rather than the price of iron ore, price of Intermediate Fuel Oil (IFO) or exchange rate. Given that the Project's operation is a relatively fixed process, the level of the Project's operational and economic activities will unlikely change over time.

We estimate the Project could contribute iron ore export earnings of NZ$658 million per annum and vanadium pentoxide (V_2O_5) export earnings of NZ$196 million per annum, and pay annual royalties of between NZ$36 million and NZ$54 million to the Crown from its output

Based on the recent average exchange rate of the New Zealand dollar against the US dollar and the assumed long-term average prices of iron ore (US$90 per metric ton) and V_2O_5 (US$5.45 per pound)[2], we estimate that the Project will contribute additional iron ore export earnings of NZ$658 million per annum and V_2O_5 export earnings of NZ$196 million per annum. These sum up to total export earnings of $854 million per annum the Project's outputs of iron ore make iron ore exports one of the top 12 of New Zealand's principal export categories. Earnings from iron ore and V_2O_5 exports combined will double New Zealand's exports in the broader iron and steel and articles of iron and steel category,

[2] We applied the assumed long-term average prices for iron ore and V_2O_5 in the Siecap NZ's pre-feasibility study for the Taranaki VTM Project. These are US$90 per metric ton of iron ore concentrate and US$5.45 per pound of V_2O_5.

adding up to a value of around NZ$1.69 billion, which would be about 2.6 percent of the total exports.

Based on TTRL's cash flow projections, the 2024 average exchange rate and assumed prices of iron ore, V_2O_5, IFO price and shipping cost, we estimate that the Project will contribute NZ$36 million to NZ$54 million of royalties from its outputs of iron ore and V_2O_5, and NZ$91 million to NZ$136 million corporate tax per year to the New Zealand Government. The lower bound of royalties and corporate tax estimates reflect the higher financing costs in the initial start-up phase of the Project.

TTRL notes the project outputs in this impact assessment are based on only iron ore concentrate sales of 4.9 million tonnes per year and some 19,000 tonnes of V_2O_5 from the VTM concentrate at metallurgical recovery rates of 77 percent. This report does not include any potential revenue credits (sales) for titanium, even though it is contained in the concentrate. TTRL refers to estimates that this potential upside in production amounts to some 327,000 tonnes of titanium dioxide (TiO_2) per annum in the VTM concentrates at metallurgical recovery rates of 77 percent to 79 percent. TTRL notes these additional metal sales have the potential to make a material contribution to the Project's future annual revenue stream, with flow-through effects on foreign exchange earnings, royalties, and corporate tax receipts for the New Zealand Government.

We explain our approach to estimating the economic impacts of TTRL's operations and results on New Zealand in more detail in the following sections.

Contents

1 The proposed Taranaki VTM Iron Sands Project 1
1.1 Our task 2
2 Methodology 2
2.1 Regions for economic impact analysis 2
2.2 Regional input-output multiplier model 3
2.3 Key inputs and assumptions 4
3 Results of economic impact analysis 11
3.1 Impacts at a local level 11
3.2 Impacts at a regional level 12
3.3 Impacts at a national level 13
4 Export earnings 14
4.1 Price and exchange rate sensitivity 15
5 Contribution to royalties and taxes 17
5.1 Sensitivity of TTRL's royalty payment to iron ore price 18
5.2 Sensitivity of TTRL's royalty payment to exchange rate and IFO price 19
6 Concluding comments 20

Figures

Figure 1 IFO 380 Singapore bunker fuel price, monthly average 7
Figure 2 NZD/USD exchange rate, monthly average, 2015 to 2024 8
Figure 3 Iron ore price, monthly average, 2015 to 2024 9
Figure 4 Price of V_2O_5 98% in the Europe spot market, monthly average 10
Figure 5 Sensitivity of total export earnings to iron ore prices 16
Figure 6 Sensitivity of total export earnings to exchange rate 17
Figure 7 Estimated contribution to total annual royalties from production of iron ore concentrates and V_2O_5 18
Figure 8 Iron ore price and TTRL's minimum royalty contribution 19

Tables

Table 1 Estimated economic impact of the VTM Project's capital investment iii
Table 2 Estimated economic impact of the VTM Project's operational activity iii
Table 3 GDP[1] and employment[2] in the local, regional and national study areas 3
Table 4 Direct employment by activity and region 4
Table 5 Direct employment by industry and region 5
Table 6 The Project's capital expenditure in New Zealand 5
Table 7 The Project's direct operational expenditure in New Zealand 6
Table 8 Economic impact of the setup phase at a local level 11
Table 9 Economic impact of operational activity at a local level 12
Table 10 Economic impact of the setup phase at a regional level 12
Table 11 Economic impact of operational activity at a regional level 13
Table 12 Economic impact of the setup phase at a national level 13
Table 13 Economic impact of operational activity at a national level 13

Table 14 New Zealand's principal exports, year ended June 2024 14
Table 15 Estimated range of direct costs and minimum royalty payment 19

1 The proposed Taranaki VTM Iron Sands Project

The proposed VTM Iron Sands Project plans to extract iron sands resource from the seabed off the South Taranaki Bight (STB). The Project will produce iron ore concentrate for export and other critical minerals, such as vanadium, which are inputs for clean energy transition. The iron sands resource is located between 22 km and 36 km off the coast of South Taranaki[3] and in waters ranging between 20 to 50 metres deep.

In setting up the project, TTRL will make a capital investment of approximately NZ$1 billion in leading edging seabed mineral extraction and shipboard mineral processing technologies and ship-to-ship bulk concentrate transfer equipment, along with mining support and marine research and monitoring vessels and equipment to establish the mineral recovery operation in the STB. More than NZ$55 million of the capital investment will be spent in New Zealand, which will cover costs associated with project management, consultancy, consenting and obtaining permits, and the setup of the TTR Charitable Trust, environmental initiatives, shipbuilding marine research and monitoring vessel and equipment, a vanadium recovery pilot plant and a training facility in Hāwera. Within the capital expenditure in New Zealand, NZ$30 million will be spent in the Taranaki Region and Whanganui District, and approximately NZ$10 million will be in the South Taranaki and Whanganui districts.

Once the Project becomes operational, TTRL plans to produce 4.9 million tonnes of iron ore concentrate per annum, which will be processed aboard Integrated Mining Vessels (IMV). The iron ore concentrate from the IMV will then be transferred to floating storage and offloading (FSO) vessels for trans-shipment, where it will be de-watered and stored and ready for transfer to bulk carrier vessels for shipping to overseas markets.

These vessels will be supported by a mid-sized Anchor Handling Tug (AHT) that will assist with the provisioning of the vessels, transfer of equipment, connecting the IMV to FSO during trans-shipment, the berthing of the FSO to the conventional bulk cargo vessels, and anchor and mooring relocation. The AHT will also provide refuelling assistance. A geotechnical survey vessel (GSV) will undertake testing and monitoring activity for the Project. TTRL will also contract a third-party company for bunker fuel supply, which has a facility in New Plymouth that employs six people.

The Project will directly employ over 170 crew to operate the IMV and FSO vessels and a further 50 plus staff in supporting engineering, environmental monitoring and fuel bunkering roles. There will also be 35 general administration staff for the day-to-day operation of the Project. In addition, TTRL plans to establish its New Zealand head office in New Plymouth, which will add 35 marketing and corporate management roles.

While TTRL is seeking a 35-year consent for the Project, the actual harvesting activity of iron ore will take place over 20 years once the Project starts to operate.

3 This is within New Zealand's Exclusive Economic Zone, but beyond the 12-mile limit so the Fast Track Approval applies.

1.1 Our task

NZIER was commissioned to assess the economic impact of the VTM Iron Sands Project, capturing the direct and the flow-on impacts of the Project's capital investment and 20-year operation in New Zealand on the local, regional and national economies.

We were also asked to estimate the Project's contribution to New Zealand's export revenue from exporting its outputs of iron ore concentrate and V_2O_5, and contributions to royalties and taxes to the New Zealand Government.

Section 2 outlines our methodology and the key inputs and assumptions used in our analysis.

2 Methodology

2.1 Regions for economic impact analysis

Our economic impact analysis is applied to three study areas: 1) the local area, 2) the regional area, and 3) the overall New Zealand economy. The local area comprises the South Taranaki and Whanganui districts, which are closest to the location of the iron sands resource.

The regional study area is the Taranaki Region and Whanganui District. Most of the Project's operational activities will take place across the South Taranaki, Whanganui and New Plymouth districts. These include the onshore operations associated with iron sand mining and most of the direct employment in supporting offshore operations.

Besides the economic impacts on the local and regional economies, our analysis also estimates the flow-on impacts of the Project's operational activities on the New Zealand economy.

Table 3 below summarises the gross domestic product (GDP) and employment in our local and regional study areas and the total New Zealand economy. MBIE and Stats NZ's GDP estimates for the year ended March 2023 suggest that our local study area combining the South Taranaki and Whanganui districts made up about 2.7 percent of the New Zealand economy, contributing a total GDP of about NZ$10,749 million. Meanwhile, our regional study area, which combines the Taranaki Region and Whanganui District, contributed NZ$25,558 million of GDP, making up 6.5 percent of the national GDP.

Based on the employee counts from Stats NZ's business demography data, as of February 2024, a total number of 32,000 people were working in our local study area, which was only 1.3 percent of the total employee count in New Zealand. The Taranaki Region and Whanganui District combined had a total count of 74,400 workers, making up 3 percent of the total employment in New Zealand.

Table 3 GDP[1] and employment[2] in the local, regional and national study areas

Millions of dollars (NZD) and headcount

	South Taranaki/ Whanganui	Taranaki Region/ Whanganui	New Zealand
GDP	10,749	25,558	393,523
Employment	32,000	74,400	2,502,700

1 GDP for the year ended March 2023

2 Count of employees as of February 2024

Source: Ministry of Business, Innovation and Employment's (MBIE) Modelled Territorial Authority GDP, Stats NZ's GDP and business demography data

2.2 Regional input-output multiplier model

We developed a regional input-output (I-O) multiplier model specifically for the three regions to look at the direct, indirect and induced impacts of the Project's operational activities on the local, regional and national economies.

We estimate two flow-on impacts based on the expenditure on inputs used in the mining process:

- Indirect impacts – the change in economic activity in industries which provide supporting goods and services to the mining process.
- Induced impacts – the change in economic activity as a result of people working in the supporting industries or upstream industries increasing their consumption given increased earnings.

The direct impacts are provided by TTRL. The sum of direct and indirect impacts is referred to as a Type I impact, whereas the sum of direct, indirect, and induced is referred to as a Type II impact.

We assess flow-on impacts by applying indirect and induced multipliers calculated using Stats NZ input-output tables for the year ended March 2020.

National output multipliers are calculated by obtaining each supporting industry's input coefficient, the amount of output required from the industry to produce a mining industry output and summing the input coefficients across industries.

Regional output multipliers are calculated using the simple location quotient approach. The location quotient is a measure of industry concentration. It is calculated by dividing the share of Taranaki/Whanganui districts' employment in the industry by the share of national employment in the industry. If the location quotient is greater than one, then Taranaki has a higher concentration of the industry than the country as a whole. In this case, we assume the regional input coefficient is equal to the national input coefficient. If the location quotient is less than one, then Taranaki has a lower industry concentration, and we assume the regional input coefficient is equal to the national input coefficient times the location quotient. We obtain the regional indirect multipliers by summing up the regional input coefficients.

This process is repeated for the South Taranaki and Whanganui areas.

There are several limitations associated with using economic multipliers to estimate flow-on impacts:

- **Linear relationships** – they assume that relationships between industries are linear and that firms always require the same quantity and mix of inputs to produce the same level of output.
- **No displacement** – they do not consider the potential for displacement that may occur when output in one industry increases and requires additional resources.
- **No price effects** – they assume that prices remain fixed and do not consider the effects of suppliers raising or lowering prices in response to changes in demand.
- **No supply constraints** – they assume that resources (including labour and capital) are available in unlimited quantities and that extra output can be produced in one industry without taking resources away from other industries.

2.3 Key inputs and assumptions

TTRL provided us with their planned employment and expenditure for the Project's operational activities and capital expenditure in New Zealand involved in the Project's setup. These are the inputs for our regional I-O multipliers analysis to estimate the economic impacts of those activities on the local, regional and national areas.

2.3.1 Direct employment

Direct expenditure and employment are the key inputs that go into our regional I-O multipliers to estimate the indirect and induced economic impacts of the Project's operational activities.

Table 4 sets out the number of employees that will be directly employed for the day-to-day operation of the Project by region. All direct employment by TTRL for the Project will be in the Taranaki/Whanganui region, adding a total of 303 full-time equivalents (FTEs). Of those, 77 FTEs will be located in the local area (South Taranaki/Whanganui). Note that the six FTEs for bunkering will be employed by TTRL's third-party bunker fuel supplier based in New Plymouth.

Table 4 Direct employment by activity and region

Number of FTEs

Activity	South Taranaki/ Whanganui	Taranaki Region/ Whanganui
IMV and FSO vessels	52	173
Anchor Handling Tug	0	36
Bunkering	0	6
Geotechnical Survey Vessel (GSV)	18	18
General and admin	7	35
Head office	0	35
Total	**77**	**303**

Source: TTRL

Table 5 summarises the number of direct FTEs created in the local and regional areas by the relevant industry classification.

Table 5 Direct employment by industry and region

Number of FTEs

Industry	South Taranaki/ Whanganui	Taranaki Region/ Whanganui
Exploration and other mining support services	52	173
Other transport	14	50
Basic material wholesaling	0	6
Scientific, Architectural and Technical Services	4	4
Legal and accounting services	7	35
Advertising, market research and management services	0	35
Total	**77**	**303**

Source: TTRL

2.3.2 Direct expenditure

TTRL provided us with their estimates of direct expenditure in New Zealand, including both the capital expenditure in the Project's setup phase and operational expenditure during the Project's 20-year operation.

Based on the inputs provided by TTRL, it plans to spend around NZ$55 million in New Zealand (in 2024 New Zealand dollars) in the Project's setup phase, accounting for about 6 percent of the Project's total capital investment. Table 6 shows the breakdown of the capital expenditure in New Zealand by industry classification and the region where it is expected to occur. Note that the expenditure in the South Taranaki/Whanganui districts is within the expenditure in the Taranaki Region/Whanganui District, which is within the expenditure in New Zealand. Within the capital expenditure in New Zealand, 54 percent will be spent in the Taranaki Region/Whanganui District (approx. NZ$30 million), and about 18 percent (approx. NZ$10 million) will be in South Taranaki/ Whanganui districts.

Table 6 The Project's capital expenditure in New Zealand

$million, NZD

Industry	South Taranaki/ Whanganui	Taranaki Region/ Whanganui	New Zealand
Advertising, market research and management services	$0.12	$3.73	$15.55
Air and space transport	0	$0.21	$1.06
Travel agency and tour arrangement services	0	$0.06	$0.06
Exploration and other mining support services	0	$1.16	$1.16
Construction services	0	$1.75	$3.50
Central government	0	$0	$10.86
Scientific, architectural and engineering services	$3.52	$3.52	$3.52
Adult, community and other education	$6.23	$6.23	$6.23
Fabricated metal product manufacturing	0	$9.34	$9.34

Industry	South Taranaki/ Whanganui	Taranaki Region/ Whanganui	New Zealand
Transport equipment manufacturing	0	$3.76	$3.76
Total	**$9.87**	**$29.76**	**$55.04**

Source: TTRL, NZIER estimates

For the operational phase, TTRL's current project plan suggests that 72 percent of the Project's annual operating expenditure will be spent in New Zealand, and the remaining portion will be spent offshore. We calculated that the Project's operational expenditure in New Zealand will be approximately NZ$238 million per annum. Within this expenditure in New Zealand, over 98 percent (approx. NZ$234 million) will be spent in the Taranaki Region/Whanganui District, and about 19 percent will be in South Taranaki/Whanganui districts.

Table 7 shows the breakdown of the Project's operational expenditure per annum by industry classification and the region where it is expected to occur.

Table 7 The Project's direct operational expenditure in New Zealand

$million, NZD, per annum

Industry	South Taranaki/ Whanganui	Taranaki Region/ Whanganui	New Zealand
Exploration and other mining support services	$27.86	$99.58	$99.58
Basic material wholesaling	0	$52.37	$52.37
Fabricated metal product manufacturing	$8.04	$16.09	$16.09
Other transport	$0.83	$23.78	$23.78
Scientific, architectural and technical services	$4.10	$13.49	$13.49
Health and general insurance	0	$0.92	$4.61
Legal and accounting services	$3.08	$15.41	$15.41
Advertising, market research and management services	$0	$12.33	$12.33
Total	**$43.92**	**$233.97**	**$237.65**

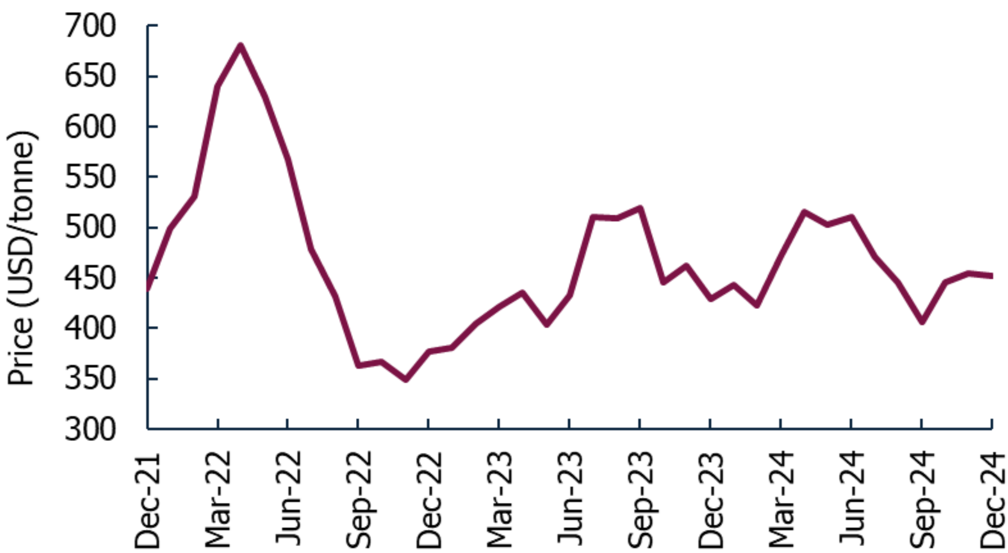
Source: TTRL, NZIER estimates

2.3.3 Intermediate Fuel Oil prices

Our economic impact analysis is based on the direct expenditure in New Zealand, as shown in Table 6 and Table 7 above. The operation of the Project is a relatively fixed process. According to information from TTRL on the cost structure of the Project, over two-thirds of the direct operational costs are considered fixed. The remainder is the cost of Intermediate Fuel Oil (IFO) used to operate the IMVs. Although TTRL will source IFO through its supplier located in New Plymouth, IFO will be imported by TTRL's third-party supplier. This means that IFO costs are exposed to volatility in the global IFO price and exchange rates.

The type of IFO TTRL plans to use for the Project is IFO 380. This type of IFO originates from Singapore, which is the closest refinery from which a New Zealand-based company can import IFO. Figure 1 shows that, over the last three years, the price of IFO 380 fluctuated between US$349 per tonne and US$680 per tonne, with the average price in the 2024 year being US$462 per tonne.

Figure 1 IFO 380 Singapore bunker fuel price, monthly average



Source: Bloomberg

Looking ahead, IFO prices tend to correlate with movements in crude oil prices. Consensus Economics' latest consensus forecasts point to a downward trend in crude oil over the coming years as the increase in global supply is expected to outpace the increase in demand.[4] This presents a downside risk to IFO prices over the coming years.

It is important to note that our economic impact analysis captures the benefits from the Project's operational and economic activities within the current structure of the local, regional, and national economies, along with TTRL's expected expenditure on the operations. According to TTRL's plan, the Project will use 7,000 tonnes of IFO 380 fuel per month. This volume is unlikely to change over the Project's operational phase. Our economic analysis is underpinned by the level of activities and the structure of the New Zealand economy, not the prices of inputs. Therefore, our economic impact estimates should not be materially affected by changes in IFO prices.

2.3.4 Exchange rate

The Project's IFO cost can also be affected by movements in the New Zealand dollar to US dollar exchange rate.

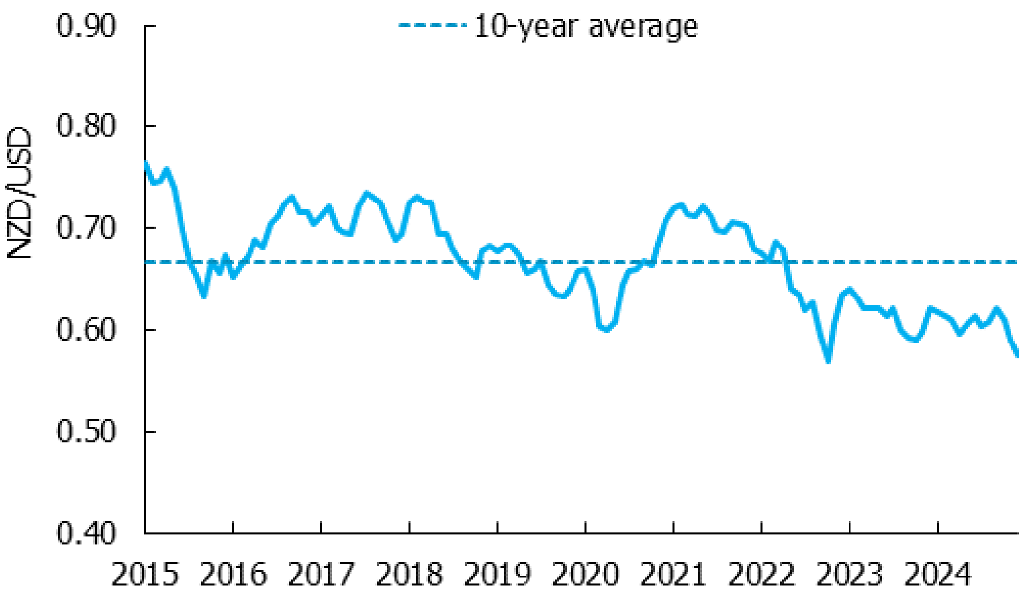
Figure 2 shows that the New Zealand dollar has fluctuated between US$0.57 and US$0.76 over the last 10 years between 2015 and 2024, with a 10-year average of US$0.67. Since

4 Energy, metals & agriculture consensus forecasts compiled by Consensus Economics Inc.

early 2021, the New Zealand dollar against the US dollar has been trending lower. In particular, the New Zealand dollar has been depreciating against the US dollar in recent months, bringing the average New Zealand dollar currency to around US$0.58. This is similar to the exchange rate used in the VTM Project pre-feasibility study by Siecap NZ[5] and TTRL's projections of the Project's cash flows.

Looking ahead, with the markets expecting further interest rate cuts by the Reserve Bank of New Zealand and the US Federal Reserve slowing in their interest rate cuts in 2025, these will weigh on the yield attractiveness of the New Zealand dollar against the US dollar over the coming year. Beyond that, we expect a pick-up in the NZD currency over the longer term.

Figure 2 NZD/USD exchange rate, monthly average, 2015 to 2024



Source: Reserve Bank of New Zealand

Because our economic impact analysis captures the direct expenditure in New Zealand in New Zealand dollars, fluctuations in the exchange rate will not have a material impact on the economic impact of the Project's activities in New Zealand. However, given that the iron ore concentrate and V_2O_5 from iron sands mining will be exported to global markets, movements in the exchange rate will directly impact TTRL's revenue generated from the Project. A lower New Zealand dollar against the US dollar means higher export earnings in New Zealand dollars.

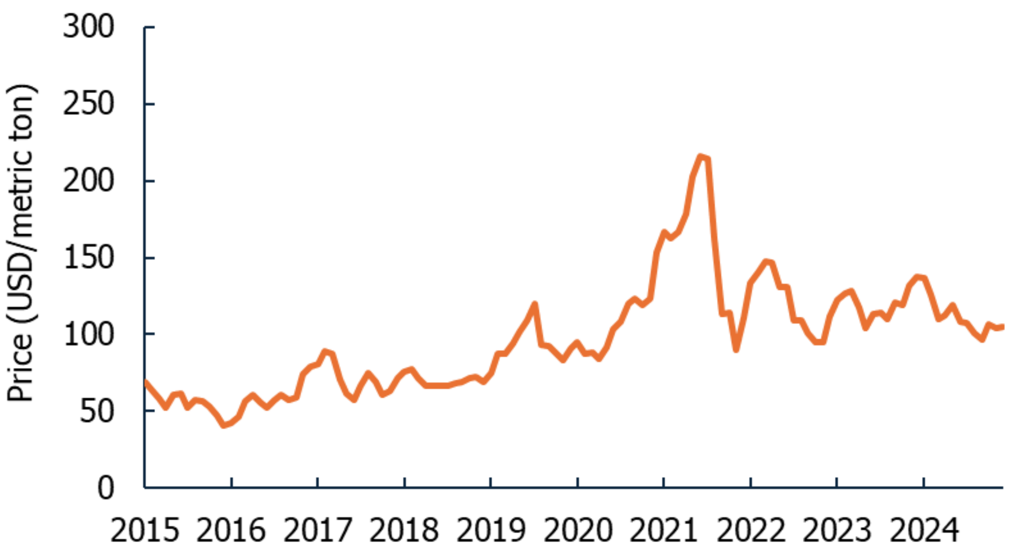
2.3.5 Prices of iron ore and vanadium pentoxide

TTRL's revenue from the Project will also depend on the prices of commodities produced by the Project, including iron ore and vanadium pentoxide (V_2O_5).

5 Provided by TTRL.

As shown in Figure 3, the average price of iron ore (compiled by the IMF) increased sharply during the first year of the COVID-19 pandemic between mid-2020 and mid-2021, reaching US$216 per metric ton by June 2021. The price then fell in late 2021 to around US$90 per metric ton. Since then, the iron ore price has been fluctuating between US$90 per metric ton and US$147 per metric ton. For the 2024 year, the average price was US$111 per metric ton. Consensus Economics' latest consensus forecasts point to expectations for iron prices to trend lower, averaging around the lower end of the US$90 to US$100 per metric ton price range. Siecap NZ's pre-feasibility study assumes a long-term average iron ore price of US$90 per metric ton based on various long-term iron ore price forecasts.

Figure 3 Iron ore price, monthly average, 2015 to 2024

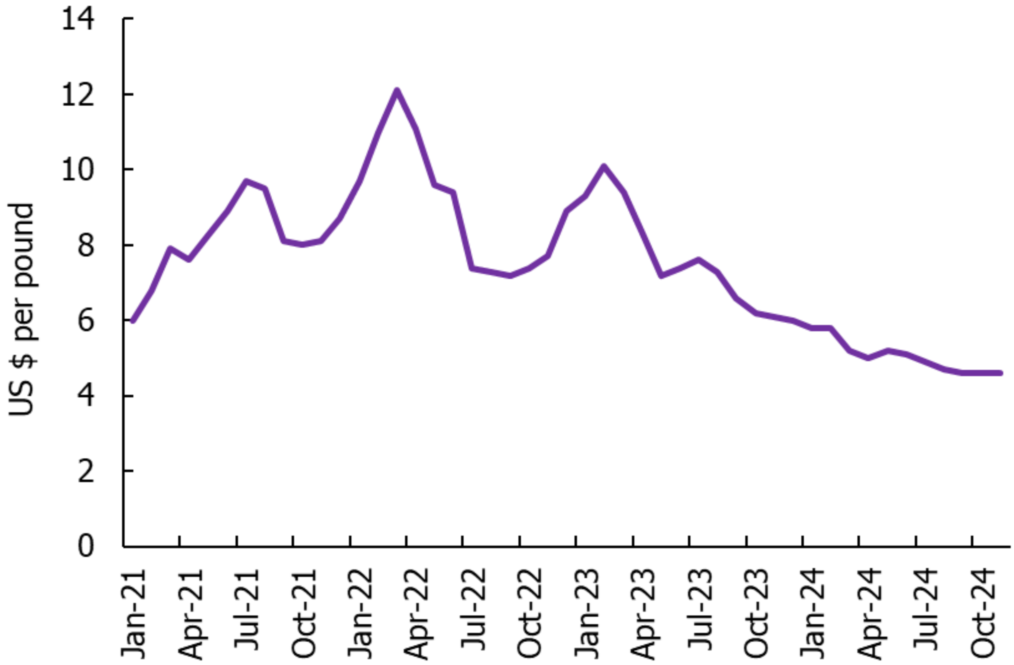


Source: IMF

The iron ore concentrate that the Project will be extracting from iron sands mining is 58 percent iron ore concentrate, which gets exported at a discount. The discount generally varies between 10 and 20 percent, and information from TTRL recommends a discount of 13.7 percent applied to the price of the 62 percent iron ore concentrate, which is very similar to the IMF's series of average iron ore prices.

The Project will also produce other minerals, such as V_2O_5, from its mining activity. Figure 4 shows the monthly average spot prices of V_2O_5 in the European spot market over the last three years. Prices have been trending lower since mid-2023 and stabilising at a lower level in late 2024. The Siecap NZ's pre-feasibility study report notes an average V_2O_5 price of US$5.45 per pound in 2024, as reported by the US Geological Survey. It assumed this as the long-term average V_2O_5 price, given that the downward trend in V_2O_5 prices over the past year reflects a stabilisation of prices following a period of fluctuations.

Figure 4 Price of V_2O_5 98% in the Europe spot market, monthly average



Source: Bloomberg

2.3.6 Royalties and taxes

As a mining permit holder, TTRL must pay royalties to the Crown with respect to all minerals obtained under the permit. It must pay the higher of:

- An *ad valorem* royalty of 2 percent of the net sales revenue of the minerals obtained under the permit, or
- An accounting profits royalty of 10 percent of the accounting profits, or provisional accounting profits, of the minerals obtained under the permit.

Besides royalties, TTRL will also have to pay company tax as it is a registered New Zealand Company. Any new employment will pay income taxes, and new spending generates GST and excise taxes on fuel. However, it is not practical to estimate individual taxes due to variations in tax provisions. In any case, they are not significantly different from any other project of similar scale, so while we acknowledge this as an additional contribution to government revenues, it is not estimated here. Royalties warrant estimation as they are a distinct revenue source.

While the focus of our economic impact analysis is on the Project's direct expenditure in its activities, changes in exchange rates and prices of iron ore and V_2O_5 or IFO prices will lead to changes in the Project's costs of inputs and revenue. These ultimately influence the Project's economic contribution in terms of royalties and taxes paid to the New Zealand Government from its production of iron ore and V_2O_5.

Our calculations of the additional economic contribution of the Project, in terms of export earnings, royalties and taxes, used the following assumptions:

- exchange rate at US$0.58, which reflects the average in recent months and is in line with the exchange rate assumed in the Siecap NZ's pre-feasibility study and TTRL's cash flow model
- IFO 380 price at US$462 per tonne, which is the 2024 average
- iron ore price at US$90 per metric ton, which is our assumed long-term average iron ore price, based on information from both the Consensus Economics' iron ore price consensus forecasts and the Siecap NZ's pre-feasibility study report
- price of V_2O_5 at US$5.45 per pound, which is our assumed long-term average V_2O_5 price, based on recent price trends and information from Siecap NZ's pre-feasibility study report.

Our analysis of export earnings royalties and corporate tax payments to the New Zealand Government is based on the data and projections provided by TTRL.

3 Results of economic impact analysis

Economic impact analysis (EIA) shows the additional impact on economic activity (gross output, GDP and employment) directly attributable to an event or action. The EIA has been calculated for the local area (South Taranaki and Whanganui districts), the regional area (the Taranaki Region and Whanganui District), and New Zealand. The three sets of economic outcomes are not additive. That is, the New Zealand impact includes the regional impact, which includes the local impact.

Expenditure in Table 7 is used to estimate the operational costs to which we have applied the multipliers.

Each section contains information on initial setup, capital contributions and operational expenditure contributions during the Project's 20-year operation phase.

3.1 Impacts at a local level

TTRL forecast that NZ$10 million will be spent on capital for the initial setup of the Project. This expenditure results in a NZ$9 million increase in GDP and an addition of 86 jobs (measured by headcount) when accounting for Type II impacts (as seen in Table 8 below).

Table 8 Economic impact of the setup phase at a local level

Millions of dollars (NZD) and headcount

	Direct	Direct + Indirect	Direct + Indirect + induced
Output	$9.87	$13.40	$17.24
GDP	$5.57	$7.31	$9.43
Employment	55.78	71.67	85.59

Source: NZIER

TTRL forecasts that NZ$44 million per annum will be spent on inputs to the operation in the South Taranaki and Whanganui Districts. The increase in direct GDP as a result of this is estimated to be NZ$19 million per annum, and an additional 103 people will be employed (see Table 9).

Direct employment measures are replaced for each contributing sector where there is available information (see Table 5). This is applied at all levels and flows into the Type I and Type II impacts.

When we account for Type II impacts, the initial direct expenditure of NZ$44 million is expected to result in an increase of NZ$37 million in GDP per annum and 224 jobs (as measured by headcount).

Table 9 Economic impact of operational activity at a local level

Millions of dollars (NZD, per annum) and headcount

	Direct	Direct + Indirect	Direct + Indirect + induced
Output	$43.92	$65.61	$80.64
GDP	$18.62	$28.78	$37.08
Employment	103.00	169.85	224.43

Source: NZIER

3.2 Impacts at a regional level

TTRL forecasts that NZ$30 million will be spent on capital for the initial setup of the Project. This expenditure results in a NZ$27 million increase in GDP and an addition of 211 jobs (measured by headcount) when accounting for Type II impacts (as seen in Table 10).

Table 10 Economic impact of the setup phase at a regional level

Millions of dollars (NZD) and headcount

	Direct	Direct + Indirect	Direct + Indirect + induced
Output	29.76	45.79	57.45
GDP	13.25	20.31	26.63
Employment	123.42	170.16	210.63

Source: NZIER

TTRL forecasts that NZ$234 million per annum will be spent on inputs for the operation in the Taranaki Region and Whanganui District. The increase in direct GDP as a result of this is estimated to be NZ$102 million per annum and additional employment of 356 people.

When we account for Type II impacts, the initial direct expenditure of NZ$234 million (in 2024 New Zealand dollars) per annum is expected to result in an increase of NZ$222 million in GDP per annum and 1,123 jobs (as measured by headcount).

Table 11 Economic impact of operational activity at a regional level

Millions of dollars (NZD, per annum) and headcount

	Direct	Direct + Indirect	Direct + Indirect + induced
Output	$233.97	$385.37	$478.55
GDP	$101.88	$171.13	$221.76
Employment	355.83	798.99	1,123.10

Source: NZIER

3.3 Impacts at a national level

TTRL forecast that NZ$55 million will be spent on capital for the initial setup of the Project. This expenditure results in a NZ$62 million increase in GDP and an additional 459 jobs (measured by headcount) when accounting for Type II impacts (as seen in Table 12).

Table 12 Economic impact of the setup phase at a national level

Millions of dollars (NZD) and headcount

	Direct	Direct + Indirect	Direct + Indirect + induced
Output	$55.04	$96.27	$127.74
GDP	$25.81	$45.53	$62.21
Employment	221.48	357.48	459.11

Source: NZIER

TTRL forecasts that NZ$238 million per annum will be spent on inputs to the operation across New Zealand. The increase in direct GDP as a result of this is estimated to be NZ$103 million per annum and an additional 359 people.

When we account for Type II impacts, the initial direct expenditure of NZ$238 million per annum is expected to result in an increase of NZ$265 million per annum in GDP and 1,365 jobs (as measured by headcount).

Table 13 Economic impact of operational activity at a national level

Millions of dollars (NZD, per annum) and headcount

	Direct	Direct + Indirect	Direct + Indirect + induced
Output	$237.65	$443.79	$567.69
GDP	$103.50	$199.57	$265.24
Employment	359.15	965.26	1,365.41

Source: NZIER

4 Export earnings

According to TTRL's proposed plan for the Project, it will export all 4.9 million tonnes of the iron ore concentrate produced from iron sand mining to global markets. Based on our assumed long-term average iron ore price (US$90 per metric ton), V_2O_5 price (US$5.45 per pound) and the 2024 average exchange rate (NZ$=US$0.58), the Project is expected to generate a total export revenue of NZ$854 million per annum. Within this total, about NZ$658 million per annum will be from exporting iron ore concentrate, and NZ$196 million will be from exporting V_2O_5.

The value of New Zealand's exports in the year to June 2024 totalled about NZ$66 billion. This means that TTRL's iron ore exports of NZ$854 million from the Project would contribute 1.3 percent of New Zealand's total exports[6] if it had been operating in 2024, and it would be one of the top 12 of New Zealand's principal export categories (see Table 14 below). Earnings from iron ore and V_2O_5 exports combined will double New Zealand's exports in the broader iron and steel and articles of iron and steel category, adding up to a value of around NZ$1.69 billion, which would be about 2.6 percent of the total exports.

These results illustrate that TTRL's VTM Iron Sands Project will contribute to the Government's goal of doubling the value of New Zealand's exports over the next 10 years.

Table 14 New Zealand's principal exports, year ended June 2024

Millions of dollars, NZD

Export category	Export value
Dairy Produce: Total	18,991
Total Meat and Edible Offal	8,616
Forest Products: Total	5,705
Fruit and Nuts	4,010
Fish, Crustaceans and Molluscs	1,958
Machinery and Mechanical Appliances	1,919
Aluminium and Articles of Aluminium	1,560
Casein and Caseinates	1,557
Electrical Machinery and Equipment	1,106
Precious Stones, Metals and Jewellery	970
TTRL VTM Iron Ore[7] and V_2O_5[8] Concentrates	**854**
Iron and Steel and Articles of Iron and Steel	837
Mineral Fuels	778
Vegetables	520
Plastic Materials and Articles of Plastic	482
Wool	448

6 FOB value of exports (excluding re-exports).

7 Based on projections, our assumed long-term average iron ore price and average NZD/USD exchange rate.

8 Based on projections, our assumed long-term average V_2O_5 price and average NZD/USD exchange rate

Export category	Export value
Raw Hides and Skins and Leather	268
Live Animals	208
Fabrics, Textiles and Apparel	140
Tallow	100
Sausage Casings	87
Carpets and Other Textile Floor Coverings	76
Printed Books, Newspapers etc	27
Methanol	Figure not available

Note: the TTRL exports of iron ore and V_2O_5 are based on TTRL's projections of export volumes, our assumed long-term average prices and the 2024 average NZD/USD exchange rate.

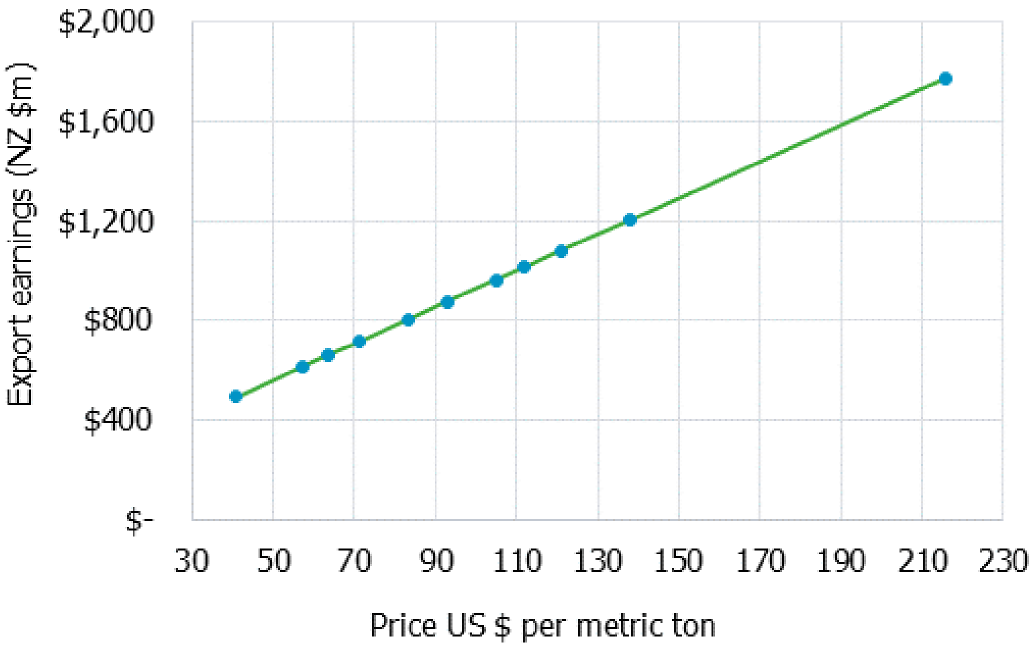
Source: Stats NZ, NZIER estimates

4.1 Price and exchange rate sensitivity

The price and the exchange rate at which the outputs produced from the Project's iron sand mining activity are traded in the global markets will directly impact the revenue TTRL receives from exporting them. Given iron ore concentrate is the main product from the Project TTRL will export, and iron ore prices have been more volatile than V_2O_5 prices over the past few years; we have undertaken analysis to test the sensitivity of expected export earnings to changes in iron ore price and exchange rate, respectively. Note that these sensitivity tests were undertaken by changing only one input at a time and holding all other variables constant.

Figure 5 below points to a strong positive relationship between iron ore price and export earnings. By taking the minimum, maximum and the 10th to 90th percentiles of the 10-year iron ore price series, we calculated a range of the Project's total export earnings between NZ$495 million per annum (when iron ore price is US$41 per metric ton) and NZ$1.8 billion per annum (when iron ore price is US$216 per metric ton).

Figure 5 Sensitivity of total export earnings to iron ore prices



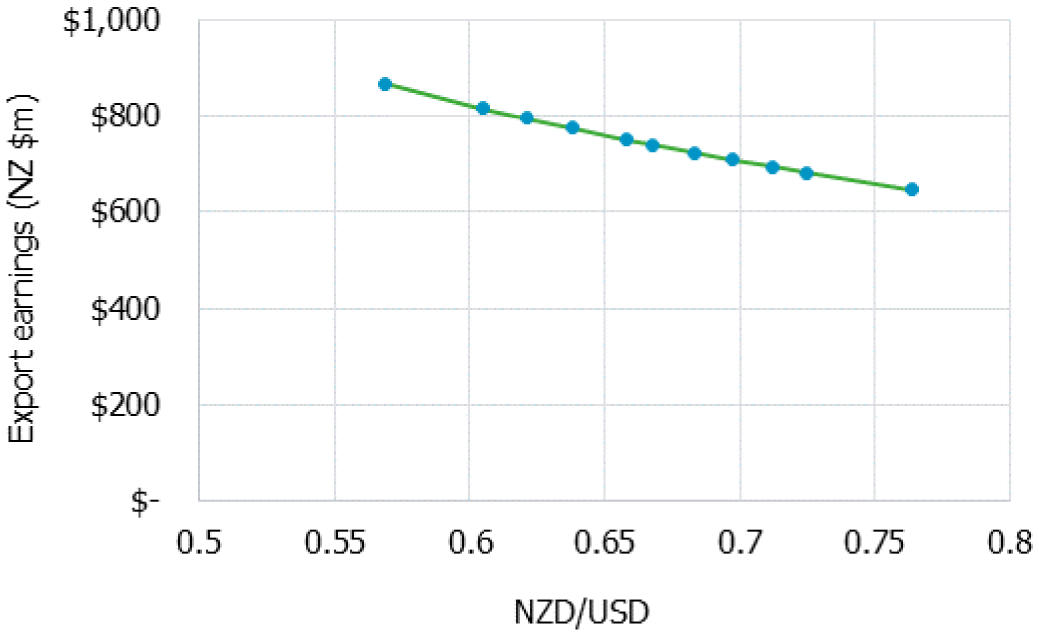
Note: Iron ore price is the only changing variable in this sensitivity test. All other variables are held constant.

Source: NZIER's estimates

In contrast, export earnings are negatively associated with the level of the exchange rate of the New Zealand dollar against the US dollar (see Figure 6 below). Holding all other variables constant, the range of exchange rate over the last 10 years would give total export earnings ranging from NZ$646 million per annum (at NZ$=US$0.76) to close to NZ$869 million per annum (at NZ$=US$0.57).

Comparing the magnitudes of the impact of exchange rate changes to that of changes in iron ore price, our sensitivity analysis suggests that export earnings are more sensitive to the volatility in iron ore prices.

Figure 6 Sensitivity of total export earnings to exchange rate



Note: Exchange rate is the only changing variable in this sensitivity test. All other inputs are held constant.

Source: NZIER's estimates

5 Contribution to royalties and taxes

Figure 7 shows the annual royalties TTRL will potentially pay to the Crown based on the projected output of iron ore from the Project's operation.

At our assumed prices of iron ore, V_2O_5, IFO, shipping cost[9] and exchange rate, TTRL will more likely pay royalties at 10 percent of the Project's accounting profits. Based on TTRL's projected cash flows for the Project, which include interest expense, depreciation and amortisation, we calculated the annual royalty payment to be between NZ$36 million and NZ$39 million in the Project's first seven years of operation, increasing to about NZ$54 million per annum thereafter. After deducting these estimates of royalty payment from the Project's net profit and applying the 28 percent corporate tax rate, we calculated that annual corporate tax paid to the Crown to range from NZ$91 million to NZ$136 million (in 2024 New Zealand dollars. Note that the lower bound of the royalties and corporate tax estimates reflect the higher financing costs in the start-up phase of the Project.

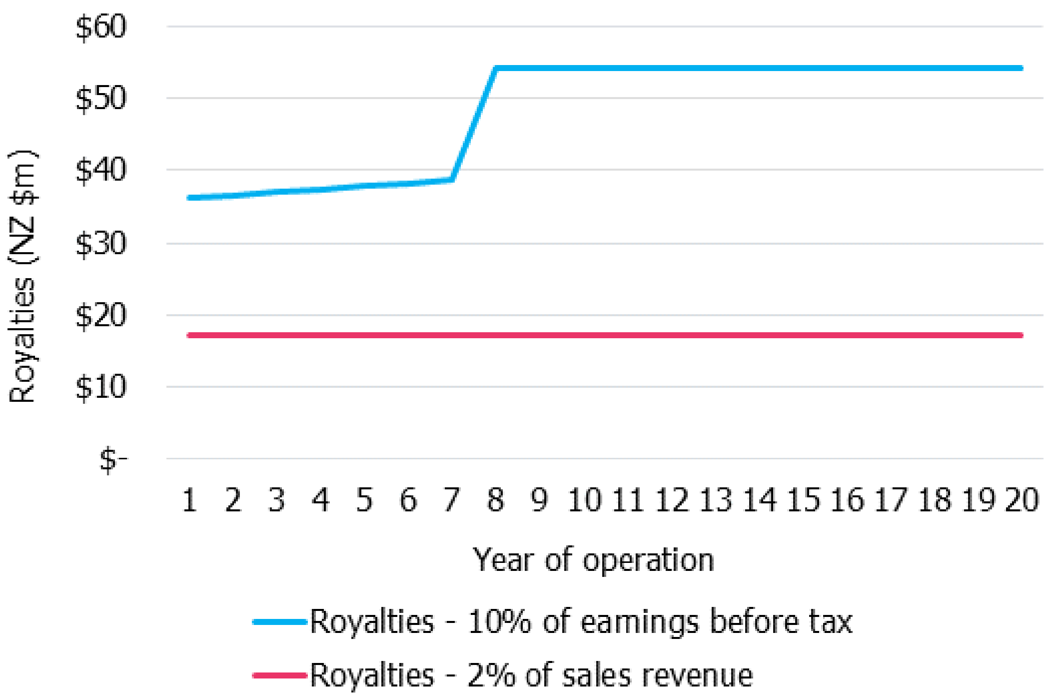
Putting the contribution to royalties into the broader context, data from New Zealand Petroleum and Minerals shows that petroleum, minerals and coal royalties were about NZ$221 million, of which minerals accounted for just over NZ$14 million (6.6 percent). With

9 Assumed at a long-term average of $10 per tonne drawing on Siecap NZ's analysis of the trends in Capesize vessel shipping costs

the Project in operation, TTRL's royalty payment would increase minerals' contribution to total petroleum, minerals and coal royalties by 20 percent to 25 percent.

TTRL notes the project outputs in this impact assessment are based on only iron ore concentrate sales of 4.9 million tonnes per year and some 19,000 tonnes of V_2O_5 from the VTM concentrate at metallurgical recovery rates of 77 percent. This report does not include any potential revenue credits (sales) for titanium, even though it is contained in the concentrate. TTRL refers to estimates that this potential upside in production amounts to some 327,000 tonnes of titanium dioxide (TiO_2) per annum in the VTM concentrates at metallurgical recovery rates of 77 percent to 79 percent.[10] TTRL notes these additional metal sales have the potential to make a material contribution to the Project's future annual revenue stream, with flow-through effects on foreign exchange earnings, royalties, and corporate tax receipts for the New Zealand Government.

Figure 7 Estimated contribution to total annual royalties from production of iron ore concentrates and V_2O_5



Source: NZIER's estimates based on current assumptions and TTRL's projected cash flows

5.1 Sensitivity of TTRL's royalty payment to iron ore price

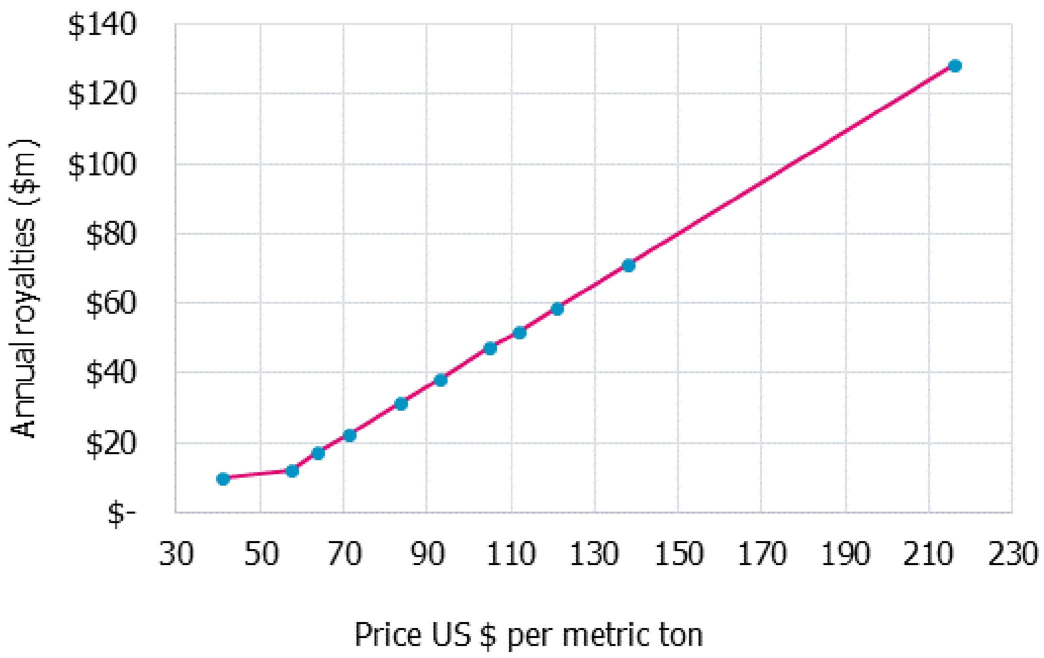
Our sensitivity analysis shows a strong positive relationship between royalties and iron ore prices. This is unsurprising given the relationship between iron ore export earnings and iron ore price illustrated in section 4.1.

Based on the range of the average iron ore price in Figure 3, the Project's minimum annual contribution to royalties can range from NZ$10 million to NZ$128 million. The kinked curve

10 TTRL internal technical report: TTR Metallurgical Review: Recovery of Vanadium from Taranaki VTM Project, Siecap (NZ) Limited 4 February 2025

shown in Figure 8 suggests that holding all other variables constant, at some iron ore price of below US$58 per metric ton, TTRL's minimum royalty payment will be 2 percent of the sales revenue.

Figure 8 Iron ore price and TTRL's minimum royalty contribution



Note: Iron ore price is the only changing variable in this sensitivity test. All other inputs are held constant.

Source: NZIER estimates

5.2 Sensitivity of TTRL's royalty payment to exchange rate and IFO price

Table 15 below shows the possible range of direct costs and minimum royalty payment using minimum and maximum exchange rates and IFO 380 price shown in Figure 1 and Figure 2.

Table 15 Estimated range of direct costs and minimum royalty payment

Millions of dollars, NZD, annual

Estimate	NZD/USD exchange rate		IFO 380 price	
	Maximum exchange rate (NZ$=US$0.76)	Minimum exchange rate (NZ$=US$0.57)	Maximum price (US$680 per tonne)	Minimum price (US$349 per tonne)
Direct costs	$173	$233	$261	$212
Minimum royalty payment	$27	$37	$33	$38

Note: The sensitivity analysis was undertaken by changing one variable only at a time and holding everything else constant.

Source: Stats NZ, NZIER estimates

Holding everything else constant, we calculated that TTRL's minimum annual royalty payment from the Project is NZ$27 million when the New Zealand dollar is at the 10-year maximum of US$0.76 and NZ$37 million when the New Zealand dollar is at the 10-year minimum of US$0.57. Although a lower New Zealand dollar increases the export earnings received (refer to Figure 6), it also leads to an increase in direct costs, in particular, the IFO cost.

Our sensitivity analysis also indicates that at a higher price of the IFO 380 bunker fuel, higher direct costs reduce the Project's contribution to royalties. Holding everything else constant, the minimum annual royalty payment paid by TTRL can range from NZ$33 million to NZ$38 million. This variability in royalty payment is rather small, given how volatile IFO 380 prices have been over the last three years (see Figure 1).

Overall, our sensitivity testing suggests that the Project's contribution to royalties is more sensitive to volatility in the iron ore prices than to the exchange rate or the IFO price.

6 Concluding comments

Our analysis demonstrates that TTRL's VTM Iron Sands Project will benefit the New Zealand economy. TTRL will make a one-off capital investment of approximately NZ$1 billion in setting up the Project, with more than NZ$55 million of this capital investment to be spent in New Zealand. In the Project's operation phase, a total of 303 new FTE jobs will be created which are directly involved in the Project's operation activity in the Taranaki Region and Whanganui District, with 77 of those located in the local area of the South Taranaki and Whanganui districts.

Compared to the current situation where the Project is not in place, we estimate the flow-on economic impacts from the Project's capital investment will:

- Increase GDP by NZ$62 million and add 459 new jobs to the total New Zealand economy
- Contribute NZ$27 to GDP and add about 211 new jobs to employment in the regional economy of the Taranaki Region and Whanganui
- Contribute NZ$9 million of GDP and add about 86 new jobs to the local economy of the South Taranaki and Whanganui districts.

We also estimate the flow-on impacts of the Project's annual operational activities will be:

- An annual GDP contribution of NZ$265 million and about 1,365 jobs to the total New Zealand economy.
- Within that national impact, an annual GDP contribution of NZ$222 million and about 1,124 jobs to the regional economy of the Taranaki Region and Whanganui District
- Within that regional impact, an annual GDP contribution of NZ$37 million and about 224 jobs to the local economy of the South Taranaki and Whanganui districts.

Those economic impacts are estimated based on TTRL's forecast direct expenditure on its activities in New Zealand in the Project's setup and operational phases, as well as a limited range of assumptions on key variables. Our multiplier approach does not account for input constraints, price changes and effects in other sectors that offset the Project's positive impacts on the economy arising from increased production.

At our assumed long-term average iron ore and V_2O_5 prices and the 2024 average exchange rate, the Project is expected to contribute export earnings totalled around NZ$854 million per annum, making VTM iron ore exports one of the top 12 of New Zealand's principal export categories and doubling New Zealand's exports in the broader iron and steel and articles of iron and steel categories. During the 20-year operation phase of the Project, TTRL will contribute NZ$36 million to NZ$54 million in royalties per year and NZ$91 million to NZ$136 million in corporate taxes per year to the New Zealand Government.

TTRL also estimates that there is upside for TiO_2 sales in the VTM concentrates. These additional metal sales, that have the potential to make a material contribution to the Project's future annual revenue streams, are subject to changes in the price of TiO_2 and exchange rates. Any future TiO_2 sales will have a positive flow-through effect on foreign exchange earnings, royalties, and corporate tax receipts for the New Zealand Government.

Appendix 19.25 - EPA Approved Marine Consent Conditions 2017

Appendix 1. Authorised Restricted Activities

The marine consents and marine discharge consents authorise the following restricted activities, subject to conditions listed in Appendix 2.

Section 20(2) (a) – the construction, placement, alteration, extension, removal, or demolition of a structure on or under the seabed.

1) The placement, movement and removal of the Integrated Mining Vessel ("IMV") anchor and the geotechnical support vessel anchor, including the anchor spread, on or under the seabed.
2) The placement, movement and removal of the crawler on or under the seabed.
3) The placement, movement and removal of the grade control drilling equipment on or under the seabed.
4) The placement, movement and retrieval of moored environmental monitoring equipment on or under the seabed.

Section 20(2)(d) – the removal of non-living natural material from the seabed or subsoil

1) The removal of sediment from the seabed and subsoil using the crawler and by grade control drilling.
2) The taking of sediment and benthic grab samples from the seabed and subsoil associated with environmental monitoring.

Section 20(2)(e) – the disturbance of the seabed or subsoil in a manner that is likely to have an adverse effect on the seabed or subsoil

1) The disturbance of the seabed and subsoil associated with the placement, movement and removal of the IMV anchor and the geotechnical support vessel anchor, including the anchor spread.
2) The disturbance of the seabed and subsoil associated with seabed material extraction via the crawler, through re-deposition of de-ored sediments, and from grade control drilling.
3) The disturbance of the seabed and subsoil associated with the placement, deployment, retrieval and mooring of environmental monitoring equipment.
4) The disturbance of the seabed and subsoil associated with the taking of sediment and benthic samples associated with environmental monitoring.

Section 20(2)(f) – the deposit of any thing or organism in, on, or under the seabed.

1) The re-deposition of de-ored sediments in, on or under the seabed.
2) The deposition of small amounts of marine organisms and solids in, on or under the seabed as a result of vessel maintenance, hull cleaning (biofouling).

Section 20(2)(g) – the destruction, damage, or disturbance of the seabed or subsoil in a manner that is likely to have an adverse effect on marine species or their habitat.

1) The disturbance and damage of the seabed and subsoil as a result of the placement, movement and removal of the IMV anchor, and the geotechnical support vessel anchor on the seabed.
2) The disturbance and damage of the seabed and subsoil as a result of seabed material extraction via the crawler, the redeposition of de-ored sediments, and the grade control drilling.

3) The disturbance and damage of the seabed and subsoil as a result of the placement, deployment, retrieval and mooring of environmental monitoring equipment.
4) The disturbance and damage of the seabed and subsoil as a result of the taking of sediment and benthic samples associated with environmental monitoring.

Section 20(4)(a) – the construction, mooring or anchoring long-term, placement, alteration, extension, removal, or demolition of a structure or part of a structure.

1) The anchoring of the IMV and the geotechnical support vessel, and the associated placement, movement and removal of the IMV anchor and the geotechnical support vessel anchor in the water column above the seabed.
2) The placement, movement and removal of the crawler in the water column above the seabed.
3) The placement, movement and removal of the grade control drilling equipment in the water column above the seabed.
4) The placement, deployment, retrieval and mooring of environmental monitoring equipment in the water column above the seabed.

Section 20(4)(b) – the causing of vibrations (other than vibrations caused by the normal operation of a ship) in a manner that is likely to have an adverse effect on marine life.

1) Vibration (noise) caused by the IMV and crawler during iron sand extraction activities.

Section 20B – No person may discharge a harmful substance from a structure or from a submarine pipeline into the sea or into or onto the seabed of the exclusive economic zone

1) The release of seabed material (sediments) arising from the seabed disturbance during grade control drilling activities;
2) The release of disturbed seabed material (sediments) arising from the seabed disturbance during the crawler extraction operations; and
3) The release of disturbed seabed material (sediments) arising from taking of sediment and benthic samples associated with environmental monitoring.

Section 20C – No person may discharge a harmful substance (if the discharge is a mining discharge) from a ship into the sea or into or onto the seabed of the exclusive economic zone or above the continental shelf beyond the outer limits of the exclusive economic zone

1) De-ored sediments and any associated contaminants discharged back to the water column from the IMV.

Appendix 2. Marine Consent Conditions

The marine consents and marine discharge consents are granted subject to the following conditions, which have been imposed under sections 63 and 87F(4) of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012:

Note: Working days are as defined in section 4 of the EEZ Act.

Table of Conditions

Condition Number **Page Number**

GENERAL CONDITIONS 277
1 278
2 278
DISCHARGE LIMITS 278
3 278
4 278
ENVIRONMENTAL LIMITS 279
Sediments *279*
5 279
6 279
Benthic Ecology *279*
7 279
Benthic Recovery *280*
8 280
Seabirds *280*
9 280
Marine Mammals *281*
10 281
Underwater Noise *283*
11 283
12 283
13 284
14 284
15 284
16 284
18 284
Archaeological Remains (Shipwrecks) *284*
19 284
21 285
22 285
23 285
24 285
OPERATIONAL CONTROLS 286
Vessel and Operational Management *286*
25 286
26 286
27 286
28 286
29 286
30 287
Effects on Existing Interests *287*
31 287
32 287
33 287
Spill Prevention *287*
34 287
35 287
"Soft Starts" *288*
36 288
37 288
Mooring of the Integrated Mining Vessel *288*
38 288
39 289
40 289
Other Discharges from Operational Vessels *289*
41 289
42 290
Biosecurity Management *290*
43 290
44 290
45 291
46 291
47 291
PRE-COMMENCEMENT MONITORING 292
48 292
49 294
50 294
51 294
OPERATIONAL SEDIMENT PLUME MODEL 295
52 295
53 296
ENVIRONMENTAL MONITORING REQUIREMENTS 296
54 296
Environmental Management and Monitoring Plan *297*
55 297
56 298
Post-Extraction Benthic Recovery Monitoring *299*
57 299
58 299
59 300
Laboratory Accreditation *300*
60 300
TECHNICAL REVIEW GROUP 300
61 300
62 301
63 302
64 302
65 302
MANAGEMENT PLANS 302
Seabird Effects Mitigation and Management Plan *302*

66 302
Marine Mammal Management Plan.........................303
67 303
Collision (Loss of Position) Contingency Management Plan 304
68 304
Simultaneous Operations Plan................................306
69 306
Biosecurity Management Plan.................................307
70 307
Safety Case 308
71 308
RELATIONSHIP WITH TANGATA WHENUA 309
72 309
73 309
74 310
75 310
76 310
77 310
78 311
79 311
80 312
COMMUNITY RELATIONSHIPS 312
81 312
82 312
83 313
84 313
85 313
FISHING INDUSTRY RELATIONSHIP 314
86 314
OPERATIONAL DOCUMENTATION 314
Operational Assessment Report..............................314
87 314
Training of Personnel...315
88 315
Complaints Register..315
89 315
MARINE SAFETY MATTERS 316
90 316
91 316
92 317
93 318
94 318
95 318
96 318
97 318
98 318
99 319
100 319
101 319
102 319
REPORTING REQUIREMENTS 319
Quarterly Operational Report 319
103 319
Annual Report...320
104 320
105 321
REVIEW CONDITION 321
106 321
RISK MANAGEMENT 322
107 322
108 322
COST RECOVERY 322
109 322

Schedule 1 – Grid References Of The Project Area 323
Schedule 2– Suspended Sediment Concentration (SSC) Limits 324
Schedule 3 – Methodology For Reviewing The Suspended Sediment Concentration 'Compliance Limit' Numerical Values In Schedule 2...............326
Schedule 4 – Benthic Ecology Monitoring Sites................327
Schedule 5 – Plan Of Consented Integrated Mining Vessel Mooring Area Boundary...327
Schedule 6– Monitoring Of Indicators..............................329
Schedule 7– 120 Decibel Contour...................................332

Glossary of Terms and Abbreviations in Conditions

ABS	American Bureau of Shipping
ANZECC 2000	Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000
Benthic	On the seabed
Crawler	Subsea sediment extraction device (SSED)
Discharge of de-ored sediment	The combined discharge of all sediment from the IMV, irrespective of its source, immediately prior to the discharge to the marine environment.
DPS	Dynamic Positioning System
EEZ Act	Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012
EEZ	Exclusive Economic Zone
EMMP	Environmental Monitoring and Management Plan
EPA	Environmental Protection Authority
HNZ	Heritage New Zealand Pouhere Taonga
IMO	International Maritime Organization
IMO Guidelines	International Marine Organization 2011 'Guidelines for the Control and Management of Ships' Biofouling to Minimise the Transfer of Invasive Aquatic Species'
IMV	Integrated mining vessel
ISQG	Interim sediment quality guidelines
JORC Code	Joint Ore Reserves Committee: Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves, 2012
KRG	Kaitiakitanga Reference Group
Kupe Operator	Operator of the Kupe Petroleum Mining License #38146
mg/L	Milligrams per litre
MMMP	Marine mammals monitoring plan
MNZ	Maritime New Zealand
Maritime Transport Act	The Maritime Transport Act 1994
NIWA	National Institute of Water and Atmosphere
OSPM	Operational Sediment Plume Model
PCEMP	Pre-commencement Environmental Monitoring Plan (previously called BEMP)
Pore water	Water that occupies the pore spaces between rocks or sediments
PSD	Particle size distribution (of sediment). The relative amounts of particles present according to size
SSC	Suspended sediment concentration
TRG	Technical Review Group
95^{th} percentile	Internationally, the 95th percentile upper confidence limit (UCL) is the most commonly used method to define an upper limit for background concentrations

GENERAL CONDITIONS

1. Pursuant to section 85 of the EEZ Act, these consents shall lapse ten (10) years after the date of their commencement unless the consents are given effect to prior to that date.

2. Subject to compliance with these consent conditions, the activities authorised by these consents shall be undertaken in general accordance with the application and supporting documents submitted as part of the application lodged on 23 August 2016. Where information contained in the application documents is contrary to the conditions of these consents the conditions will prevail.

   Advice note: For the purpose of these consents, the term 'pit' refers to the pit that remains following the extraction of seabed materials by the Crawler.

DISCHARGE LIMITS

3. The Consent Holder shall not extract more than 12.5 million tonnes of seabed material during any three (3) month period, and 50 million tonnes of seabed material during any twelve (12) month period for the term of these consents.

   The Consent Holder shall continuously record the mass of seabed material extracted and report on this as part of the Quarterly Operational Report required by Condition 103.

4. The following limits shall apply:

   a. The rate of extraction of seabed material, averaged over any monthly period, shall not exceed 8,000 tonnes per hour ("t/hr"); and
   b. The rate of discharge of de-ored sediment onto the seabed, averaged over any monthly period, shall not exceed 7,190 t/hr; and
   c. The rate of discharge of de-ored sediment having a size of <38 microns ("µm") shall not exceed:
      i. 130 cubic metres per hour ("m^3/hr"), averaged over any 48 hour period; an
      ii. 83 m^3/hr, averaged over any seven (7) day period; and
      iii. 66 m^3/hr, averaged over any three (3) month period.
   d. Averaged over any one (1) week period, the extraction of seabed material having a size of <8µm, shall not exceed 1.8% of the total seabed material extracted.

   For the purpose of (c) of this condition, the average value shall be derived from the use of continuous flow measurement and the analysis of one daily composite sample comprised of not less than the 12 individual samples collected during each 24 hour period at a point immediately prior to discharge to the marine environment.

   For the purpose of (d) of this condition, the average value shall be derived from the analysis of a minimum of 20 representative samples of the excavated seabed material.

   The Consent Holder shall record Particle Size Distribution, and the rate and volume/mass of the discharge of de-ored sediment continuously. The Consent Holder shall advise the EPA of any exceedances of the discharge limits specified in clauses (b), (c) and (d) within 24 hours of any exceedance.

The information collected in accordance with this condition shall be reported on as part of the Quarterly Operational Report required by Condition 103.

ENVIRONMENTAL LIMITS

Sediments

5. The activities authorised by these consents shall not result in:

   a. An exceedance of a 95^{th} percentile Suspended Sediment Concentration Limit ("SSC Limit") specified in Schedule 2; or
   b. An exceedance of any modified numerical values of an SSC Limit determined in accordance with Condition 51 (in which case a. above will no longer apply); or
   c. Any significant change of the 25th, 50th, or 80th percentile Suspended Sediment Concentrations ("SSC") at any of the ten monitoring sites identified in Schedule 2 when the difference between the measured actual SSC and modelled background statistical metric, as predicted by the validated OSPM, and as determined over any twelve (12) month period, is more than 10%.

   In the event that monitoring shows that limits in Condition 5.a. or 5.b. are exceeded, or the significance of change under Condition 5.c. exceeds 10%, then extraction activities shall cease until the Consent Holder can demonstrate compliance with those conditions, to the satisfaction of the EPA.

6. The activities authorised by these consents shall not result in an exceedance of any Interim Sediment Quality Guideline-High ("ISQG-High") value in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 ("ANZECC 2000"), or any subsequent versions thereof, at any of the ten monitoring sites identified in Schedule 2.

   For the purpose of these consents, any reference herein to either ISQG-High is deemed to be a reference to the ISQG-High values for metals, metalloids, organometallic and organic compounds provided in the ANZECC 2000, or any subsequent versions thereof. The metals subject to this condition are those specified in Schedule 6.

Benthic Ecology

7. The activities authorised by these consents shall not, result in a:

   a. more than a 5% reduction in overall abundance of macro fauna and flora; and
   b. more than a 5% reduction in the average number of macro-faunal and floral taxa present; and
   c. more than a 5% reduction in total macro-faunal and floral biomass;

   at the monitoring sites listed in Schedule 4 when compared against the pre-commencement monitoring data as determined in accordance with Condition 48, but taking into account natural variation.

For the purpose of this condition, "a 5% reduction" at any specified location, shall be determined by comparing the mean values of all replicate samples collected at that location at the particular time.

Benthic Recovery

8. No later than five (5) years following the completion of all seabed material extraction within two (2) km of the location where extraction has first occurred, the Consent Holder shall be required to demonstrate that recovery of the macroinfauna benthic community at that location has occurred, provided that the annual monitoring results for that area (Condition 54) indicate that that such recovery is on track to be achieved.

   For the purpose of this condition, "recovery of the macroinfauna benthic community" will have occurred when the macroinfauna communities at a specified location are within 15% of the average pre-mining total abundance, biomass and species richness, but taking into account natural variation.

   In the event that annual monitoring shows that recovery is not on track to be achieved, then the Consent Holder shall, in the next quarterly report, provide information to the EPA that:

   a. highlights the results of monitoring at the location that show that recovery is not on track to be achieved; and
   b. includes analysis by a duly qualified benthic ecology expert of:
      i. possible reasons why recovery is not on track to be achieved; and
      ii. potential measures to enhance recovery; and

   d. explains how the Consent Holder will comply with the obligation to demonstrate that recovery of the macroinfauna benthic community has occurred no later than 5 years following completion of all seabed material extraction within two (2) km of the location where extraction first occurred.

Seabirds

9. At all times during the term of these consents, the Consent Holder shall comply with the following:

   a. There shall be no adverse effects at a population level of seabird species that utilise the South Taranaki Bight that are classified under the New Zealand Threat Classification System as "Nationally Endangered", "Nationally Critical" or "Nationally Vulnerable" or classified as "Endangered" or "Vulnerable" in the International Union for the Conservation of Nature "Red List"; and
   b. Adverse effects on seabirds, including but not limited to effects arising from:
      i. Lighting (including the Integrated Mining Vessel ("IMV"), Floating Storage and Offloading Vessel);
      ii. Spills; and
      iii. The effect of sediment in the water column on diving birds that forage visually

   shall be mitigated, and where practicable avoided

Marine Mammals

10. Notwithstanding the requirements of Conditions 11, 37, 67 and 88, with respect to marine mammals (excluding seals), the Consent Holder shall ensure that:

  a. There are no adverse effects at a population level on:
    i. Blue whales; or
    ii. Marine mammal species classified under the New Zealand Threat Classification
    iii. System as “Nationally Endangered”, “Nationally Critical” or “Nationally Vulnerable”; or
    iv. Marine mammal species classified as “Endangered” or “Vulnerable” in the International Union for the Conservation of Nature “Red List”;

  that utilise the South Taranaki Bight.

  b. Adverse effects on marine mammals, including but not limited to effects arising from:
    i. Noise;
    ii. Collision and entanglement;
    iii. Spills; and
    iv. Sediment in the water column,

  are avoided to the greatest extent practicable.

  c. At all times during the exercise of these consents, at least one (1) designated and trained marine mammal observer is on-board each of the operational vessels, but not including bulk carriers. While the vessel is in motion, the observer shall be in a position where a clear field of vision is provided over the forward section of the vessel and beyond the bow;
  d. A video camera is placed in a prominent position on all operational vessels where a clear field of vision is provided over the forward section of the vessel, beyond the bow and to the sides of the bow, and is recording at all times while the vessel is in motion. Further to the camera, a monitoring screen shall be installed on the bridge of each vessel and the video feed from each of the cameras will be made available on the Consent Holder’s website or such other website as may be established from time to time (Condition 81). The purpose of the cameras is to record passage of the vessels and any contact with marine mammals while in motion;
  e. All employees and contractors undertaking airborne, seagoing and watch-keeping duties are informed of their obligations under the Marine Mammals Protection Act 1978 and Marine Mammals Protection Regulations 1992 or any subsequent Regulations;
  f. All employees and contractors record any sightings of whales or dolphins including the date, time and, where possible, GPS position of the vessel;
  g. Any sightings of Maui or Hector’s dolphins are immediately reported to the Department of Conservation;
  h. Masters of all vessels are instructed to reduce speed to a safe maximum within 500 m of any large cetaceans and feeding aggregations of blue whales, and take all necessary steps to avoid contact

with the animals by detouring around and, where practicable, maintaining a distance of at least 500 m from the animal/s;

i. Helicopters servicing the operation (subject to compliance with Safety and Civil Aviation Authority requirements) maintain a minimum altitude of 600 m (2,000 feet) except when landing and taking off;
j. Any marine mammal strikes, entanglements, injuries or deaths are reported to the Department of Conservation and the EPA as soon as practicable, but no later than five (5) working days, following any such event;
k. If a, strike, entanglement, injury or death involves Maui or Hector's dolphin, the carcass is recovered, the Department of Conservation and the EPA are notified immediately of that recovery and the carcass is returned to shore as soon as practicable, but no later than five (5) working days following such event, for collection by the Department of Conservation subject to the Consent Holder's obligations under the Marine Mammals Protection Act 1978 or any subsequent Regulations;
l. Records are kept of all sightings of marine mammals (except seals). All records shall be contained in an Observation Log and be made available to EPA and/or Department of Conservation staff upon request and Annual Report required by Condition 104; and
m. Any other relevant operational response in relation to marine mammals that has been approved by the EPA is undertaken.

For the purpose of this condition, any observer engaged by the Consent Holder shall be a qualified observer as defined in the 2013 Department of Conservation Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations (or any subsequent updated Code of Conduct).

For the purpose of this condition, the term 'in motion' refers to any period when the Consent Holder's operational vessels are moving under the power of their own engines, but does not apply to movement of the IMV at those times when it is anchored to the seabed.

For the purpose of this condition, the term 'large cetaceans' refers to any of the following marine mammal species:

n. All members of the Mysticeti group (i.e. Baleen whales); and/or
o. All members of the Physeteriodea group (i.e. Sperm whales); and/or
p. All members of the Ziphioidea group (i.e. Beaked whales); and/or
q. All members of the Globicephala group (i.e. Pilot whales); and/or
r. All members of the Orcinus group (i.e. Killer whales).

Underwater Noise

11. At all times during the operation of marine vessels and/or project equipment, the Consent Holder shall comply with the following requirements in relation to underwater noise:

   a. The combined noise from the IMV and the Seabed Sediment Extraction Device (“Crawler”) operating under representative full production conditions shall be measured at a nominal depth of ten (10) m below the sea surface and at 300 m, 500 m, 750 m and 1,000 m from the port or starboard side of the IMV;

   b. The overall combined noise level at 500 m shall not exceed 130 dB re 1µPa RMS linear in any of the following frequency ranges: low frequency 10-100 Hz, mid-frequency 100-10,000 Hz, and high frequency >10,000 Hz;

   c. The overall combined noise level at a nominal depth of ten (10) m below the sea surface and 500 m from the IMV, across all frequencies shall not exceed a sound pressure level of 135 dB re 1µPa RMS linear;

   d. Measurements shall be undertaken in calm sea conditions (e.g. Beaufort sea state less than 3 (beginning of white-capping)), with no precipitation and no external noise sources (e.g. passing ships);

   e. The monitoring equipment shall be calibrated before and after measurements; and

   f. The combined noise shall be monitored:

      i. Within twenty (20) working days of seabed material extraction activities authorised by these consents reaching no less than 90% of full production but no later than six (6) months following the commencement of the seabed material extraction activities, the Consent Holder shall undertake continuous noise measurement for a period of no less than six (6) weeks;

      ii. An additional two times in the first twelve (12) months of the commencement of 90% of full production. Each measurement being separated by a period of at least six (6) months;

      iii. Annually for the following four (4) years;

      iv. Every five (5) years thereafter; and

      v. At any time reasonably requested by the EPA.

      vi. Should the operation of the IMV and Crawler be altered in any way which may change the magnitude or character of the underwater noise production, the noise shall be monitored within twenty (20) working days of the change to demonstrate compliance with Condition 11.b. has been maintained.

Advice note: For the purpose of this condition, the reference to “full production conditions” equates to an operational extraction of 8,000 tonnes per hour as required by Condition 4.a.

12. The Consent Holder shall design and construct the crawler and IMV to achieve a total combined noise source level (measured in water), when operating at full production, of not more than 171 dB re 1µPa RMS linear at one (1) metre.

13. Prior to deployment in New Zealand, the Consent Holder shall obtain certification from a suitably qualified and experienced acoustic engineer that the crawler and IMV has been designed to achieve the criterion set out in Condition 12 above, and that the criterion set out in Condition 12 has been demonstrated for full production operation during pre-deployment commissioning. The testing undertaken in accordance with this condition shall include both theoretical assessment and noise data collected from field measurements during pre-deployment commissioning.

14. For the avoidance of doubt, the Consent Holder shall not commence extraction activities until the certification required by Condition 13 has been received by the Consent Holder and provided to the EPA.

15. The Consent Holder shall undertake noise monitoring in the vicinity of the IMV and crawler once per week during the period referred to in Condition 11.f.i., in order to assess compliance with the criterion set out in Condition 12.

16. Underwater monitoring of the total combined noise from the crawler and IMV shall also occur at the same times as monitoring is undertaken under Conditions 11.f.ii to v.

17. Underwater monitoring at and beyond the 120 dB contour identified in Schedule 7 shall occur to ensure that a sound pressure level of 120 dB re 1µPa is validated.

18. Within twenty (20) working days of any noise monitoring undertaken in accordance with Condition 11, the Consent Holder shall provide a detailed report on the monitoring and results to the EPA. As a minimum, this report shall include:

    a. Details of the equipment used and calibration methods used;
    b. A description of the measurement conditions and location;
    c. A summary of the noise levels measured, including broadband and one third octave band frequency data and compliance of the operation with respect to the noise standards specified in Condition 11; and
    d. At the commencement of operations, validation of the noise model and extent of the predicted 120 dB contour (as shown by Schedule 7) generated by the IMV and crawler when operating at the centre of the mining area.

19. Notwithstanding Conditions 3 - 18 above, the Consent Holder shall ensure that the activities authorised by these consents do not result in any adverse effects that were not anticipated at the time of the granting of these consents.

    The Consent Holder shall advise the EPA of any such adverse effects that are identified.

Archaeological Remains (Shipwrecks)

20. If any of the following:

    a. Steel;
    b. Brass;

c. Other metals in solid state;
d. Manufactured or worked timbers; or
e. Other material not naturally found in the seabed material extraction area,

are discovered during seabed material extraction activities authorised by these consents that are of potential historical or cultural importance, the Consent Holder shall immediately stop extraction activities within the discovery area.

21. The Consent Holder shall record all discoveries made under Condition 20 and as a minimum record:

a. GPS location and depth of the find;
b. Photos of the find; and
c. A detailed description of the find.

This record shall be provided to an appropriately qualified and experienced archaeologist for interpretation and identification, and provided to the EPA and Heritage New Zealand Pouhere Taonga ("HNZ") upon completion.

22. Further to the requirements of Condition 21, the Consent Holder shall notify the EPA within five (5) working days of any discoveries made in accordance with Condition 20.

Additionally, the Consent Holder shall consult with HNZ and the iwi representatives referred to in Condition 72 to confirm the origin and any other relevant information to the discovery including, as a minimum:

a. What it is that has been discovered; and
b. What the age of the discovery is.

23. If the discoveries under Condition 20 are found to be a legally protected archaeological site (origins pre- dating 1900), the Consent Holder shall obtain the relevant Archaeological Authority from HNZ prior to any seabed material extraction activities recommencing within the discovery area.

24. The Consent Holder shall not recommence seabed material extraction activities authorised by these consents in the discovery area until HNZ has confirmed the discovery does not qualify as a legally protected archaeological site (pre-1900 shipwreck) as described under the Heritage New Zealand Pouhere Taonga Act 2014 or the relevant Archaeological Authority has been obtained in accordance with Condition 23.

The Consent Holder shall inform the EPA of the outcome of any engagement with HNZ as soon as practicable, but no later than (5) working days) following the completion of any engagement process.

OPERATIONAL CONTROLS

Vessel and Operational Management

25. The Consent Holder shall ensure that when extracting seabed material using the Crawler, the cut depths shall not be deeper than eleven (11) m below the pre-mined seabed level and that only one (1) Crawler is in use, or in place, on the seabed at any time.

    The Consent Holder shall continuously record the cut depth of the Crawler and report on this as part of the Quarterly Operational Report required by Condition 103.

26. The IMV shall be anchored to the seabed at all times when the Crawler is operating.

    Upon each resetting of any anchor, the Consent Holder shall undertake a ‘proof-load test’ for the anchor and keep a record of each test. In addition to recording the proof-loading tests, each test shall be witnessed by the relevant Class society or Marine Warranty Surveyor. The record of all tests undertaken shall be made available to the EPA upon request following a review by a suitably qualified expert.

    In situations where the mooring or thruster assistance of the IMV is in a degraded capability situation and is deemed unsafe by the Captain of the IMV, all Floating Storage and Off-loading transhipment operations shall cease immediately and the IMV shall be removed to a safe location until the capability situation is, in the opinion of the Captain of the IMV, deemed operationally safe.

    For the purpose of this condition, "safe location" is defined as "safe for the Consent Holder's personnel and assets, the Kupe assets, and shipping”.

27. The discharge of all de-ored sediment from the IMV, shall take place by means of a dedicated pipe which discharges at a nominal distance of four (4) m above the seabed.

    The height and GPS position of any mounds created on the seabed during the deposition of de-ored sediments shall be recorded and reported on in the Quarterly Operational Report required by Condition 103. Re-deposition mound heights shall be recorded with accuracy for both height and location of +/- one (1) m.

    All mounds remaining at the beginning of each lane shall be no higher than 4 metres above the level of the original seabed.

    For the purpose of this condition, the ‘seabed’ refers to the area immediately below the point of discharge, whether that be the natural seabed or the base of the mining pit.

28. The direct deposition of de-ored sediment onto the seabed shall not occur within 300 m of the seaward boundary of the Coastal Marine Area.

29. All pits remaining at the end of each mining lane shall be no deeper than ten (10) m maximum depth and five (5) m average depth below the pre-mined seabed level.

The average and maximum depth and GPS position of any unfilled pits remaining after completion of a mining lane shall be recorded and reported in the Quarterly Operational Report required by Condition 103.

30. The Consent Holder shall ensure that:

    a. Pits created by the removal of seabed material, other than those at the end of each mining lane, are backfilled using de-ored sediments; and
    b. Other than at the commencement of each mining lane, all de-ored sediment is backfilled into the mining lanes.

Effects on Existing Interests

31. At all times during the term of these consents, the Consent Holder shall, to the greatest extent practicable, mitigate and where practicable avoid, any adverse effects on the environment or on existing interests (including infrastructure and operations of licences) as a result of mooring failure or loss of position.

32. At all times during the term of these consents, the Consent Holder shall:

    a. Mitigate, and where practicable avoid, adverse biosecurity effects resulting from activities being undertaken by the IMV, Floating Storage and Offloading Vessel and other support vessels; and
    b. Ensure that there are effective procedures in place to manage biosecurity risk from overseas and domestic vessels.

33. The Consent Holder shall manage all activities associated with the seabed material extraction operations, including the project vessels and their operation, to ensure that the activities authorised by these consents do not result in any adverse effects on the Operator of the Kupe Petroleum Mining License #38146 (“the Kupe Operator”) Kupe assets and Infrastructure.

Spill Prevention

34. At all times during the term of these consents, the Consent Holder shall undertake all necessary measures to ensure that there are no discharges or spills of oils or fuels from any of the operational vessels into any environment.

35. Notwithstanding Condition 34, in the event that there is a discharge or spill of oil or fuels, the Consent Holder shall implement all necessary operational responses, including the measures set out in oil spill contingency plans required under Parts 130A and 131 of the Marine Protection Rules, to ensure that any adverse effects associated with such event/s are remedied or mitigated.

    As soon as practicable following any spill or discharge of oil or fuels, the Consent Holder shall notify the EPA of any such event. Notification shall include a description of the event, its location and the Consent Holder’s response.

    Advice Note: Parts 130A and 130 of the Marine Protection Rules require oil spill contingency plans to be approved by MNZ for ships and installations.

"Soft Starts"

36. The Consent Holder shall ensure that any start-up, whether related to commencement or re-commencement after a break, of the seabed material extraction activities authorised by these consents shall be completed as a "soft start" whereby equipment shall be gradually increased in power over a minimum of twenty (20) minutes. For clarity, a "soft start" includes noise from the IMV, Crawler and any associated plant.

    Soft starts may only commence in daylight hours and during good sighting conditions (visibility to at least 500 m).

37. Prior to each start-up, the Consent Holder shall use suitably trained marine mammal observer(s), in accordance with Condition 88, to conduct pre-start observations over a 500 m radius (mitigation zone) surrounding the IMV for at least thirty (30) minutes to ensure no whales, dolphins, seals or sea lions are present within the mitigation zone.

    If any whales, dolphins, seals or sea lions are observed in the mitigation zone during pre-start observations, then the soft start shall be delayed until the marine mammals are seen to leave the mitigation zone or have not been detected within the mitigation zone for a further thirty (30) minutes from the last sighting.

    A record of pre-start observations shall be kept and made available to the EPA on request and included in the Quarterly Operational Report required by Condition 103 and the Annual Report required by Condition 104.

    For the purpose of this condition, any observer engaged by the Consent Holder shall be a qualified observer as defined in the 2013 Department of Conservation Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations (or any subsequent updated Code of Conduct.

Mooring of the Integrated Mining Vessel

38. All mooring lines and associated anchors for the IMV shall be located within the area bounded by the co-ordinates set out below and within the boundary shown in Schedule 5:

Longitude	Latitude
174 02 25.991 E	39 50 31.772 S
174 02 50.521 E	39 50 36.773 S
174 03 01.220 E	39 50 44.081 S
174 03 37.595 E	39 51 19.249 S
174 06 08.626 E	39 51 11.999 S
174 06 34.844 E	39 51 10.325 S
174 07 03.608 E	39 51 26.161 S
174 07 29.690 E	39 51 19.249 S
174 07 34.410 E	39 51 10.688 S

Longitude	Latitude
174 07 48.173 E	39 51 00.184 S
174 09 17.294 E	39 50 08.963 S
174 01 54.984 E	39 50 44.354 S
174 01 38.867 E	39 51 00.295 S
174 01 29.982 E	39 51 19.120 S
174 01 27.257 E	39 52 37.056 S
174 01 38.838 E	39 53 00.222 S
174 02 21.106 E	39 53 34.505 S
174 02 21.106 E	39 53 34.505 S
174 03 20.239 E	39 54 15.826 S
174 03 24.102 E	39 54 18.205 S
174 04 08.746 E	39 54 42.628 S
174 04 27.660 E	39 54 48.330 S
174 05 33.180 E	39 54 54.950 S
174 07 17.836 E	39 55 01.477 S
174 07 43.140 E	39 54 56.884 S
174 09 26.539 E	39 54 08.428 S
174 12 40.756 E	39 52 22.433 S
174 12 45.767 E	39 52 19.229 S
174 13 29.914 E	39 51 45.857 S
174 10 22.771 E	39 49 12.680 S

39. If any equipment or machinery greater than one (1) m x one (1) m in size is lost overboard from any project or operational vessel, the Consent Holder shall collect it from the seafloor as soon as practicable but no later than five (5) working days from the time it was lost overboard.

Where it is not practicable to recover the item, the Consent Holder shall provide a description of the item (including dimensions) and record the location and depth that the item was lost overboard. This information shall be provided to the EPA, Land Information New Zealand, and the Harbour Master (if within the twelve (12) nautical mile limit) and placed on the Consent Holder's website (Condition 81) within twenty four (24) hours of the item going overboard.

40. Notwithstanding the requirements of Condition 39 the Consent Holder shall ensure that any equipment or structures involved with the extraction operations are removed from the seabed, no later than twenty (20) working days following the completion of all seabed material extraction activities authorised by these consents.

Advice Note: Conditions 39 and 40 do not remove any obligation of the Consent Holder to comply with Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act.

Other Discharges from Operational Vessels

41. The Consent Holder shall not dispose of, or discharge, any harmful substances at sea.

All hazardous and/or oily waste shall be stored on board each project vessel for transport in suitable containers or packaging to a shore side reception facility that is authorised to accept such material. The Consent Holder shall keep a record of all such material and the reception facility/facilities and make this information available to the EPA upon request.

For the purpose of this condition, 'harmful substances' do not include any 'mining discharges' from the seabed material extraction activities authorised by these consents as defined by section 4 of the EEZ Act.

42. All fuel used in the operational vessels shall have a sulphur content compliant with the current International Maritime Organization limit, or no greater than 3.5% (w/w) by weight, whichever is the lesser.

A record of all fuel used in, and the sulphur content of, any of the project vessels shall be kept and provided as part of the Annual Report required under Condition 104 and shall be made available to the EPA upon request.

Biosecurity Management

43. All operational vessels carrying ballast water that travel to and from overseas ports, including bulk carriers, shall be required to have a shipboard ballast water treatment system as part of their charter agreements with the Consent Holder. The ballast water treatment system shall be in the Ministry for Primary Industry List of Approved Ballast Water Treatment Systems, or be an equivalent system approved by the International Maritime Organization.

Any vessel that does not comply with the above requirements shall not be used for any part of the activities authorised by these consents, unless the vessel's Master can demonstrate that the vessel complies with additional ballast water management options listed in the Ministry for Primary Industries' Import Health Standard: Ballast Water from All Countries, 16 December 2015, or any replacement rule or standard, including the Maritime New Zealand ("MNZ") Marine Protection Rules (Part 300: Ballast Water Management).

The Consent Holder shall keep a record of the approved ballast water management for each vessel and shall provide this information to the EPA upon request.

44. The Consent Holder shall ensure that:

a. All long term stay overseas vessels that are to be located in the project area, including but not limited to the IMV and Crawler; and
b. All vessels servicing the seabed material extraction operation that regularly travel to and from overseas ports, including bulk carriers,

meet the 'Clean Hull' for 'long-stay vessels' requirement specified in the Ministry for Primary Industries Craft Risk Management Standard: Biofouling on Vessels Arriving to New Zealand, 15 May 2014 ("the CRMS"), or any subsequent version thereof. For vessels identified in Clause a. above, special measures to minimise biofouling risk shall be included in the Biosecurity Management Plan ("BMP") developed under Condition 70.

Any vessel that does not comply with the above requirements shall not be used for any part of the seabed material extraction activities authorised by these consents.

45. Within twenty (20) working days of each anniversary of the commencement of these consents, the Consent Holder shall provide a copy of the 'Biofouling Record Book' (Condition 70.b.iv) to a nominated representative of the Aquaculture Industry, as appointed by Aquaculture New Zealand.

The Consent Holder shall provide a copy of the Biofouling Record Book to the EPA upon request.

46. Vessels associated with operations authorised by these consents shall only enter and anchor in Admiralty Bay for the purpose of seeking shelter in adverse weather or vessel safety requirements, and under no circumstances shall any operational or maintenance activities, including the discharge of ballast water, be undertaken at this location unless:

a. An emergency situation arises and, in the opinion of the vessel's Master, there is no practicable alternative; and
b. MNZ, the Marlborough District Council, Aquaculture New Zealand and a nominated representative of Ngāti Koata are notified as soon as practicable, but no later than five (5) working days, following the occurrence of any such emergency event.

The Consent Holder shall keep a record of all notifications required by this condition and shall provide this information to the EPA upon request.

The Consent Holder does not need to comply with this condition in the event that the Director of MNZ directs a vessel to enter Admiralty Bay as a safe anchorage in accordance with the Maritime Transport Act 1994.

47. Prior to any vessels associated with operations authorised by these consents entering and anchoring in Admiralty Bay in accordance with Condition 46, the Consent Holder shall notify Ngāti Koata as soon as reasonably practicable, but no later than five (5) working days, and, to the extent practicable:

a. Provide the opportunity for a nominated representative from Ngāti Koata to have input in the anchoring location within the bay; and
b. Provide the opportunity for a nominated Ngāti Koata iwi observer to monitor the presence of marine mammals.

The Consent Holder shall keep a record of all notifications required by this condition and shall provide this information to the EPA upon request.

PRE-COMMENCEMENT MONITORING

Pre-commencement Environmental Monitoring Plan

48. Prior to the commencement of any seabed material extraction activities authorised by these consents, the Consent Holder shall ensure that a minimum of two (2) years of environmental monitoring has been undertaken and shall, as a minimum, include monitoring of:

- Suspended sediment concentrations as measured from two weekly grab samples and as calculated from continuous turbidity measurements;
- Sediment quality;
- Subtidal and intertidal biology;
- Optical water quality;
- Physio-chemical parameters;
- Heavy metals;
- Oceanography;
- Primary production;
- Zooplankton;
- Seafood resources;
- Marine mammals;
- Underwater noise;
- Seabirds;
- Commercial fishing;
- Beach profiles; and
- Recreational fishing.

The Consent Holder shall also undertake testing and monitoring of the matters, and for the purposes, set out in Schedule 6.

The Consent Holder shall prepare, and undertake pre-commencement environmental monitoring, in accordance with the procedures and methods, at the locations (including representative points around the Kupe Well Head Platform and along the pipeline and umbilical route), and for the duration and frequency detailed in the certified Pre-commencement Environmental Monitoring Plan ("PCEMP") the purpose of which is to:

a. Establish a set of environmental data that identifies natural background levels while taking into account spatial and temporal variation;

b. Confirm the current understanding of the seasonality and natural variability of environmental parameters that will be monitored during seabed material extraction activities authorised by these consents;
c. Provide data to validate the background data used in the Operational Sediment Plume Model (Condition 52), which predicts the sediment transportation processes in the South Taranaki Bight; and
d. Provide data to verify that the ‘SSC Limit’ values in Schedule 2 are appropriate following the validation of the Operational Sediment Plume Model (Condition 52); and
e. Ensure compliance with all regulatory requirements and guidelines; and
f. Provide data to establish the proxy relationship between turbidity and SCC at the monitoring sites listed in Schedule 2 and at a control site.

The PCEMP shall also include:

(a) The roles and responsibilities of parties who are to undertake the pre-commencement environmental monitoring;

(b) Objectives for the pre-commencement environmental monitoring associated with the activities authorised by these consents;

(c) All parameters being monitored, including sampling design, methodology, frequency, duration and monitoring locations;

(d) Details of data analysis and processing for all parameters being monitored; and

(e) Report methods for all parameters being monitored.

The PCEMP shall be prepared by a suitably qualified and experienced person(s) in general accordance with the draft BEMP dated August 2016. The PCEMP shall then be independently peer reviewed by a suitably qualified and experienced person(s) and then reviewed by the Technical Review Group (“TRG”) (Condition 61) to confirm that the intended monitoring meets the purposes of the PCEMP as set out in this condition.

The PCEMP together with comments and recommendations of the TRG including, where necessary, an explanation as to why a TRG recommendation has not been accepted, shall be submitted to the EPA for certification that the PCEMP meets the requirements of this condition.

If within thirty (30) working days the EPA has not certified the PCEMP, or advised the Consent Holder that it has not yet been certified, the PCEMP will be deemed to have been so certified.

The pre-commencement monitoring required by these consents shall be undertaken in accordance with the certified PCEMP.

Advice Note: The PCEMP is a renaming of the draft BEMP (Baseline Environmental Monitoring Plan) referred to in Condition 48.

49. The Consent Holder may amend the PCEMP at any time. Any amendments shall be prepared by a suitably qualified and experienced person(s), and shall then be independently peer reviewed by a suitably qualified of experienced person(s), and then reviewed by the Technical Review Group (TRG), unless the EPA confirms that a peer review is not necessary. Any changes will only come into effect once they have been certified by the EPA that such amendment is consistent with purposes of, and follows the preparation and review processes of, Condition 48, and that the monitoring locations, duration and frequency of monitoring are representative and relevant to each of the environmental components being monitored.

    If within twenty (20) working days the EPA has not certified the amended PCEMP, or advised the Consent Holder that it has not yet been certified, the amended PCEMP will be deemed to have been so certified

    Where certification for an amended plan is not received, the Consent Holder shall continue to use the plan which was in place prior to the lodgement of the amended plan.

    Minor amendments that take into account unforeseen circumstances, or that address circumstances that require immediate action on site do not need to be submitted in advance of the work being undertaken, provided the effects of such amendments are no greater than those provided for under the consents. The Consent Holder should submit any such amendments as soon as practicable but no later than five (5) working days after the minor amendments are made.

50. For the purpose of all monitoring in accordance with the conditions of these consents, the Consent Holder shall undertake monitoring at all required times except:

    a. During a mechanical or technical breakdown or malfunction of monitoring equipment; or
    b. Where monitoring equipment has been damaged or is being replaced; or
    c. Due to unforeseen circumstances.

    If any of the above situations occur the Consent Holder shall as soon as practicable, but no later than twenty four (24) hours following, notify the EPA of any such occurrence identifying:

    (a) What monitoring was affected and for how long; and

    (b) When the monitoring will recommence.

51. Prior to the commencement of seabed material extraction activities authorised by these consents and following completion of the pre-commencement environmental monitoring required under Condition 48, the Consent Holder shall determine updated numerical values of the SSC Limits in Schedule 2 of these consents utilising the methodology specified in Schedule 3. The review of the numerical values must be undertaken by suitably qualified and experienced person(s) and submitted to the TRG for review and comment prior to being submitted to the EPA for certification.

    In the event that the updated numerical values of the SSC Limits as a result of monitoring are different from the numerical values of the SSC Limits in Schedule 2 of these consents, then the updated numerical values shall supersede the numerical values of the SSC Limits in Schedule 2 for the purpose of these consents

Any change to the numerical values in accordance with this condition shall not require a change of consent conditions but are to be identified in the Environmental Monitoring and Management Plan ("EMMP") required under Condition 55.

OPERATIONAL SEDIMENT PLUME MODEL

52. At all times during the term of these consents, the Consent Holder shall maintain an Operational Sediment Plume Model ("OSPM"), in order to ensure that activities authorised by these consents comply with the conditions of these consents and to provide an effective mechanism to assist in:

a. Predicting background and extraction derived Suspended Sediment Concentrations to inform the management of the seabed material extraction activities authorised by these consents;
b. Distinguishing operationally derived contributions to Suspended Sediment Concentrations from background processes; and
c. Forecasting, as accurately as practicable, sediment plume dynamics including but not limited to:
d. Intensity; and
e. Geographic spread.

The OSPM shall be run in real time forecast mode using up to date Met Ocean three (3), five (5), seven (7) or ten (10) day forecasts to inform the day to day mine operations and ensure that compliance with the SSC Limits specified in Condition 5 is maintained.

The OSPM shall be developed and maintained by a suitably qualified and experienced person(s).

The OSPM shall be updated and independently peer reviewed by a suitably qualified and experienced person at the following intervals:

(a) Once at the conclusion of the PCEMP period prior to any seabed material extraction activities authorised by these consents; and

(b) During seabed material extraction activities authorised by these consents, immediately following each calibration and validation exercise at the frequencies defined in Condition 53.

The scope of the OSPM independent review shall include the model, its calibration, validation, availability and applicability of data and the use of the OSPM in management of the seabed material extraction activities authorised by these consents. The predictive fine sediment identification methods and sampling density (Condition 87) shall be included within the review scope.

An OSPM report shall be prepared that summarises the establishment, calibration, validation, operation and updating of the OSPM. The OSPM report, including that updated OSPM, shall, together with the independent peer review, be provided to the TRG for review prior to lodgement with the EPA.

The OSPM report, including the updated OSPM, the comments and recommendations of the peer reviewer and the TRG, and explanations as to why any recommendation has not been accepted shall be provided to the EPA certification, that the updated OPSM satisfies the requirements of this Condition 52.

If within thirty (30) working days the EPA has not certified the updated OSPM, or advised the Consent Holder that it has not yet been certified, the updated OSPM will be deemed to have been so certified.

No seabed material extraction shall commence until the EPA has certified the updated OSPM required following the pre-commencement environmental monitoring period.

The Consent Holder shall at all times operate an EPA certified OSPM. If certification of an updated OSPM is not received, the Consent Holder shall continue to use the certified OSPM that was in use prior to lodgement of the updated OSPM.

53. The Consent Holder shall calibrate and validate the OPSM at least:

a. Every six (6) months during the PCEMP and for the first three (3) years of seabed material extraction activities authorised by these consents; and
b. Every twenty-four (24) months thereafter,

utilising the sediment data from the PCEMP (Condition 48), the Operational Assessment Report (Condition 87) and the on-going monitoring information collected in accordance with Conditions 54.

The calibration and validation exercise shall review the modelled and measured sediment plume properties. The Consent Holder shall review whether the benthic ecology and SSC monitoring sites are appropriately located to detect any adverse effect of SSC and report the outcome of that review to the TRG under Condition 61.b. Any change to the location of benthic ecology or SSC monitoring sites shall be by way of a change of conditions.

ENVIRONMENTAL MONITORING REQUIREMENTS

54. Following the completion of the pre-commencement monitoring required by Condition 48 and the review of the SSC Limits under Condition 51, the Consent Holder shall, as a minimum, undertake monitoring of:

- Suspended Sediment Concentrations, as measured from two weekly grab samples and as calculated from continuous turbidity measurements;
- Sediment quality;
- Subtidal and intertidal biology;
- Optical water quality;
- Physio-chemical parameters;
- Heavy metals;

- Oceanography;
- Primary production;
- Zooplankton;
- Biosecurity;
- Seafood resources;
- Marine mammals;
- Underwater noise;
- Beach profiles; and
- Recreational fishing.

The Consent Holder shall also undertake testing and monitoring of the matters, and for the purposes, set out in Schedule 6. For the avoidance of doubt, both Schedule 6 and the matters set out above in this condition shall be addressed.

The Consent Holder shall prepare, and undertake environmental monitoring in accordance with the procedures and methods, at the locations, and for the duration and frequency detailed in the certified EMMP required by Condition 55.

Environmental Management and Monitoring Plan

55. The Consent Holder shall ensure that monitoring required by Condition 54 and Schedule 6 is appropriate to ensure that the activities authorised by these consents do not result in any adverse effects that were not anticipated at the time of the granting of these consents.

The EMMP shall, as a minimum:

a. Identify the sampling design and methodology for each of the parameters being monitored, including the frequency, duration and monitoring locations;
b. Describe how the results of the pre-commencement environmental monitoring programme provided for in the PCEMP has been incorporated into the EMMP (Condition 48);
c. Outline the process for the on-going validation of the OSPM including the calibration and validation of the plume component of the model (Condition 52);
d. Identify the limits contained in the ISQG-High values (Condition 6);
e. Specify procedures for comparing the monitoring data against the background data that assist in determining if any activities authorised by the consents have resulted in adverse effects that were not anticipated at the time of the granting, including recovery of the benthic environment, as defined in Condition 8;
f. Identify the TRG membership, and their evaluation process in accordance with Conditions 61 - 65;
g. Identify the operational responses to be undertaken if unanticipated adverse effects are identified;

h. Detail data analysis and processing for all parameters being monitored;
i. Define the reporting methods and schedule for all parameters being monitored; and
j. To continue the ongoing calibration of the relationship between SSC and turbidity.

The EMMP shall be prepared by a suitably qualified and experienced person(s) in general accordance with the draft EMMP dated August 2016. The EMMP shall then be independently peer reviewed by a suitably qualified and experienced person(s) and then reviewed by the TRG (Condition 61) to confirm that the intended monitoring meets the purposes of the EMMP as set out in this condition.

The EMMP together with comments and recommendations of the TRG including, where necessary, an explanation as to why a TRG recommendation has not been accepted, shall be submitted to the EPA for certification that the EMMP meets the requirements of this condition.

The environmental monitoring required by these consents shall be undertaken in accordance with the certified EMMP and shall commence no later than one (1) month prior to the commencement of the seabed material extraction activities authorised by these consents.

If within thirty (30) working days the EPA has not certified the EMMP, or advised the Consent Holder that it has not yet been certified, it will be deemed to have been so certified.

No seabed material extraction shall commence until the EMMP has been certified by the EPA.

The environmental monitoring required by these conditions shall be undertaken in accordance with the EPA certified EMMP and shall commence at least twenty (20) working days prior to the commencement of the seabed material extraction activities authorised by these consents.

56. The Consent Holder may amend the EMMP at any time. Any amendments to the EMMP shall be prepared by a suitably qualified and experienced person(s) and then independently peer reviewed by a suitably qualified and experienced person(s), and then reviewed by the TRG. Any changes will only come into effect once they have been certified by the EPA, that:

a. Such changes are consistent with the requirements of Conditions 54, 55 and Schedule 6; and
b. The processes set out in Condition 55 have been followed; and
c. The monitoring locations, and the duration and frequency of monitoring, continue to be representative and relevant to each of the environmental components being monitored; and/or
d. The change in monitoring location or timing of monitoring is necessary to reflect operational changes, or changes in methodology, due to advances in technology or scientific understanding.

If within twenty (20) working days the EPA has not certified the amended EMMP, or advised the Consent Holder that it has not yet been certified, the amended EMMP will be deemed to have been so certified.

Where certification for an amended plan is not received, the Consent Holder shall continue to use the plan which was in place prior to the lodgement of the amended plan.

Minor amendments that take into account unforeseen circumstances on site, or that address circumstances that require immediate action do not need to be submitted in advance of the work being undertaken, provided any effects of such amendments are no greater than those provided for under these consents. The Consent Holder should submit any such amendments made under this condition as soon as practicable, but no later than five (5) working days after the minor amendments are made.

Post-Extraction Benthic Recovery Monitoring

57. Following the completion of the seabed material extraction activities authorised by these consents, the Consent Holder shall undertake five (5) years of post-extraction monitoring of the biological environment, including heavy metal concentrations, within the consent area and its surrounds, the purpose of which is to assess whether recovery of the benthic environment, as defined in Condition 8, has been achieved.

At least three (3) months prior to the completion of the seabed material extraction activities authorised by these consents, the Consent Holder shall provide to the EPA for certification, a Post- extraction Monitoring Plan ("PEMP") which shall, as a minimum, include:

a. The roles and responsibilities of parties who are to undertake each aspect of the environmental monitoring;
b. Objectives for the post-extraction monitoring of the activities authorised by these consents;
c. Description of the TRG, their role and their evaluation process in accordance with Conditions 61 - 65;
d. Identification of the sampling design and methodology for each of the parameters being monitored, including the frequency, duration and monitoring locations as set out in Schedule 6;
e. Procedures for comparing the monitoring data against the background data that will assist in determining if the biological environment within the extraction area is recovering following the completion of the extraction activities;
f. Details of data analysis and processing for all parameters being monitored; and
g. Reporting methods for all parameters being monitored.

The PEMP shall be prepared by a suitably qualified and experienced person(s) and shall then be peer reviewed by the TRG (Condition 61) to confirm that the PEMP meets the purposes of the PEMP, as set out in this condition.

If within thirty (30) working days the EPA has not certified the PEMP, or advised the Consent Holder that it has not yet been certified, it will be deemed to have been so certified.

The post-extraction monitoring shall be undertaken in accordance with the certified PEMP.

58. Within twenty (20) working days of each anniversary of the commencement of the post-extraction monitoring programme, the Consent Holder shall, following consultation with the TRG, prepare and lodge with the EPA, an Annual Post-extraction Monitoring Report that includes as a minimum:

a. The monitoring undertaken in the previous twelve (12) month period;
b. The monitoring to be undertaken in the next twelve (12) month period;

c. Data collected from the monitoring undertaken and a comparison against all relevant environmental limits specified in the conditions of these consents;
d. Any remediation undertaken and the results of any such remediation;
e. A summary of any commentary or recommendations from the TRG and, where necessary, an explanation as to why any TRG recommendation has not been accepted; and
f. A summary report of the findings of the monitoring undertaken with conclusions drawn as to the recovery and overall biological heath of the extraction area.

59. Within three (3) months of the completion of the post-extraction monitoring programme, the Consent Holder shall, following consultation with the TRG, prepare and lodge with the EPA, a Final Post-extraction Monitoring Report that includes as a minimum:

a. A summary of all of the monitoring undertaken in the previous four (4) year period;
b. A summary report of the findings of the monitoring undertaken, including a comparison against all the relevant environmental limits specified in the conditions of these consents, and conclusions drawn as to the recovery and overall biological heath of the seabed material extraction area; and
c. Identification of any commentary or recommendations from the TRG and, where necessary, an explanation as to why any TRG recommendation has not been accepted.

Laboratory Accreditation

60. All laboratory based analyses undertaken in conjunction with the requirements of these consents shall be performed by an IANZ accredited laboratory or, where applicable, any other accredited laboratory.

TECHNICAL REVIEW GROUP

61. At least six (6) months prior to the commencement of the PCEMP required by Condition 48, the Consent Holder shall provide for the formation of a TRG, the role of which is to provide technical advice to the Consent Holder, including but not limited to the following:

a. Prior to their lodgement with the EPA, review and advise on the appropriateness of the monitoring provided for in the PCEMP and EMMP (Conditions 48 and 55), and any review of the PCEMP and EMMP (Conditions 49 and 56);
b. Compare the monitoring data against the pre-commencement data in order to assist in determining if any activities authorised by these consents have resulted in adverse effects on the marine environment that were not anticipated at the time of the granting;
c. Consider and make recommendations on the need for any new parameter to be monitored in accordance with Conditions 54 and 55;
d. Community knowledge and “mātauranga māori” issues when reviewing the monitoring data;
e. The environmental management component of the seabed material extraction activities authorised by these consents, by an annual data review whereby each year’s monitoring results will be tabulated, reviewed, and compared against the previous monitoring data collected; and

f. Make recommendations to the Consent Holder that it recommends to the EPA that a review of the consent conditions in accordance with Condition 106 of these consents be instigated for the purpose of dealing with any adverse effects on the environment which may arise from the exercise of these consents and which it is appropriate to deal with at a later stage.

The Consent Holder shall invite the following parties to nominate one suitably qualified and experienced representative to be involved in the TRG:

g. The Consent Holder;

h. Taranaki Regional Council;

i. Fisheries Inshore New Zealand;

j. The Kaitiakitanga Reference Group (Condition 73);

k. Te Tai Hauāuru Regional Fishing Forum;

l. The Department of Conservation; and

m. The Kupe Operator.

Each representative shall have specialist expertise in one or more of the key environmental, ecosystem, mātauranga māori (Māori traditional knowledge) and engineering components being monitored.

In the event that a Kaitiakitanga Reference Group, as specified in Condition 73, is not formed the Consent Holder is not required to extend an invitation to any alternative party. (refer to the Advice Note below)

In the event that Fisheries Inshore New Zealand do not accept the invitation to nominate a representative, the Consent Holder shall invite Sanford Limited to do so.

At any time during the term of these consents, any party who appoints a representative to the TRG may change that representative on the basis that any new representative also has the relevant qualifications and experience.

At any time during the term of these consents, including if any party is not able, for whatever reason, to provide a representative to the TRG, the TRG may recommend to the Consent Holder that other suitably qualified and experienced specialists be seconded, or technical studies be commissioned for the proper exercise of the TRG functions. The decision on whether to act on such a recommendation will rest with the Consent Holder after consultation with the EPA, however the Consent Holder shall ensure that the TRG always has a membership which includes specialist expertise in all of these specified fields.

Advice Note: The Consent Holder is still required to comply with Condition 80.

62. The Consent Holder shall maintain the TRG for the duration of these consents, and beyond as necessary, to provide for the review and commentary on any post-extraction monitoring undertaken in accordance with these consents.

63. The Consent Holder shall convene meetings of the TRG:

   a. Annually, following the completion of each year of monitoring, during the pre-commencement environmental monitoring period;
   b. Then, for the first five (5) years following the commencement of the seabed material extraction activities authorised by these consents, on a quarterly basis (during the months of January, April, July and October of each year) with one meeting to occur following completion of each annual monitoring period;
   c. Then annually, following completion of each annual monitoring period, for the duration of these consents;
   d. Then annually, following the completion of each annual post-extraction monitoring period; and
   e. At any other time requested by the Consent Holder.

   For the purpose of this condition, the 'annual monitoring period' is the twelve (12) month period commencing in the month in which the pre-commencement environmental monitoring or the operational environmental monitoring commenced. Further, the 'annual post-extraction monitoring period' is the twelve (12) month period commencing in the month following the month that the seabed material extraction activities authorised by these consents ceased.

64. The Consent Holder shall fund the administration of each meeting of the TRG and shall meet all actual and reasonable costs incurred by any other specialists seconded to the TRG, as provided for in Condition 61.

65. Minutes of each of the TRG meetings, including the identification of any disagreements between the TRG members and any recommendations provided by the TRG to the Consent Holder, shall be taken and forwarded to its members, the Consent Holder, the Kaitiakitanga Reference Group, and the EPA, and provided on the Consent Holder's website (Condition 81), within ten (10) working days of any meeting being held.

   Minutes of each meeting shall also be summarised in the Annual Report required by Condition 104.

MANAGEMENT PLANS

Seabird Effects Mitigation and Management Plan

66. The Consent Holder shall prepare a Seabird Effects Mitigation and Management Plan ("SEMMP") that has been prepared following consultation with the Department of Conservation and the KRG (if it has been formed), which shall, as a minimum:

   a. Set out how compliance with Condition 9 will be achieved;
   b. Set out indicators of adverse effects at a population level of seabird species that utilise the South Taranaki Bight due to mortality or injury of seabirds of the species classified under the New Zealand Conservation Status as "Nationally Endangered", "Nationally Critical" or "Nationally

Vulnerable" or classified "Endangered" or "Vulnerable" in the International Union for the Conservation of Nature "Red List";

c. Identify responses / actions to be undertaken by the Consent Holder if the indicators in (b) are reached; and
d. Outline any monitoring requirements for bird strike due to vessel lighting and, where necessary, provide for procedures to alter vessel lighting and vessel operations to reduce the incidence of bird strike.

The SEMMP shall be prepared by a suitably qualified and experienced person(s) in general accordance with the draft SEMMP dated August 2016, and submitted to the EPA for certification that the requirements of this condition have been met.

No seabed material extraction shall commence until the SEMMP has been certified by the EPA.

The Consent Holder may amend the SEMMP at any time provided such amendments have been prepared in consultation with the Department of Conservation, such amendments are consistent with the purpose of this condition.

Any amendments to the SEMMP shall be submitted to the EPA for certification and shall only be implemented following confirmation from the EPA that the amended SEMMP meets the requirements of this condition. Where certification of an amended plan is not received, the Consent Holder shall continue to use the plan which was in place prior to the lodgement of the amended plan.

The activities authorised by these consents shall be undertaken in accordance with the latest certified SEMMP.

A copy of the certified SEMMP, or any subsequently certified amendment, shall be held on-board each of the Consent Holder's project vessels and at the Consent Holder's head office.

Marine Mammal Management Plan

67. The Consent Holder shall prepare a Marine Mammal Management Plan ("MMMP") following consultation with the Department of Conservation and the KRG (if it has been formed), which shall, as a minimum, set out:

a. How compliance with Condition 10 will be achieved; and
b. Procedures and protocols to minimise the risk of whale and dolphin entanglement; and
c. Set out indicators of adverse effects at a population level of marine mammals that utilise the South Taranaki Bight listed in Condition 10.a.; and
d. A training framework relating to marine mammal operational responses; and

Integrate any obligations under the Marine Mammals Protection Act 1978 and Marine Mammals Protection Regulations 1992, or any superseding legislation.

The MMMP shall be prepared by a suitably qualified and experienced person(s) in general accordance with the draft MMMP dated August 2016, and submitted to the EPA for certification that the requirements of this condition have been met.

No seabed material extraction shall commence until the MMMP has been certified by the EPA.

Any amendments to the MMMP shall be submitted to the EPA for certification, and shall only be implemented following confirmation from the EPA that the amended MMMP meets the requirements of this condition. Where certification of an amended plan is not received, the Consent Holder shall continue to use the plan which was in place prior to the lodgement of the amended plan.

The activities authorised by these consents shall be undertaken in accordance with the latest certified MMMP. A copy of the latest MMMP shall be held on-board each of the Consent Holder’s project vessels and at the Consent Holder’s held office.

Collision (Loss of Position) Contingency Management Plan

68. The Consent Holder shall prepare a Collision (Loss of Position) Contingency Management Plan (“CCMP”) following consultation with the Kupe Operator.

The purpose of the CCMP is to demonstrate how the objectives set out below will be achieved and to outline the specific operating procedures to be implemented during the seabed material extraction operations. The CCMP shall, as a minimum, identify the following:

a. How compliance with Conditions 31 and 33 will be achieved;
b. The processes, methods, procedures and responses to be implemented after any unplanned / emergency event that potentially results in mooring failure or loss of position;
c. The measures which will be taken to avoid, remedy or mitigate any adverse environmental effects or effects on existing interests such as the infrastructure and operations of the licensee of Petroleum Mining License #38146;
d. How the IMV will be operated to ‘sit out’ severe environmental conditions such that the risk of collision between the Consent Holder's assets and the Kupe assets is as low as reasonably practicable;
e. The emergency procedures to be implemented in the event of a mooring failure / loss of station-keeping by the IMV;
f. The protective measures / procedures proposed should any aspect of the thruster system, and its associated systems, be rendered out of service by accident or planned maintenance, such that they are immediately available in the event of a mooring leg failure;
g. The procedure for ensuring that, when the IMV is operating in any position where a station keeping failure may result in a potential collision of the IMV or its dragged mooring system with the Kupe assets, the thruster system be fully operational and active to enable immediate control of the IMV in the event of an incident. This shall include having such power generation capacity on line at these times;

h. The procedures for the recovery and setting of the IMV anchors such that the required anchor holding capacity is achieved including an operability assessment assessing the likelihood that an anchor handling operation cannot be completed due to a fast rising storm;
i. The measures to address the reduced station keeping integrity of the mooring whilst recovering, running and re-setting anchors;
j. The planned inspection regime for the safety critical TAM systems including the discard criteria for the mooring wires;
k. The detailed emergency response procedure (including communication requirements and notification periods) addressing incidents such as mooring leg failure, loss of heading control, thruster drive off, and disablement of thruster system. The response must address the risk of collision between the Consent Holder's assets and the Kupe assets to ensure the risk is 'As Low As Reasonably Practicable';
l. The procedure for recovering and resetting of the mooring line and anchor buffer zone with regard to the requirements for the Anchor Handling Tug to recover and set anchors; and
m. The joint operating procedures for the trans-shipment of ore between the IMV and the Floating Storage and Off-loading Vessel.

All operational procedures shall be developed to reflect the safe operating requirements outlined in the final version of the CCMP with clear descriptions on when each procedure is applicable (i.e. normal operations, or under emergency trigger conditions).

The CCMP shall be prepared by a suitably qualified and experienced person(s) and submitted to the EPA for certification that the requirements of this condition have been met.

Prior to being finalised, the CCMP shall be independently reviewed by a suitably qualified and internationally recognised person or body. The review shall confirm that the CCMP is fit for purpose and demonstrates that the objectives above will be achieved, including sufficient detail as to the operating procedures required to achieve them. The recommendations of the review shall be incorporated into the final version of the CCMP.

No seabed material extraction shall commence until the CCMP has been certified by the EPA.

The Consent Holder may amend the CCMP at any time during the term of these consents following consultation with the Kupe Operator. At the Kupe Operator's request, the proposed amendments to the CCMP shall be subject to a further independent peer review. The Consent Holder shall consult with the Kupe Operator on the recommendations of that peer review prior to them being incorporated into the final amendments to the CCMP that are lodged with the EPA.

Any changes to the CCMP will only come into effect once consultation with the Kupe Operator has occurred and any such amendment is consistent with the purpose of these conditions. A copy of the CCMP shall be held on all operational vessels and at the Consent Holder's head office and shall be provided to the EPA and the Kupe Operator upon request.

The reviewer shall be mutually agreed between the Consent Holder and the Kupe Operator. In the event that the Consent Holder and the Kupe Operator cannot reach agreement, each party shall recommend one suitably qualified independent reviewer to the Chief Executive of the EPA who will decide on the reviewer to be appointed from the two recommendations. The costs of the review will be met by the Consent Holder.

Simultaneous Operations Plan

69. The Consent Holder shall prepare a Simultaneous Operations Plan (“SIMOPP”) in accordance with the requirements of IMCA M 203 Guidance on Simultaneous Operations (SIMOPS) following consultation with the Kupe Operator.

The purpose of the SIMOPP is to:

a. Define the procedures to be followed when two or more vessels are operating in the same general area and in close proximity to each other;
b. Outline the consultation framework under which the Kupe Operator may provide input into the Consent Holder’s design and execution of the mining operations;
c. Identify how the Consent Holder will operate within the guidelines as specified in IMCA M 203, Guidelines on Simultaneous Operations; and
d. Identify how the operations of both the Consent Holder and the Kupe Operator within the area of Petroleum Mining Licence #38146 will be conducted for the duration of the seabed material extraction operations.

The SIMOPP shall, as a minimum, set out:

(a) How mining operations will be managed in the event that a ‘Jack-up Drill Rig’ is being moved into position or temporarily moored adjacent to the Kupe platform prior to spudding in or jacking down of a rig;

(b) How the Consent Holder shall confer with the Kupe Operator regarding the sequence of blocks of areas to be mined to ensure that any proposed pipeline corridor or location for a ‘Jack -up Drill Rig’ has time to consolidate, based on the geotechnical data relevant to that block.

(c) How the Consent Holder shall confer with the Kupe Operator with regards to the planning of maintenance activities undertaken by the Kupe Operator on the Kupe assets.

Prior to being finalised, the SIMOPP shall be independently reviewed by a suitably qualified and internationally recognised person or body. The review shall confirm that the SIMOPP is fit for purpose, and identifies how the Consent Holder will operate within the guidelines as specified in IMCA M 203, Guidelines on Simultaneous Operations. The recommendations of that review shall be incorporated into the SIMOPP.

The SIMOPP shall be finalised and provided to the EPA and the Kupe Operator at least three (3) months prior to the commencement of any seabed material extraction activities authorised by these consents.

The SIMOPP may be amended at any time during the term of these consents following consultation with the Kupe Operator. At the Kupe Operator's request, proposed amendments to the SIMOPP shall be subject to a further independent peer review. The recommendations of that review shall be incorporated into the SIMOPP.

The Consent Holder shall ensure that the EPA has a copy of the most update version of the SIMOPP at all times, and shall provide a copy to the Kupe Operator upon request.

The reviewer shall be mutually agreed between the Consent Holder and the Kupe Operator. In the event that the Consent Holder and the Kupe Operator cannot reach agreement, each party shall recommend one suitably qualified independent reviewer to the Chief Executive of the EPA who will decide on the reviewer to be appointed from the two recommendations.

Biosecurity Management Plan

70. The Consent Holder shall, following consultation with the Ministry for Primary Industries and a nominated representative from Aquaculture New Zealand, prepare, a Biosecurity Management Plan (“BMP”) which shall, as a minimum, contain or require the following:

a. For overseas vessels, describe the ‘acceptable measures’ for biofouling management that will be implemented to meet the ‘Clean Hull’ requirement of the CRMS, or demonstrate an equivalent level of risk;

b. For all vessels, both overseas and domestic, prepare a vessel-specific ‘Biofouling Management Plan’, in accordance with the International Marine Organization 2011 ‘Guidelines for the Control and Management of Ships' Biofouling to Minimise the Transfer of Invasive Aquatic Species’ (“the IMO Guidelines”), or any subsequent version thereof. The Biofouling Management Plan shall include or require the following:

   i. Details of the anti-fouling systems and operational practices or treatments to be used, including those for niche areas (e.g. ‘sea chests’);

   ii. Identification of hull locations susceptible to biofouling, and a schedule of planned inspections, repairs, maintenance and renewal of anti-fouling systems;

   iii. Details of the recommended operating conditions suitable for the chosen anti-fouling systems and operational practices;

   iv. Other relevant details as described in Appendices 1 and 2 of the IMO Guidelines, including maintenance of a ‘Biofouling Record Book’, which records details of all inspections and biofouling management measures undertaken on the vessel;

c. For overseas vessels that are to be permanently located in the vicinity of the project area, the BMP shall consider additional special measures that can be implemented to minimise biosecurity risk. These could include, but are not limited to, any of the following:

i. Using new-build vessels that have appropriate anti-fouling systems;
ii. Minimising the time vessels spend idle in water before departure from the overseas source port, in order to minimise the risk of colonisation by biofouling organisms;
iii. Ensuring appropriate measures are in place for sources of risk in addition to biofouling, such as cleaning and removal of sediment; and
iv. Acquiring vessels from regions that are not 'climatically matched' to the project area, in order to further mitigate any residual risk.

The BMP shall be prepared by a suitably qualified and experienced person(s) and submitted to the EPA for that the requirements of this condition have been met.

No seabed material extraction shall commence until the BMP has been certified by the EPA.

The Consent Holder may amend the BMP at any time provided such amendments have been prepared in consultation with the Ministry for Primary Industries and a nominated representative from Aquaculture New Zealand, and the changes are consistent with the purposes of this condition.

The BMP shall be updated as necessary to reflect the most up-to-date marine standards and guidelines, and any amendments to the BMP shall be submitted to the EPA for certification, and shall only be implemented following confirmation from the EPA that the amended BMP meets the requirements of this condition. Where certification for an amended plan is not received, the Consent Holder shall continue to use the plan which was in place prior to the lodgement of the amended plan.

The activities authorised by these consents shall be undertaken in accordance with the latest BMP. A copy of the latest BMP shall be held on-board each of the Consent Holder's project vessels and at the Consent Holder's head office.

Safety Case

71. The Consent Holder shall, following consultation with WorkSafe New Zealand, prepare a Safety Case which shall, as a minimum identify:

a. What the major hazards are associated with the activities authorised by these consents, from a safety and environmental perspective; and
b. What control measures are necessary to prevent harm arising from these hazards; and
c. The standards that such control measures would need to meet.

The Safety Case shall include the matters set out in Appendix 1 and Appendix 2 attached to WorkSafe New Zealand's letter to the EPA dated 2 May 2017 presented during the hearing process.

The Safety Case shall be prepared by a suitably qualified and experienced person(s). The Safety Case shall then be independently peer reviewed by a suitably qualified and experienced person(s) to ensure that the requirements of this condition have been met before it is submitted to the EPA.

No seabed material extraction shall commence until the independently reviewed Safety Case has been submitted to the EPA.

The Consent Holder may amend the Safety Case at any time provided such amendments have been prepared in consultation with WorkSafe New Zealand, and any changes are consistent with purposes of this condition.

The activities authorised by these consents shall be undertaken in accordance with the latest Safety Case and a copy of the latest Safety Case shall be held on-board each of the Consent Holder's project vessels and at the Consent Holder's head office, and provided to the EPA upon request.

RELATIONSHIP WITH TANGATA WHENUA

Advice Note: To the extent that any of conditions 72 – 85 are ultra vires, they have been proffered by the Consent Holder on an Augier basis.

Advice Note: Notwithstanding Conditions 72 and 79, the Consent Holder acknowledges the relationship of tangata whenua, including but not limited to Ngāti Ruanui, Ngaa Rauru and Ngāruahine, with the South Taranaki Bight, and undertakes to use its best endeavours to facilitate engagement with tangata whenua during the term of these consents.

72. The relationship of tangata whenua, including but not limited to Ngāti Ruanui, Ngā Rauru Kītahi and Ngāruahine, with the South Taranaki Bight shall be recognised and provided for by the Consent Holder through:

    a. Provision for the establishment and maintenance of a Kaitiakitanga Reference Group (Condition 73);
    b. Provisions for involvement of the Kaitiakitanga Reference Group, in accordance with their defined role, in:
        i. The TRG (Condition 61); and
        ii. The Kaimoana Monitoring Programme (Condition 77).

73. Within twenty (20) working days of the commencement of these consents, the Consent Holder shall provide to tangata whenua, including but not limited to Ngāti Ruanui, Ngā Rauru Kītahi and Ngāruahine, a written offer to establish and maintain a Kaitiakitanga Reference Group, the purpose of which is to:

    a. Recognise the kaitiakitanga of tangata whenua, including but not limited to Ngāti Ruanui, Ngā Rauru Kītahi and Ngāruahine, and their relationship with the South Taranaki Bight;
    b. Review and advise the Consent Holder on the suitability of the Kaimoana Monitoring Programme (Condition 77);
    c. Provide for the on-going involvement of tangata whenua, who have a relationship with the South Taranaki Bight as kaitiaki, in monitoring the effects of the activities authorised by these consents, including a process for considering any future change to the membership of the Kaitiakitanga Reference Group;
    d. Provide for kaitiaki responsibilities and values to be reflected in the monitoring of the seabed material extraction area and of the surrounding marine environment undertaken under these consents, including:

i. To advise the Consent Holder on monitoring for changes to risk, or threat to, the cultural values of the South Taranaki Bight;
ii. To evaluate the data obtained from physical monitoring insofar as it relates to the cultural values of the South Taranaki Bight and the effects on those values from the seabed material extraction and, in the event that changes to effects are identified, advise the Consent Holder on possible monitoring or operational responses;
iii. To advise the Consent Holder on the appropriateness of any operational responses as they relate to cultural values, proposed by others;
iv. To provide a means of liaison between tangata whenua, including but not limited to Ngāti Ruanui, Ngā Rauru Kītahi and Ngāruahine, and the Consent Holder through providing a forum for discussion about the implementation of these consents; and

Be responsible for receiving requests for, and facilitating the provision of, any cultural ceremonies by tangata whenua, including but not limited to Ngāti Ruanui, Ngā Rauru Kītahi, Ngāruahine, and other tangata whenua groups who have a relationship with the South Taranaki Bight.

Advice note: The Consent Holder records its commitment to implementing this condition in good faith and to using the services of an independent mediator, as necessary, in doing so.

74. Once the Kaitiakitanga Reference Group is formed, the Consent Holder shall provide details of its membership, and any subsequent changes, to the EPA.

75. The Consent Holder shall:

a. Be entitled to appoint one member of the Kaitiakitanga Reference Group.
b. Facilitate and fund the administration of each formal meeting of the Kaitiakitanga Reference Group. The first Kaitiakitanga Reference Group meeting shall convene within three (3) months of the formation of the Kaitiakitanga Reference Group. As a minimum, meetings shall be held at a sufficient frequency to ensure that the obligations of the Kaitiakitanga Reference Group are met, but in any event, shall not be less than one time per year.
c. Take minutes of the Kaitiakitanga Reference Group meetings, which shall be forwarded to members and the EPA, within twenty (20) working days of each meeting being held.
d. Give members at least twenty (20) working days' notice of the date, time and location of the next Kaitiakitanga Reference Group meeting.
e. Ensure that, where appropriate, the agreed outcomes from the Kaitiakitanga Reference Group meetings are available to other tangata whenua groups and the wider public.

76. The Consent Holder shall meet the actual and reasonable costs incurred by the Kaitiakitanga Reference Group for providing the services required of it by these consents, subject to normal business practice of invoicing and accounting.

77. At least (20) working days prior to the commencement of any seabed material extraction activities authorised by these consents, the Consent Holder shall prepare, and implement, a Kaimoana

Monitoring Programme following consultation with the Kaitiakitanga Reference Group if this group has been established.

The objective of the Kaimoana Monitoring Programme is to provide for the monitoring of species important to customary needs, including from customary fishing grounds around the site, of Māori who have a relationship to the site and shall identify as a minimum:

a. The roles and responsibilities of parties who are to conduct the kaimoana monitoring;
b. The methodology to be employed in the kaimoana monitoring, including to minimise the risks to health and safety, and the environment;
c. The kaimoana indicators to be monitored and any thresholds for desired actions that may arise from monitoring as a result of effects from the activities authorised by these consents;
d. Any components of the EMMP that provide information on the kaimoana values and indicators; and
e. A reporting mechanism for results of the kaimoana monitoring to the Consent Holder, who shall provide them to the EPA.

The Kaimoana Monitoring Programme may be amended at any time during the term of these consents. Any proposed changes to the Kaimoana Monitoring Programme shall be prepared by the Consent Holder following consultation with the Kaitiakitanga Reference Group if this group has been established.

The Consent Holder shall ensure that the EPA has a copy of the most update version of the Kaimoana Monitoring Programme at all times.

78. The Consent Holder shall use its best endeavours to engage tangata whenua representatives, including but not limited to Ngāti Ruanui, Ngā Rauru Kītahi, Ngāruahine and Te Tai Hauāuru Regional Fishing Forum representatives, to undertake the monitoring identified in the Kaimoana Monitoring Programme (Condition 77).

The Consent Holder shall meet the actual and reasonable costs of implementing the Kaimoana Monitoring Programme subject to the receipt of itemised invoices.

Advice Note: The Consent Holder records its willingness to work collaboratively with tangata whenua, including Ngāti Ruanui, Ngā Rauru Kītahi and Ngāruahine, and to assist them financially in undertaking environmental initiatives or other initiatives that advance their cultural well-being.

79. In the event that a Kaitiakitanga Reference Group has not been established twelve (12) months following the date of the offer made by the Consent Holder required by Condition 73, and the Consent Holder has demonstrated, to the satisfaction of the EPA, that it has acted in good faith, the Consent Holder shall have no further obligation under Conditions 73 - 76.

For the avoidance of doubt, The Consent Holder shall still comply with Conditions 77 and 78 in the event that the Kaitiakitanga Reference Group has not been established.

80. In addition to Condition 79, in the event that that a Kaitiakitanga Reference Group has not been established twelve (12) months following the date of the offer made by the Consent Holder required by Condition 73, the Consent Holder shall, at least once every twelve (12) months, inform and seek to engage with relevant iwi entities on the general scope of the planned activities authorised by these consents. The Consent Holder shall keep a record of how it has complied with this condition and make this information available to the EPA upon request.

Advice Note: The Consent Holder should seek advice from the EPA as to who the relevant iwi entities are. The Consent Holder is also encouraged to use this opportunity to investigate the involvement of the relevant iwi entities, as kaitiaki, in environmental management practices and the development of environmental indicators using both mātauranga Māori and western science.

COMMUNITY RELATIONSHIPS

81. The Consent Holder shall provide the public with up to date information on the seabed material extraction activities authorised by these consents and environmental monitoring, including the pre-commencement environmental monitoring, undertaken in accordance with the conditions of these consents.

The information shall be made available through a website maintained by the Consent Holder for the duration of these consents.

The Consent Holder shall advise the EPA of the website address within five (5) working days of it going live.

82. For the duration of these consents, the Consent Holder shall provide for and facilitate community meetings to keep the public informed of the seabed material extraction activities authorised by these consents and any recent monitoring results and/or actions, or other matters that may be of interest to the public.

The community meetings shall be held six (6) monthly (during the months of February and July of each year) for the first five (5) years of the seabed material extraction activities authorised by these consents and annually at all other times.

At least twenty (20) working days prior to the date of any community meeting, notice shall be placed on the Consent Holder's website (Condition 81) and by way of advertisements in the regional newspapers, including the Taranaki Daily News, the South Taranaki Star and the Wanganui Chronicle, and on local radio stations. Notice shall include the date, time and location of the meeting and contact details of the meeting facilitator.

The Consent Holder shall keep a record of the details of each community meeting, including details of the notification mechanisms used for each meeting. A copy of these records shall be provided to the EPA upon request.

83. Following the commencement of seabed material extraction activities, the Consent Holder shall provide an annual fund of $50,000 per year to be administered by the South Taranaki District Council in collaboration with the Consent Holder. The annual fund shall be inflation adjusted.

    The purpose of the fund is to assist in the establishment of projects for the benefit of the South Taranaki community, in particular for the social and economic wellbeing of the community.

    The Consent Holder shall keep records of the annual contributions and provide a copy of these to the EPA upon request.

84. Within twelve (12) months of the commencement of the construction of the IMV associated with the activities authorised by these consents, the Consent Holder shall establish and maintain a training facility located in the township of Hawera.

    The purpose of the training facility is to provide technical and marine skills based training to prospective trainee process operators and maintenance support staff from the South Taranaki communities who then can be employed by the Consent Holder as part of the seabed material extraction activities authorised by these consents.

    In establishing the training facility, the Consent Holder shall consult with the Hawera business community, local iwi, South Taranaki District Council and Accredited Education providers to ensure that the purpose of the training facility is being met.

    The Consent Holder shall keep records of the consultation required by this condition and provide a copy of these to the EPA upon request.

    Advice note: The Consent Holder has confirmed that it will, where practicable, offer training positions to members of local iwi and the community.

85. Prior to the commencement of any seabed material extraction activities authorised by these consents, the Consent Holder shall establish and maintain a geotechnical and environmental monitoring base located in the port of Whanganui.

    The purpose of the base is to support the seabed material extraction activities authorised by these consents by providing, as a minimum:

    a. A permanent berthing site for a vessel;
    b. A secure laydown area;
    c. A storage area and warehouse;
    d. An operation and maintenance workshop;
    e. Administration offices; and
    f. Scientific Laboratory.

    The Consent Holder shall provide written confirmation to the EPA that the base has been established.

    Advice note: The Consent Holder is committed to employing suitably qualified and experienced local residents at the base.

Advice note: The Consent Holder is committed to acquiring any additional consents required to enable the construction and operation of the Support Base. Construction of the base and associated berthing site will occur subject to any such consents being granted

FISHING INDUSTRY RELATIONSHIP

86. The Consent Holder shall provide for six (6) monthly meetings between itself and representatives of the commercial fishing industry including any representatives nominated by Fisheries Inshore New Zealand. The purpose of the meetings shall be to enable parties to share relevant information and to establish a coordinated approach between the seabed material extraction activities authorised by these consents and commercial fishing activities, including communications protocols.

The first meeting shall occur no later than six (6) months prior to the commencement of the seabed material extraction activities authorised by these consents.

The Consent Holder shall:

a. Facilitate and fund the administration of each formal meeting; and
b. Take minutes of each meeting, which shall be forwarded to attendees, within twenty (20) working days of each meeting being held. The minutes shall be included in the Annual Report required by Condition 104.

OPERATIONAL DOCUMENTATION

Operational Assessment Report

87. No less than three (3) months prior to the commencement of any seabed material extraction activities authorised by these consents, and every twelve (12) months thereafter the Consent Holder shall prepare, and provide to the EPA, an Operational Assessment Report which shall include but not be limited to:

a. An outline of the area where removal of seabed material, targeting the extractable resource of titanomagnetite seabed material, will take place during the next twelve (12) month period, and the timing thereof;
b. Bathymetry of the seabed in the area where removal of seabed material is planned;
c. Bathymetry of the pits and mounds created during the extraction and deposition of sediments;
d. Extraction plan schedules;
e. Identification of the occurrence of fine sediments (<8 µm) in the area subject to extraction via grade control drilling conducted in accordance with the requirements for a ‘Measured Mineral Resource’ by “The Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves, 2012 or subsequent editions (the “JORC” code). The Operational Assessment Report is to demonstrate how compliance with Condition 4 has been achieved; and
f. Procedures for avoiding identified fine sediments to the extent necessary to meet the requirements of Conditions 4, 5 and 7.

Where extraction activities within the following twelve (12)-month period will occur within the area of Petroleum Mining Licence #38146, the Consent Holder shall also provide the Kupe Operator with a copy of the Operational Assessment Report at the same time the report is provided to the EPA.

Training of Personnel

88. Pursuant to section 25(1)(b)(i) of the EEZ Act, the Consent Holder shall ensure that all personnel on-board project related vessels receive the appropriate training prior to taking part in any duties related to any activities authorised by these consents.

    Training shall be appropriate to ensure compliance with the conditions of these consents is achieved, including but not limited to training on:

    a. The Consent Holder's obligations under these consent conditions, including any obligations under the EMMP and associated management plans;
    b. Their responsibilities under any condition, the EMMP or management plan and how to meet those responsibilities; and
    c. Their obligations under the Marine Mammals Protection Act 1978 and Marine Mammals Protection Regulations 1992, or any superseding legislation.

    A record of all training carried out in accordance with this condition shall be maintained by the Consent Holder and made available to the EPA upon request.

Complaints Register

89. The Consent Holder shall maintain a permanent register of any complaints received by any person or company about activities authorised by these consents.

    The register shall include:

    a. The contact details of the complainant, including the name and address of the complainant;
    b. The nature of the complaint, and the time which it was received;
    c. The location, date and time of the complaint and of the event associated with the complaint;
    d. The cause or likely cause of the event and any factors, such as weather conditions (including wind direction and approximate wind speed, the real-time New Zealand Met Service forecast for the seabed material extraction area and any forecast warning for the area and the presence of precipitation, fog or any other weather related impact on visibility), that may have influenced its severity;
    e. The outcome of any investigation into the complaint, including the nature and timing of any measures implemented by the Consent Holder to remedy or mitigate any adverse effects, if associated with the event;
    f. Details of any steps taken to prevent the reoccurrence of similar events; and g. Any other relevant information.

This register shall be held in the form of a Complaints Log at the Consent Holder's head office and should be made available to the EPA upon request.

The Log shall be updated within forty eight (48) hours following the receipt of any new complaint and should also be included as part of the Quarterly Operational Report required by Condition 103.

MARINE SAFETY MATTERS

90. The Consent Holder shall ensure that the design and construction of the IMV complies with 'best practice' international marine standards and, as a minimum, shall include:

    a. A thruster assisted mooring system that meets the requirements of America Bureau of Shipping ("ABS") ✠TAM-R notation with the system built, installed and commissioned to the satisfaction of ABS Survey;
    b. A thruster system, including power, distribution, control and position reference systems that meet the redundancy requirement of ABS DPS-2 with the system built, installed and commissioned to the satisfaction of ABS Survey. Additionally, a Failure Modes, Effects, and Criticality Analysis ("FMECA") of the system shall be completed as an extension of the FMEA process required by class for achieving many of the special or optional Classification notations ACC, ACCU and DPS-2. (Ref: ABS GUIDANCE NOTES ON FAILURE MODE AND EFFECTS ANALYSIS (FMEA) FOR CLASSIFICATION. 2015);
    c. Compliance with the ABS notation for Station Keeping Performance ("SKP") for the specified limiting environmental conditions in the South Taranaki Bight;
    d. A mooring system that complies with the design requirements for a permanent mooring system as specified in API 2SK, and that clearly defines the system's mode of operation, including its normal operating condition limits and performance in severe environmental conditions (including its proposed return period); and
    e. Incorporation of an operational vessel motion monitoring and forecasting software system.

    The Consent Holder shall provide documentation to the EPA which confirms that the IMV complies with all the requirements of this condition.

91. Prior to the IMV being used in the seabed material extraction operations, the IMV's mooring design shall be independently reviewed, in a technical capacity, by a suitably qualified and internationally recognised person or body. The review shall confirm that the IMV mooring is fit for purpose and complies with 'best practice' international marine standards and the standards specified in Condition 90 above. The review shall also:

    a. Confirm that approval from ABS for the IMV mooring concept has been provided;
    b. Consider the final mooring and thruster design assessment and confirm it is appropriate for the intended operational purposes (including in relation to proximity to the first de-ored sediment mound);

c. Confirm that the thruster capacity is adequate to maintain the IMV position/heading in the event of a mooring failure;
d. Confirm that the operational (limit) environmental conditions specified for the IMV are appropriate for / consistent with the mooring system design.
e. Confirm that the location and design of the fairleads on the IMV are capable of accommodating the large changes expected in departure angle without the mooring rope clashing with deck structures or the articulation limits of the fairleads; and
f. Confirm the operation of the TAM system and the segregation of thruster power supply, control and distribution from that required for mining operations is fit for purpose.

The recommendations of the review shall be incorporated into the final design of the IMV mooring system.

The Consent Holder shall provide documentation to the EPA which confirms that the IMV's mooring design complies with the requirements of this condition.

The independent reviewer shall be mutually agreed between the Consent Holder and the Kupe Operator. In the event that the Consent Holder and the Kupe Operator cannot reach agreement, each party shall recommend one a suitably qualified independent reviewer to the Chief Executive of the EPA who will decide on the reviewer to be appointed from the two recommendations. The costs of the review will be met by the Consent Holder.

92. Annually, on the anniversary of the commencement of the seabed material extraction operations, or where notice is received from the Kupe Operator providing confirmation of a commitment to deploy a 'Jack-up Drill Rig' within the Project Area identified in Schedule 1, the Consent Holder shall prepare a Geotechnical Report for the previous twelve (12) months seabed material extraction activities authorised by these consents for the identified location (where confirmation of a commitment to deploy has been received in accordance with this condition).

Each Geotechnical Report shall report on the geotechnical properties of the backfilled mining lanes and include, as a minimum, the following information:

a. A detailed explanation of the geotechnical investigations undertaken, including the location of the investigations and the methodology undertaken, for the previous 12 month period;
b. All of the data / results from the geotechnical investigations including but not limited to:
    i. Particle / grain size distribution;
    ii. In-situ bulk density; and
    iii. Cone penetrometer or shear strength value.
c. A summary of the findings from the geotechnical investigations and the properties of the seabed investigated.

The Consent Holder shall provide each Geotechnical Report to the Kupe Operator within three (3) months of the completion of the annual geotechnical investigations or within six (6) months of the receipt by the Consent Holder of notice from the Kupe Operator providing the confirmation above. The Geotechnical Report shall be made available to the EPA upon request.

93. Annually, and within twenty (20) working days after each anniversary of the commencement of the seabed material extraction operations, the Consent Holder shall undertake an assessment of the impact of de-ored sediment discharges on the cathodic protection systems associated with the Integrated Mining Vessel's safety critical systems.

    The Consent Holder shall provide a copy of its assessment report to the Kupe Operator within twenty (20) working days of the completion of the assessment outlined above and will make the report available to the EPA upon request.

94. Following the completion of the pre-commencement environmental monitoring required by Condition 48, the Consent Holder shall commission an assessment of the visibility limits at the Kupe Platform and at the inshore border of the Project Area identified in Schedule 1.

    The results of this assessment shall be provided to the Kupe Operator within twenty (20) working days of its completion and make the assessment available to the EPA upon request.

95. The Consent Holder shall install and have operational, a Barge Management System for all of its vessels operating within the area of Petroleum Mining Licence #38146.

    A display from the Barge Management System shall be made available to the Kupe Operator's control room for the Kupe assets at all times.

96. The Consent Holder shall ensure that no iron ore transhipments take place when any aspect of the thruster or mooring system of the IMV or the Floating Storage and Off-loading vessel is inoperative due to maintenance or failure.

97. The Consent Holder shall ensure that activities within the 'Kupe Platform Safety Zone' do not occur without prior approval in accordance with the requirements of the SIMOPP (Condition 69). Approval under this condition is not required during an emergency situation.

    The Consent Holder shall keep records of any related correspondence with the Kupe Operator and these records shall be made available to the EPA upon request.

98. The Consent Holder shall undertake bathymetric surveys annually around the boundaries of the Kupe Operator's exclusion zones (existing or future), and representative points around the Kupe Well Head Platform and along the pipeline and umbilical route, to determine any migration of the mound and pit bathymetry. Access by the Consent Holder to representative points around the Kupe Well Head Platform and pipeline and umbilical route will be agreed with the Kupe Operator in advance in accordance with the SIMOPP (Condition 69).

    The Consent Holder shall supply results of these surveys to the Kupe Operator within twenty (20) days of their completion and provide the results to the EPA upon request.

99. The Consent Holder shall ensure that the Kupe Operator retains all rights to explore and develop assets within the Petroleum Mining Licence area #38146 to the extent provided for in that permit where it overlaps with the Project Area identified in Schedule 1.

100. The Consent Holder shall ensure that all operations proposed by the Kupe Operator within the area of Petroleum Mining Licence #38416 have precedence over the Consent Holder's operations provided that the Kupe Operator gives at least twelve (12) months' notice its intentions to undertake such operations and provides specific details not less than six (6) months prior to the scheduled commencement of such operations.

101. For the duration of this consent, the Consent Holder shall maintain a 500 m protection zone around all wellheads (except Kupe South 4 wellhead where the size of the protection zone will be sufficient to ensure that the Consent Holder's activities do not result in the well-casing being exposed at any time), and a 1.5 km protection zone around the Kupe Well Head Platform.

For the purpose of this condition, the “protection zone” is an exclusion zone where the Consent Holder’s vessels shall not operate and no mining activities will occur, without the prior approval of the Kupe Operator.

Advice note: The Kupe South 4 wellhead refers to the abandoned wellhead located within the Consent Holder’s Mineral Mining Permit area.

102. Notwithstanding any of the requirements of the conditions above, the Consent Holder shall manage all activities associated with the seabed material extraction operations, including the project vessels and their operation, to ensure that the activities authorised by these consents do not result in any adverse effects on the Kupe assets.

REPORTING REQUIREMENTS

Quarterly Operational Report

103. Following the commencement of seabed material extraction, the Consent Holder shall prepare a Quarterly Operational Report summarising the seabed material extraction activities authorised by these consents undertaken for the previous quarter (three (3) months). The Quarterly Operational Report shall, as a minimum, include the following operational information:

    a. GPS positions of anchor placements on the seabed and coordinates illustrated on a map with the seabed material extraction area clearly marked;
    b. GPS positions of the Crawler placement and tracks during seabed material extraction activities authorised by these consents and coordinates illustrated on a map with the extraction area clearly marked;
    c. Any bathymetry measurements of the seabed measured in the reporting period for the area where removal of seabed material has taken place. (Note: Bathymetry will be assessed on a six (6) monthly basis);

d. Quantity and rate of seabed material excavated and quantity and rate of de-ored sediment discharged including the PSD data recorded to assess compliance with Condition 4;
e. Maximum and average depth of seabed material extracted by the Crawler throughout each mining lane (from bathymetry);
f. Average and maximum depth, and GPS position of any unfilled pits remaining after completion of a mining lane (from bathymetry);
g. Average and maximum height, and GPS position of any mounds created during the deposition of de-ored sediment (from bathymetry);
h. Location and height above the seabed of discharge pipe whilst discharging de-ored sediments;
i. Details of any complaints received, including the Complaints Log; and
j. Details of any investigations, including recommendations, undertaken by the Consent Holder, the TRG or the Kaitiakitanga Reference Group including a summary of any commentary or recommendations from the TRG and, where necessary, an explanation as to why any TRG recommendation has not been accepted;
k. Actual 25, 50, 80 and 95th percentile SSC values during the preceding three (3) month period, including a comparison with the "naturally occurring" values predicted by the validated OSPM;
l. A record of pre-start observations as required by Condition 37; and m. Any other components required by the conditions of these consents.

The Consent Holder shall provide the Quarterly Operational Report to the EPA and the Kupe Operator within two (2) months of each quarter ending (being 31 March, 30 June, 30 September and 31 December) during the seabed material extraction activities authorised by these consents.

Annual Report

104. The Consent Holder shall prepare an Annual Report for the previous twelve (12) month period from the commencement of seabed material extraction activities authorised under these consents. Subsequently, an Annual Report shall be prepared for each twelve (12) month period following the anniversary of commencement of the seabed material extraction activities.

Each Annual Report shall, as a minimum, include the following information:

a. A critical evaluation of all monitoring data collected prior to the reporting date, including, but not limited to:
    i. The information contained in earlier Annual Reports; and
    ii. Identifying any trends in the monitoring and any emerging issues of actual or potential concern.
b. An Extraction Schedule detailing:
    i. The areas in which extraction and deposition is proposed to occur over the next twelve (12) month period;
    ii. The timing of proposed extraction and deposition activities in areas identified in Condition 104.a.i.;

   iii. The volume, mass, and rate of seabed material extracted and de-ored sediments deposited during the previous twelve (12) month period;
   iv. GPS locations or chart references detailing the location of extraction and deposition in the previous twelve (12) month period;
   v. Depths of extraction that are scheduled to occur; and
   vi. All updates of the extraction schedule that were notified to the EPA..

c. A summary report on all monitoring undertaken in the previous twelve (12) months in accordance with the EMMP required under Condition 55, including identification of any trends in results;
d. Details of monitoring proposed for the next twelve (12) months in accordance with the EMMP required under Condition 55 including the rationale for this, including by reference to clause a above;
e. Details of any exceedances of the limits as identified in Conditions 4, 5, 6, or 7, as well as any management / mitigation action(s) implemented in response to any exceedance including details of any investigations;
f. A record of all fuel used, and the sulphur content of the fuel, for each project related vessel as required under Condition 42;
g. A record of pre-start observations as required by Condition 37;
h. Details of the TRG review of the annual monitoring data and the EMMP, along with recommendations for any actions or changes to the EMMP or the seabed material extraction activities, and how these were provided for as well as any reasoning as to why recommendations were not accepted; and
i. Any other component required by the conditions of these consents.
j. The Consent Holder shall provide the Annual Report to the EPA and the Kupe Operator within three (3) months of the completion of each twelve (12) month monitoring period.

105. The Consent Holder shall inform the EPA of any modified operational extraction and deposition areas or periods which differ from those identified in the “the next twelve (12) month” period of any Annual Report required by Condition 104.

Where any such changes are in the Petroleum Mining Licence area #38146, or the project area immediately adjacent to the Kupe assets, the Consent Holder shall also inform the Kupe Operator of any modified operational extraction and deposition areas or periods which differ from those identified.

The EPA, and where necessary the Kupe Operator, shall be informed of any such changes no later than thirty (30) working days prior to commencement of works in the modified areas, or as otherwise agreed in the SIMOPP.

REVIEW CONDITION

106. Within twenty (20) working days of the receipt of either the Quarterly Report or Annual Report, or within twenty (20) working days of the EPA receiving the recommendation from either the Consent Holder or from the TRG, including any recommendations from the TRG not accepted or implemented

by the Consent Holder, the EPA may serve notice on the Consent Holder, in accordance with sections 76 and 77 of the EEZ Act, of its intention to review the conditions of these consents for the purpose of:

a. Adding, amending or cancelling any discharge limits, environmental limits, or operational controls (Conditions 4 - 47); and/or
b. Including any new discharge limits, environmental limits, or operational controls; and/or
c. Dealing with any adverse effects on the environment that may arise from the exercise of the consents and which it is appropriate to deal with after the consent(s) have been granted; and/or
d. Reviewing monitoring or reporting required by any condition(s) of these consents.

RISK MANAGEMENT

107. The Consent Holder shall, while giving effect to these consents, maintain public liability insurance for a sum not less than NZ$500,000,000 (2016 dollar value) for any one claim or series of claims arising from giving effect to these consents to cover costs of environmental restoration and damage to the assets of existing interests (including any environmental restoration as a result of damage to those assets), required as a result of an unplanned event occurring during the exercise of these consents.

108. The Consent Holder shall submit a certificate demonstrating that it holds the insurance required by Condition 107 prior to giving effect to these consents and an updated certificate annually by 1 July of each year for the term of these consents to the EPA.

COST RECOVERY

Advice Note: To the extent that condition 109 is ultra vires, it has been proffered by the applicant on an Augier basis.

109. The Consent Holder shall meet the actual and reasonable costs incurred by the EPA when obtaining external advice it considers necessary to:

a. Exercise its certification functions as required by these conditions; and
b. Audit compliance with the conditions of consent, including, but not limited to, assessing the Annual Report required by Condition 104.

Advice Note: Where a condition requires the Consent Holder to submit a plan or document to the EPA "for certification" the EPA may, if it considers it necessary, seek the advice of a suitably qualified and experienced external expert(s) before it certifies the plan/document. In addition, the EPA may request further information/clarification from the Consent Holder after it submits the plan/document. In such cases the EPA will advise the Consent Holder that it has not yet certified the plan/document and the clause in the respective condition which states that the plan is "deemed to be certified" after a specified time period will not apply. For clarity, certification includes the exercise of the responsibilities assigned to the CEO of the EPA by any condition.

SCHEDULE 1 – Grid References Of The Project Area

Point	Longitude	Latitude
1	174° 10' 51" E	39° 49' 39" S
2	174° 13' 03" E	39° 51' 21" S
3	174° 12' 16" E	39° 51' 56" S
4	174° 09' 02" E	39° 53' 42" S
5	174° 07' 21" E	39° 54' 29" S
6	174° 05' 37" E	39° 54' 23" S
7	174° 04' 33" E	39° 54' 16" S
8	174° 03' 49" E	39° 53' 52" S
9	174° 02' 52" E	39° 53' 12" S
10	174° 02' 09" E	39° 52' 38" S
11	174° 02' 12" E	39° 51' 20" S
12	174° 02' 28" E	39° 51' 04" S
13	174° 03' 18" E	39° 51' 53" S
14	174° 06' 30" E	39° 51' 43" S
15	174° 06' 30" E	39° 51' 39" S
16	174° 06' 40" E	39° 51' 34" S
17	174° 07' 23" E	39° 51' 45" S
18	174° 08' 10" E	39° 51' 28" S
19	174° 09' 46" E	39° 50' 33" S

Datum: NZGD2000

Note 1: This schedule is referred to in conditions 93, 94 and 99.

SCHEDULE 2 – Suspended Sediment Concentration (SSC) Limits

South Taranaki Bight Sites	Background Percentiles (SSC mg/L)							
	Surface				Bottom			
	25th	50th	80th	95th	25th	50th	80th	95th
Rolling Grounds (WGS 1984: 39 57 22.58780 S, 174 22 29.90885 E)	TRG	TRG	0.3	1.1	TRG	TRG	3.5	15.3
Graham Bank (WGS 1984: 39 53 16.22020 S, 174 24 40.68384 E)	TRG	TRG	1.7	4.5	TRG	TRG	32.8	84
Source A to Whanganui 1 km (WGS 1984: 39 51 22.41692 S, 174 13 46.13207 E)	TRG	TRG	1.1	2.7	TRG	TRG	16.9	44.2
Source A to Whanganui 20 km (WGS 1984: 39 53 14.34932 S, 174 27 08.62846 E)	TRG	TRG	2.3	5.9	TRG	TRG	29	76.6
South Traps (WGS 1984: 39 51 53.21010 S, 174 32 48.75387 E)	TRG	TRG	6.3	11.1	TRG	TRG	37.7	97.4
North Traps (WGS 1984: 39 51 02.22374 S, 174 31 10.63364 E)	TRG	TRG	7.2	12.4	TRG	TRG	46.5	115
Tūteremoana (WGS 1984: 39 55 00.03802 S, 174 47 41.29085 E)	TRG	TRG	8.5	13.6	TRG	TRG	23.7	62.5
The Crack 1 (WGS 1984: 39 49 12.00 S, 174 15 00.00 E) provisional	TRG	TRG	TRG	TRG	TRG	TRG	TRG	TRG
The Crack 2 (WGS 1984: 39 51 00.00 S, 174 18 00.00 E) provisional	TRG	TRG	TRG	TRG	TRG	TRG	TRG	TRG
The “Project Reef” (location to be set by TRG)	TRG	TRG	TRG	TRG	TRG	TRG	TRG	TRG

Note 1: This schedule is referred to in conditions 5, 6, 48, 51 and Schedule 3.

Note 2: The source of the numerical values of the levels of "naturally occurring" 80th and 95th percentile background limits contained in this table are as set out in Daniel Govier's evidence (Appendix 10) 16 December 2016, and have been derived from the sediment plume modelling ("no mining" scenario) which was informed by measurements of background sediment concentrations and other oceanographic parameters addressed by NIWA, as set out in the NIWA Oceanographic Measurements Report, the Nearshore Measurements Report, and the Remote Sensing Report.

For the purposes of operational management, the SSC Limits contained in this table are to be considered as inclusive of both natural and mining derived suspended sediment concentrations. All percentile values marked "TRG" are to be derived by the Technical Review Group. The SSC limits and location coordinates for The Crack 1 and 2, and The "Project Reef" are also to be derived by the TRG.

Note 3: Turbidity may be used as a proxy for suspended sediment concentrations when assessing against the limits in this table.

Note 4: The numerical values of this table that represent a percentile limit at a location may be amended by way of the process set out in Condition 51 but any change to the percentiles themselves (for instance amending 95th percentile to 90th) can only be changed by way of Condition 106 or in accordance with the EEZ Act.

Note 5: The 95th percentile is a fixed limit and is subject to Condition 5.a., unless subject to Condition 5.b. after the value has been modified under Condition 51. The 25th, 50th and 80th percentiles are subject to Condition 5.c. which allows variation of up to 10%.

SCHEDULE 3 – Methodology For Reviewing The Suspended Sediment Concentration 'Compliance Limit' Numerical Values In SCHEDULE 2

The suspended sediment concentrations collected as part of the Pre-commencement Environmental Monitoring Programme (PCEMP) will be used to calibrate and validate the Operational Sediment Plume Model and provide data to verify the SSC Limit numerical values set in Schedule 2. As per Condition 53, calibration and validation of the Operational Sediment Plume Model will occur every six (6) months during the PCEMP and for the first three years of seabed material extraction activities, and then every 24 months thereafter with independent peer review as per Condition 52.

Validation will occur by statistically comparing the modelled and actual measured values to provide a measure of the Operational Sediment Plume Model accuracy. The aim of the validation process is to assess whether the actual measurements differ from the predicted values and if so by what margin, and over how much of the period that was being reviewed (i.e. the percentage of time the values differ and the range, median, mean, etc. of this difference). A range of statistical techniques (within suitable statistical programmes) can be employed to assess any differences, including, but not limited to, scatterplots of predicted vs actual concentrations (and examining the adjusted R2 value), residual plots (observed – predicted values) and calculating the root mean squared error (or standard error of the regression).

If the actual measured suspended sediment concentration values do not fall within 10% of the modelled values listed in Schedule 2 for 95% of time within each six (6) month review period, the model will be revised using the actual data to update the compliance limit values. Long term time series data are preferable for comparison with the Schedule 2 statistical limits. Therefore, as the measured data accumulates over the PCEMP period comparisons are to make use of as much of the aggregated time-series data as possible.

As per Condition 51, in the event that the updated numerical values of the SSC Limits are different from the numerical values of the SSC Limits in Schedule 2, then the updated numerical values of the SSC Limits shall supersede the numerical values of the SSC Limits in Schedule 2. Any updated numerical values of the SSC Limits shall represent "background" conditions and not be influenced by any actual or model simulated seabed material extraction activity.

Note 1: This schedule is referred to in condition 51.

SCHEDULE 4 – Benthic Ecology Monitoring Sites

(a) Rolling Grounds (WGS 1984: 39 57 22.58780 S, 174 22 29.90885 E)

(b) Graham Bank (WGS 1984: 39 53 16.22020 S, 174 24 40.68384 E)

(c) Source A to Whanganui 1 km (WGS 1984: 39 51 22.41692 S, 174 13 46.13207 E)

(d) Source A to Whanganui 20 km (WGS 1984: 39 53 14.34932 S, 174 27 08.62846 E)

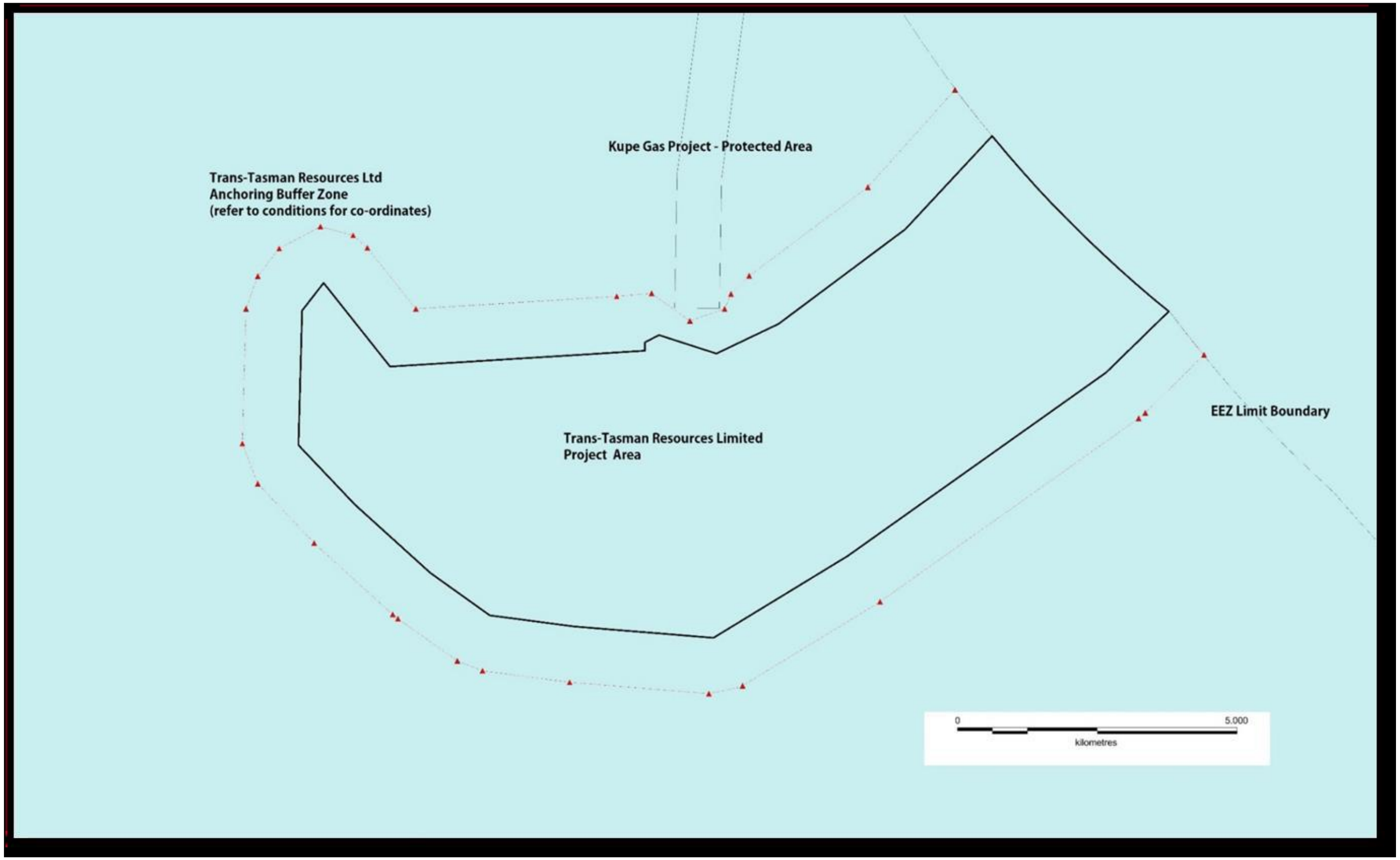
(e) South Traps (WGS 1984: 39 51 53.21010 S, 174 32 48.75387 E)

(f) North Traps (WGS 1984: 39 51 02.22374 S, 174 31 10.63364 E)

(g) Tūteremoana (WGS 1984: 39 55 00.03802 S, 174 47 41.29085 E)

Note 1: This schedule is referred to in condition 7.

SCHEDULE 5 – Plan Of Consented Integrated Mining Vessel Mooring Area Boundary



Note 1: This schedule is referred to in condition 38.

SCHEDULE 6 – Monitoring Of Indicators

Schedule 6– Monitoring Of Indicators			
Indicator	**Methods and Locations**		
Metals Testing			
To be undertaken on:	Testing for:		
a. Sediments	e. Cadmium	j. Chromium	n. Antimony
b. Water column (plume)	f. Copper	k. Zinc	o. Manganese
c. Biological indicators	g. Nickel	l. Tributyltin	p. Selenium
d. Tailings slurry	h. Mercury	m. Arsenic	q. Iron
	i. Lead		r. Silver
Biological Indicators for Metals			
Indicator:	Locations:		
a. Green lipped mussels	b. Source A to Whanganui 1km, The Traps		
Ecotoxicology			
Indicator:	Method:		
a. Relevant local species (larval and adult stages) to assess lethal and sub-lethal end points	b. Species exposed to dilute-acid extracted metals derived from elutriate tests of the fine fraction of the de-ored sediment, as would be released in the plume		
Chronic Ecotoxicity			
Indicator:	Method:		
a. Relevant local species to address potential long terms effects on sensitive life stages	b. Testing of sensitivity to dissolved and particulate nickel and copper		
Benthic Fauna			
Indicator:	Method:		
a. All benthic fauna	b. Identified to lowest practicable taxonomic level (genus or species)		

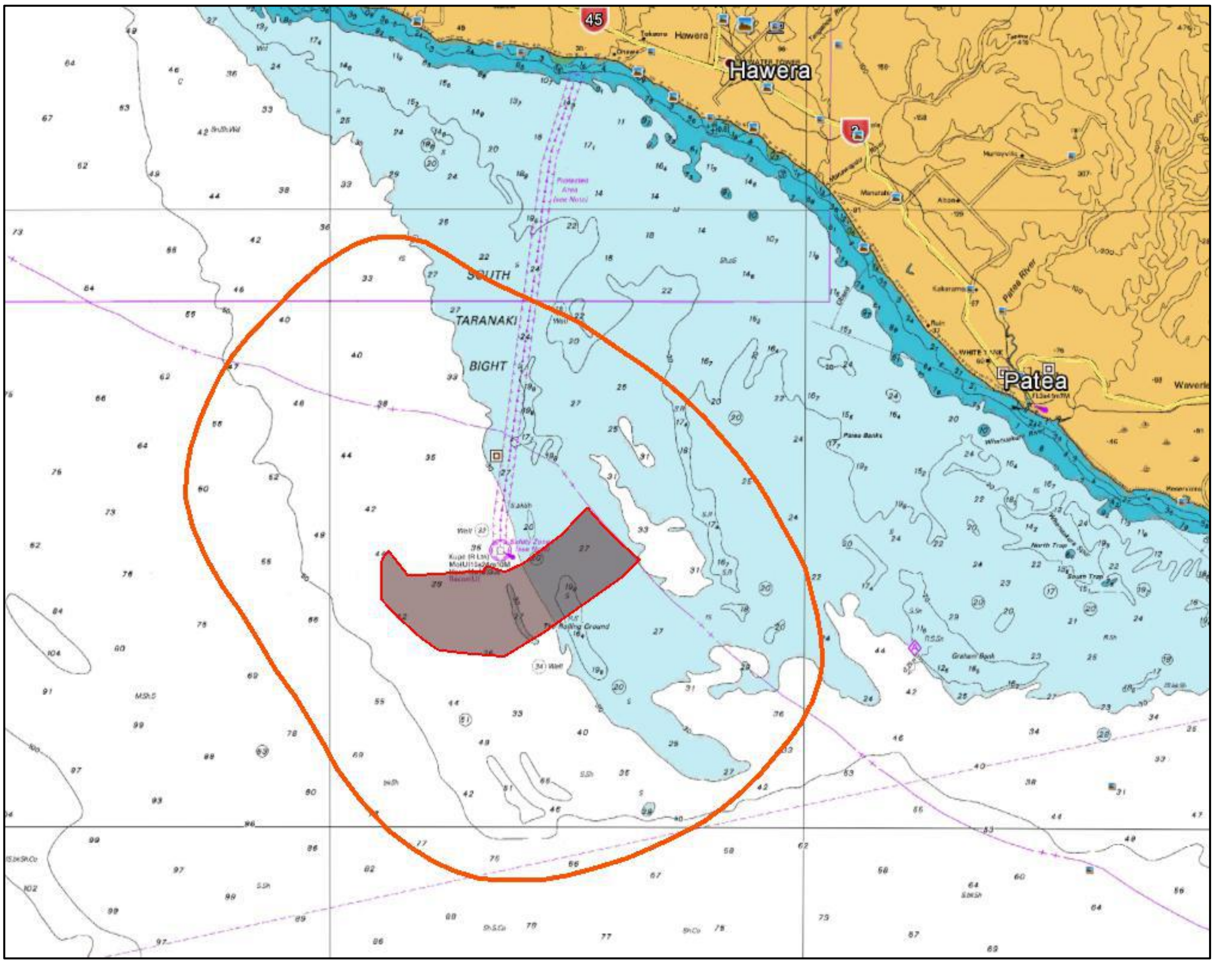
Schedule 6– Monitoring Of Indicators	
Indicator	**Methods and Locations**
Acid Volatile Sulphides	
Indicator:	Method:
a. Bioavailability potential for organisms inhabiting the seabed	b. Sampled from tailings slurry
Metals in Pore Water	
Indicator:	Method:
a. Metals in pore water	b. Analysis as required
Beach Profiles	
Indicator:	Locations:
a. Rates of erosion / accretion and associated changes in beach volume	b. Ohawe, Hawera, Manawapou, Patea, Waverley, Waiinu, Ototoka, Kai Iwi
Marine Mammal Monitoring	
Indicator:	Method:
a. Vessel strike	b. Post mortem
Fur Seals	
Indicator:	Method:
a. Fur seal distribution	b. Counts from IMV and FPSO
Marine Mammal Acoustic Surveys	
Indicator:	Method:
a. Marine mammal distribution	b. Three acoustic loggers to establish benchmark sound levels. Broad spectrum monitoring. Inclusion of bottlenose dolphin.
Resalinated Water	
Indicator:	Method:
a. Metals in water	b. Six monthly sampling

Schedule 6– Monitoring Of Indicators	
Indicator	**Methods and Locations**
Origin Kupe Assets	
Indicator:	Locations and Method:
a. Migration of mounds and pits	b. Bathymetric surveys, including around the WHP, pipeline, and umbilical route
Biosecurity Monitoring Plan	
Indicator:	Location and Method:
a. Algal blooms and marine pests	b. Surveillance in and surrounding project area. Primary productivity and subtidal benthos monitoring programmes.
Operational Monitoring	
Indicator:	Location and Method:
a. Near-field effects and recovery	b. Six stations within operational area c. Nine stations placed along first strip of mined seabed and monitored for term of consent d. Fifteen stations monitored quarterly, in triplicate

Note 1: This schedule is referred to in conditions 6, 54, 55, 56 and 57.

SCHEDULE 7 – 120 Decibel Contour

This map sets the position of the 120 dB contour referred to in Condition 16.



Note 1: This schedule is referred to in conditions 17 and 18.

Note 2: The 120 dB contour is an indicative location based on the combined operation of the IMV and crawler, when operating at the centre of the mining site.

END OF MARINE CONSENT DOCUMENT

Appendix 3. Application Reports

The following reports are those lodged with the application. The report numbers are those assigned by the EPA and used on the EPA website.

- Report 1 South Taranaki Bight (STB) Baseline Environmental
  - *STB Baseline Environmental Appendix 1*
  - *NIWA STB Baseline Environmental Appendix 2*
  - *NIWA STB Baseline Environmental Appendix 3*
  - *NIWA STB Baseline Environmental Appendix 4*
- Report 2 Benthic Habitats, Macrobenthos and Surficial Sediments of the Nearshore South Taranaki Bight
- Report 3 Benthic Flora and Fauna of the Patea Shoals Region, South Taranaki Bight
- Report 4 Habitat Models of Southern Right Whales, Hector's Dolphin, and Killer Whales in New Zealand
- Report 5 Coastal Stability in the South Taranaki Bight – Phase 1
- Report 6 Coastal Stability in the South Taranaki Bight – Phase 2
- Report 7 Effects of Ships Light on Fish, Squid and Seabirds
- Report 8 Seabirds of the South Taranaki Bight
- Report 9 Zooplankton Communities and Surface Water Quality in the South Taranaki Bight
- Report 10 NIWA South Taranaki Bight Fish and Fisheries
  - *NIWA Fish and Fisheries Appendix A*
  - *NIWA Fish and Fisheries Appendix B*
  - *NIWA Fish and Fisheries Appendix C*
- Report 11 Geological Desktop Summary
  - *NIWA Geological Desktop Summary Appendix A*
  - *NIWA Geological Desktop Summary Appendix B*
  - *NIWA Geological Desktop Summary Appendix C*
  - *NIWA Geological Desktop Summary Appendix D*
  - *NIWA Geological Desktop Summary Appendix E*
  - *NIWA Geological Desktop Summary Appendix F*
- Report 12 South Taranaki Bight Iron Sand Mining: Oceanographic Measurements
- Report 13 Nearshore Optical Water Quality in the South Taranaki Bight
- Report 14 South Taranaki Bight Iron Sand Mining: Shoreline Monitoring Data Report
- Report 15 South Taranaki Bight Iron Sand Mining Nearshore Wave Modelling
- Report 16 Effects on Primary Production of proposed Iron Sand Mining in the South Taranaki Bight
- Report 17 Assessment of the Scale of Marine Ecological Effects
- Report 18 South Taranaki Bight Commercial Fisheries
- Report 19 Zooplankton and the Processes supporting them in Greater Western Cook Strait
- Report 20 Aquatic Environmental Sciences - Trans-Tasman Resources Ltd Consent Application: Ecological Assessments

- Report 21 Tonkin & Taylor Ltd – Air Dispersion Modelling Studies on Gas turbine discharges
- Report 22 Tonkin & Taylor Ltd – Air Dispersion Modelling Studies on Reciprocating engine discharges
- Report 23 Clough and Associates Ltd – Trans-Tasman Resources South Taranaki Bight Offshore Iron Sand Project: Archaeological Assessment
- Report 24 Martin Cawthorn Associates Ltd – Cetacean Monitoring Report
- Report 25 Fathom – Assessment of Potential Impacts on Commercial Fishing
- Report 26 R N Barlow and Associates Limited – Maritime and Navigational Impacts of the Project
- Report 27 Marico Marine – South Taranaki Bight Marine Traffic Study
- Report 28 Hegley Acoustic Consultants – Assessment of Noise Effects
- Report 29 Rob Greenaway & Associates – Recreation and Tourism Assessment of Effects
- Report 30 Corydon Consultants Ltd – Social Impact Assessment
- Report 31 Boffa Seascape Natural Character Assessment
    - *Boffa Miskell – Visual Effects Report and Graphic Supplement*
- Report 32 OCEL Consultants – Implications of Loose Tailings Seabed Material on Future Jack-Up Deployment
- Report 33 MetOcean Solutions Ltd – Oil Spill Trajectory Modelling
- Report 34 Te Taihauauru Iwi Forum Fisheries Plan 2012 – 2017
- Report 35 Richardson. K, 'A perspective of marine mining within De Beers', The Journal of The South African Institute of Mining and Metallurgy, Volume 107
- Report 36 Findlay. K, P. The Impact of Diamond Mining Noise on Marine Mammal Fauna off Southern Namibia, June 1996
- Report 37 Institute for Maritime Technology – Environmental Impact Study: Underwater Radiated Noise, 1994
- Report 38 Institute for Maritime Technology – Environmental Impact Study: Underwater Radiated Noise II, 1995
- Report 39 eCoast Potential Effects of Trans-Tasman Resources Mining Operations on Surfing Breaks in Southern Taranaki Bight
- Report 40 Martin Jenkins Ltd - Economic Impact Analysis of the Offshore Iron Sands Project
- Report 41 Tahu Pōtiki - Cultural Values Assessment and Analysis
- Report 42 Auckland University of Technology – Iron Sand extraction in the South Taranaki Bight: effects on trace metal contents of sediment and seawater