Annex I – Stage 3 Preliminary Sand Assessment and Mining Plan

BOBS FARM SAND DEPOSIT
STAGE 3 INVESTIGATION

Report Title	Bobs Farm Sand Deposit Stage 3 Investigation	Report Number	2015-07-15- D
Client	Ammos Resource Management Pty Ltd	Prepared by	MP, MvK, PB
Date	15/07/2015	Checked by	MvK

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EXECUTIVE SUMMARY

Ammos Resource Management Pty Ltd (Ammos) engaged Quarry Mining Systems (QMS) to investigate the quality and quantity of sand available at their Nelson Bay Rd site at Bobs Farm, to determine what potential markets the identified sand may suit and what further work may be done to mine, process and sell this sand into these markets. This report presents the results of the third of potentially five (5) stages of investigations and development, as defined in the scope later in this report.

Further testing was undertaken in this stage 3 work to confirm suitability of the sand, for higher end market uses. The tested samples were those retrieved previously from earlier QMS stage 2 drilling operations within the Bobs farm site. The results from this further investigation confirm that there are sand lenses that appear to be suitable for a series of high end applications, after washing/processing, including; industrial moulding sand, fire furnace sand, and coloured glass sand. The sand tested was also confirmed to be unsuitable for fracking applications as it was too soft, under crushing tests, and while sphericity would appear close to that required the sand was also within a very small physical size band and unlikely to be in high demand. In addition under acidic ground conditions the sand samples were not believed to be suitable.

The impurities within the sand are also believed to preclude it from meeting clear glass specification; but further testing for high end uses is recommended on potential sand lenses as the mine develops overtime.

The concept design for processing mine feed into final product was developed in this stage of the QMS investigation and based upon the information provided by Tattersall Lander (TL) and other sub-consultants, (VGT, Martens, Vipac, Seca, Aecom, and Wildthing), the sand mining is proposed to be conducted in both dry and wet processes over the life of the deposit. In this way the different lenses of sand can be extracted and processed to suit the requirements of the specific markets they are being supplied into; and the final landform would provide a recreational and tourist watercourse expected to benefit the local area. The detail of the final landform is proposed to be a bunded water surface to be confirmed by TL and does not form part of this report.

The proposed mining plan developed by QMS allows extraction of the different sand lenses above the water table by conventional excavator and haul truck to deliver a dry sand to the dedicated processing plant. By controlling the winning of sand feed in this way it allows flexibility to determine the most suitable processing required to meet the most valuable market segment for that sand. In addition should a change in market use be required for given sand lenses, due to unforeseen market pressures etc. this may be accommodated.

Wet mining of the sand on site, below the water table, is proposed to be done with dedicated suction/cutter dredge which would be established within the deposit by year three (3) of the quarry life and would remain in service until the end of resource life. This would bring significant improvements in mining efficiency as the most economical way to win feed, minimise dust and vibration across the site and maintain minimal water losses from the system which is critical for this site. By transporting the dredged sand/water mixture to the processing plant external water inputs will be minimal and losses are expected to be as low as 2%.

To control windblown sand across the site the deposit is planned to be opened up in active extraction cells, with minimum disturbance to the site elsewhere. In this way each cell will be stripped of vegetation and prepared for winning of feed with rehabilitation commencing on each cell as soon as possible after it is opened up to again minimise unplanned sand movement by wind. Stripped vegetation is to be saved and stored where possible to provide the required seed bank of natives etc. for later re-use in rehabilitation. Where this is not possible a tub grinder is to be used to reduce the unusable vegetation to a suitable mulch that can be used to assist rehabilitation across the site or in development of bunded areas or berms. Rehabilitation planning will form part of later stages of site development and be provided by TL or others.

In addition, to minimise development of airborne dust, main haul roads will be surfaced with a bituminous seal or suitable gravel and will be maintained, as required by production for the life of the deposit.

The rate of feed extraction and final sand production from the Bobs Farm site will be dictated by the markets into which the sand will be sold. The aim is to produce final saleable sand products that are of high quality, in high demand and consistently comply with specific market requirements; while managing the waste stream by-products in an environmentally responsible and cost-effective way. Any excess final sand stock product will not remain onsite for extended periods, in line with a sustainable operational plan which will follow in future development stages of this site.

The processing plant to be used to produce the final sand products will comprise of different operational modules that can be added or removed depending on the market segments being sold into. Where higher end market products are being produced additional plant would be commissioned to achieve the required higher level of processing. Waste management will be planned and controlled within the dedicated operational plan for the site.

Control of specific environmental issues such as Potential Acid Sulphate Soils (PASS) will be undertaken as per the design plan provided by Martens to control this risk.

The competitive market analysis undertaken, by QMS as part of this stage 3, confirmed there are significant opportunities locally within Australia and, with the Newcastle deep water port located nearby, significant potential for direct export of sand into Asia and beyond.

Based upon the work undertaken, in this stage 3 investigation, the Bobs Farm site has the potential to provide approx. 7 million cubic metres of mineable sand feed (~10 million tonnes) which is likely to be suitable for a number of different market applications. Changes in volume estimates from previous QMS investigations are due to slope stability geotechnical advice from Martens providing acceptable safe slopes across the deposit and PASS treatment and associated processes.

The proposed next QMS Stage 4 of investigation into the Bobs Farm site is to refine the concept processing plant design from Stage 3 and move into operational planning of the site for mining commencement, dependent on the mining approval process and guidance from TL and Ammos.

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1. Introduction and Background

The proposed Bobs Farm deposit is situated on the northern end of the Stockton Bight Dunal system, approximately 200km north of Sydney, in Port Stephens, NSW Australia. The following scope was developed to investigate the Bobs Farm site as a potential sand deposit.

1.1 Overall Scope of Investigation

From the original Quarry Mining Systems proposal –
The overall scope of this investigation was to establish the projected viability of mining the sand deposit on this property. The work was to be completed in stages depending on the instructions of the owners and the results of the previous stage. Each stage was to provide greater levels of certainty about the quantity and quality of the sand deposit.

Stage 1 (Completed)
5 test pits dug by long reach excavator to establish resource sand quantity and quality at various points on the site. Dependant on site conditions during sampling.

a. Analysis of samples from the pits.
b. Preliminary indications of sand volumes and quality available at the site.

Stage 2 (Completed)
5 boreholes were drilled up to 16 metres below the existing water table, logged and tested to confirm sand quality with depth in these locations across the site.
A comprehensive analysis of potential market applications was also undertaken to identify potential sales for the various sand lenses.

Stage 3 presented later in this report

Stage 4 is proposed to extend on work done in Stage 3 and complete the detail required for a complete quarry plant design, costing and operational budget. The site operational plan would be developed based upon site approvals and market opportunities.

Stage 5 is proposed to be the development of the overall operation, ongoing management, maintenance of the plant, product testing and quality of sand supplied to the various markets.

1.2 Review- QMS Stages 1 and 2

Previous QMS investigations, stages 1 and 2, confirmed that there were significant volumes of minable sand lenses present at different depth across the site. The Stage 1 work involved the establishment of test pits at various locations to gain an understanding of the quality and consistency of the sand with depth. Stage 2 involved further drilling and sampling of sand lenses with depth and these samples were used as a basis for further testing in this Stage 3 work reported here. It was clear from these stages that a series of sand lenses existed and a range of potential markets also existed for these sands.

1.3 Outcomes of Stage 2

Figure 1 below identifies test pit and borehole location sunk onsite to date by QMS. This forms the basis of the data available for analysis.

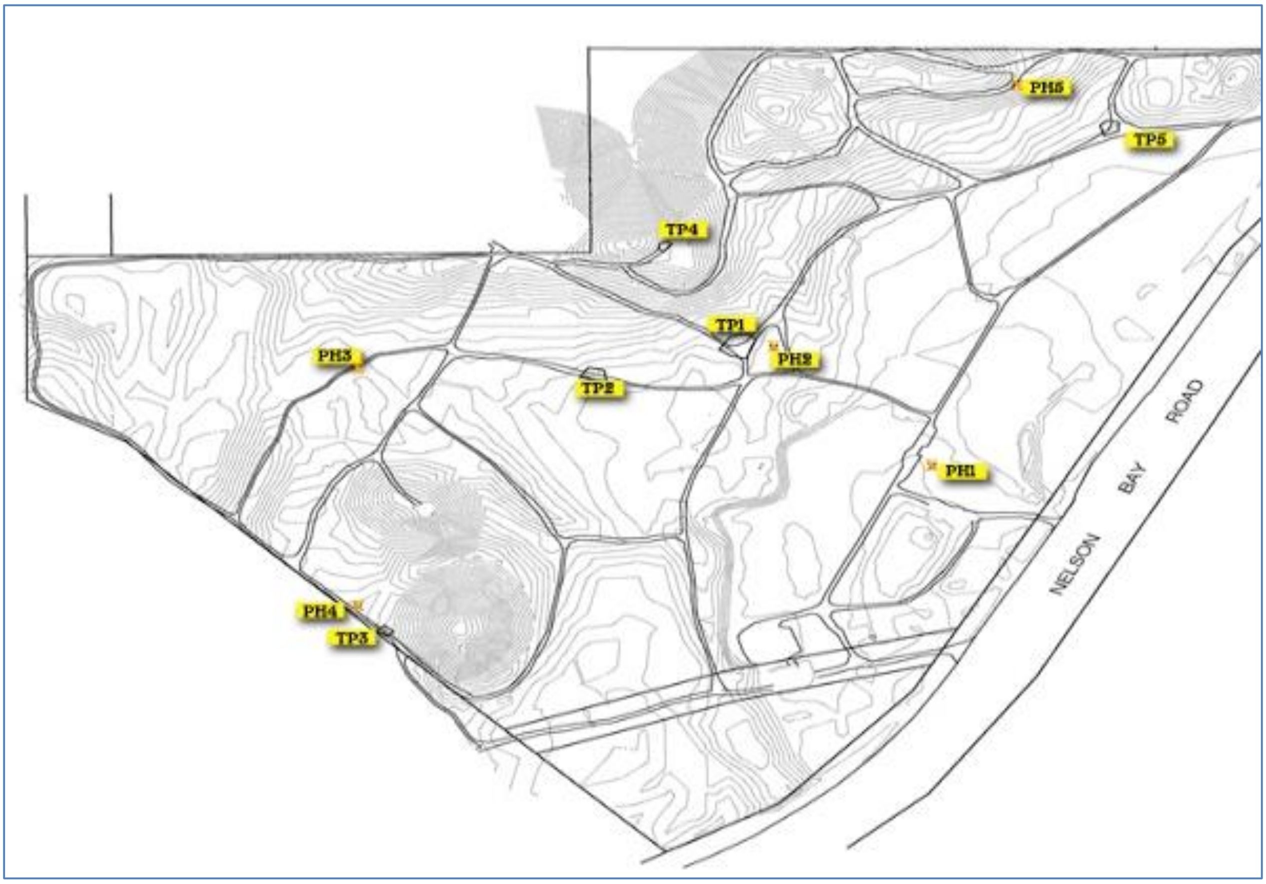


Figure 1: Bore Hole and Test Pit Locations- (Extract from QMS Stage 2 Report):

Note: PH= Proposed Hole; TP = Test Pit

Table 1 below details the layers thickness with depth across the Bobs Farm site.

Hole Number	Upper Grey Sand Unit (RL m)	Blonde Sand Unit (RL m)	Black Palaeosol Unit (RL m)	Lower grey Sand (RL m)	Hole Depth (m)
BH 1	5.8 – 4.8	4.8 – 2.0	2.2 – 1.3		19.00
BH 2	11.7 – 6.8	6.8 – 1.2	1.2 - -0.3	-0.3- -14.8	26.50
BH 3	15.4– 12.4	12.4 – 0.0	0.0 - -1.4	-1.4- -11.9	26.50
BH 4			2.8 – 1.9	1.9 -	24.00
BH 5					26.50

Table 1: Resource Average Thickness Summary- (Extract from QMS Stage 2 Report)

Table 2 below summarises the basis for QMS stage 2 volume estimates, when broken into three main extraction groups; Upper, Mid and Lower units. This is expected to change with Martens geotechnical report changing the maximum batter slope angles.

Resource Category	Status	Base of Extraction RL (m)	Batter angle (degrees)	Volume (BCM)	Tonnes
Upper	Dry	4.3	18	2,226,563	3,562,500
Mid	Moist	2.3	18	546,495	874,392
Lower	Wet	-13.7	42	3,830,347	6,128,555
Total				6,603,405	10,565,448

Table 2: Resource Category Summary- (Extract from QMS Stage 2 Report)

Table 3 below represents the reserve estimates from the Stage 2 drilling program of five (5) separate drill holes that confirmed the presence of five (5) mineable sand units and a Topsoil unit for site rehabilitation, classified as:

Resource Unit	Volume	Tonnes
Top Soil	151,477	242,364
Upper Grey Sand	331,808	530,892
Blonde Sand to 4.3m RL	1,743,278	2,789,244
Blonde Sand Remaining	546,495	874,392
Black Carbonaceous	343,110	548,976
Lower Grey Sand	3,487,237	5,579,579

Table 3: Resource Unit Summary- (Extract from QMS Stage 2 Report)

Note: volume estimates are based upon the available information and contain assumptions of degree of compaction within the sand as deposited and will likely be reduced when more specific mining planning is undertaken. See QMS Stage 2 Appendix 4- Borehole Logs).

Each of these sand layers were believed, based upon QMS stage 2 investigations, to have the potential to be processed into different products to satisfy different market needs; from turf sands/ sports field, cricket/golf, decorative, and construction material uses to potentially higher end uses in coloured glass, foundry and other specialist applications.

1.4 Stage 3 Scope

The investigation in stage 3 was designed to produce a number of outcomes;

1. To identify if specific sand lenses within the site could be used for higher end uses that may attract a higher selling price and hence maximise revenue for the operation.
2. Testing for process requirements into higher end markets
3. Concept process design for sand into identified markets
4. Concept process design and cost estimate for beneficiating of sand to higher value markets
5. Development of a potential mining plan based on available information
6. Market analysis on future opportunities for sales into Australian and overseas export markets.

1.5 Outcomes of Stage 3

Sampling and laboratory testing

Samples retrieved from the QMS Stage 2 drilling program confirmed that the different sand lenses onsite were suited to a number of different markets with blending or additional processing required in most cases. To determine if further processing of the sand would be likely to bring it to higher market uses appropriate samples from the stage 2 drilling were sent for further analysis and testing with the following outcomes;

Product quality, product types

1. Further testing in the QMS Stage 3 investigation of sand samples confirmed that the sand onsite was not suitable for Fracking sand applications as it was too soft (too low an Unconfined Compressive Strength -UCS), was too small in size and the sphericity was close but may not comply with required specification. In addition acid testing indicated that under potentially aggressive low pH ground conditions the sand may not be suitable. See Appendix 1-5 McLanahan report and Table 4

below. The sand lenses further tested for Frac were identified in the QMS stage 2 investigation as being those most likely to comply with the relevant specifications.

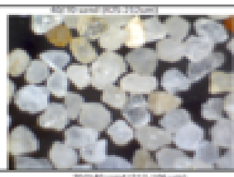
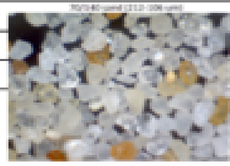
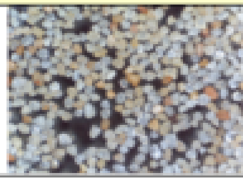
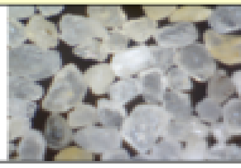
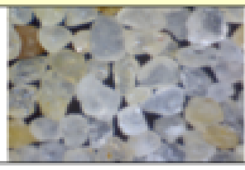
Frac Testing						
Sample Location (Borehole ID)	Primary Frac Sand Size					Images
BH2-22.5 – 23.5 – G - ML	6/12 (3350 – 1700um)	12/20 (1700 – 850um)	20/40 (850 – 425um)	40/70 (425-212um)	70/140 (212-106um)	
Roundness / Sphericity	Fail	Fail	Fail	Fail	Fail	
Acid Test	Fail	Fail	Fail	Fail	Fail	
Crush Test	N/A	N/A	N/A	Fail	N/A	
BH3- BL-B-ML	6/12 (3350 – 1700um)	12/20 (1700 – 850um)	20/40 (850 – 425um)	40/70 (425-212um)	70/140 (212-106um)	
Roundness / Sphericity	Fail	Fail	Fail	Fail	Fail	
Acid Test	Fail	Fail	Fail	Fail	Fail	
Crush Test	N/A	N/A	N/A	Fail	N/A	
BH3- BL-G-ML	6/12 (3350 – 1700um)	12/20 (1700 – 850um)	20/40 (850 – 425um)	40/70 (425-212um)	70/140 (212-106um)	
Roundness / Sphericity	Fail	Fail	Fail	Fail	Fail	
Acid Test	Fail	Fail	Fail	Fail	Fail	
Crush Test	N/A	N/A	N/A	Fail	N/A	
BH5- BL-B-ML	6/12 (3350 – 1700um)	12/20 (1700 – 850um)	20/40 (850 – 425um)	40/70 (425-212um)	70/140 (212-106um)	
Roundness / Sphericity	Fail	Fail	Fail	Fail	Fail	
Acid Test	Fail	Fail	Fail	Fail	Fail	
Crush Test	N/A	N/A	N/A	Fail	N/A	
Conclusions						
Sand lenses and size fractions tested were deemed unsuitable for Frac Applications after further specialist testing.						

Table 4: Frac Testing Results Summary

2. Further testing of sand lenses within the site confirmed that, due to the high silica content and relatively low impurities of the sand lenses tested, with further

processing those sand lenses may be suitable for higher end applications potentially attracting better sales revenue. See Table 5.

Geochempet- Chemical Property Summary and Potential Application							
Application =>	Moulding sand		Fire/ Furnace Sand		Glass		
Constituent	Spec %	Result %	Spec %	Result %	Clear Glass Spec %	Coloured Glass Spec %	Result %
Silica (SiO_2)	>98	97.9	>95	97.9	>99	>98	97.9
Al_2O_3		-	<1.00	0.65	-	0.2-1.6	0.65
Fe_2O_3		-	<1.00	0.16	<0.03	<0.2	0.16
TiO_2		-	-	-	<0.1	-	-
Na_2O		-	-	-	-	<0.2	0.05
Cr_2O_3		-	-	-	<6ppm	-	-
LOI		-	-	-		<0.4	0.4
Co		-	-	-		1ppm	TBA
Cr		-	-	-		7ppm	TBA
Cu		-	-	-		3ppm	TBA
Mn		-	-	-		10ppm	TBA
Ni		-	-	-		3ppm	TBA
V		-	-	-		3ppm	TBA
Calcium Carbonate	<0.2	-	-	-			
Sodium Chloride	<0.1	-	-	-			
Other Oxides		-	<1.00	1.29			
Combustibles	<0.2	0.4		-			
Comments	Potential for Moulding Sand after washing		Potential for Fire/Furnace Sand after washing		May not be suitable for clear glass after washing	Potential for Coloured glass after washing	

Table 5: Chemical Property Summary Bobs Farm Sand

3. Concept process design for sand into all markets. Based upon the sand identified and the feed properties, QMS approached a number of quarry plant suppliers to

understand the best processing solutions to allow mainline products to be produced ready for sale but also to bolt on additional processing equipment required to raise some sand lenses to a higher value product where possible.

The sand value chain hierarchy was established and was based upon maximising potential value of the sand products from the site.

Sand Value Chain Hierarchy (In Order of Expected Sale Price- may vary):

1. Frac sand- Not Suitable
2. High Purity Glass Sand- LCD TVs, Silicon Computer Chips etc..
3. Optical sand glass / watches etc.
4. Glass sand (Clear- general)
5. Glass sand (Coloured)
6. Foundry/furnace sand
7. Specialist grout sand
8. Horticulture sand - propagation sands etc.
9. Landscape sand (High end)- horse sand/golf, bunker, green, fairway sands
10. Decorative sands- resorts, national / international
11. Filter sands / bio retention
12. Soft fall / sand pit sands- kindergartens, wet & wild etc..
13. Landscape sand (lower end)- top dress etc.
14. Construction sands
15. Fill sands

QMS engaged Geochempet to undertake a high level analysis of sand samples deemed most likely to yield high end products. The review was focussed on the developed hierarchy of potential market segments above.
From this analysis it was clear that with washing and potential scrubbing of sand during processing it is likely that some of the above high end market uses may be achieved. This analysis then led to the development of the proposed concept plant provided in this report.

Note: It should be made clear that a full and complete plant design is required to accurately size individual pieces of plant and equipment and as such the information provided here is for concept consideration only and may change significantly depending on the sand feed provided for processing and the demands of the market into which the sands are being sold.

The concept process design involves dry mining and wet mining of feed and as such the sand will arrive at the processing plant in different moisture conditions and hence be processed differently.

Hardness / abrasiveness of material

4. Based upon testing of samples retrieved from the QMS stage 2 drilling program the sand lenses within the deposit are rich in silica which is a hard and abrasive mineral. The handling and process equipment to be used onsite is expected to wear due to the nature of this material and consideration should be made to incorporate replaceable wear parts where practical. This may include specialist chute and pump liners and hard facing of loader buckets or edges etc. From the previous QMS stage 1 and 2 investigations it appears that there will be no need for crushing of oversize rock or other particles as the deposit is understood to comprise entirely of sand lenses and a single mud layer band. Should oversize rock be encountered it will be quarantined onsite for later campaign crushing using mobile crushing equipment. This is likely to be outsourced to subcontract specialists and processed offsite as required.

1.6 Processing Plant

Option 1- (Rivergum Industries).

a. Dry Mining- Option 1

- Winning of feed
- Feed delivered to processing plant by haul truck
- Haul truck tips into feed stockpile / hopper
- Loader feeds grizzly screen if oversize present then onto a feed conveyor
- Feed conveyor to double deck screen (maybe a wash screen as required by product)
- Fines to waste stream and possible treatment
- Sand screw to radial stacker and final product

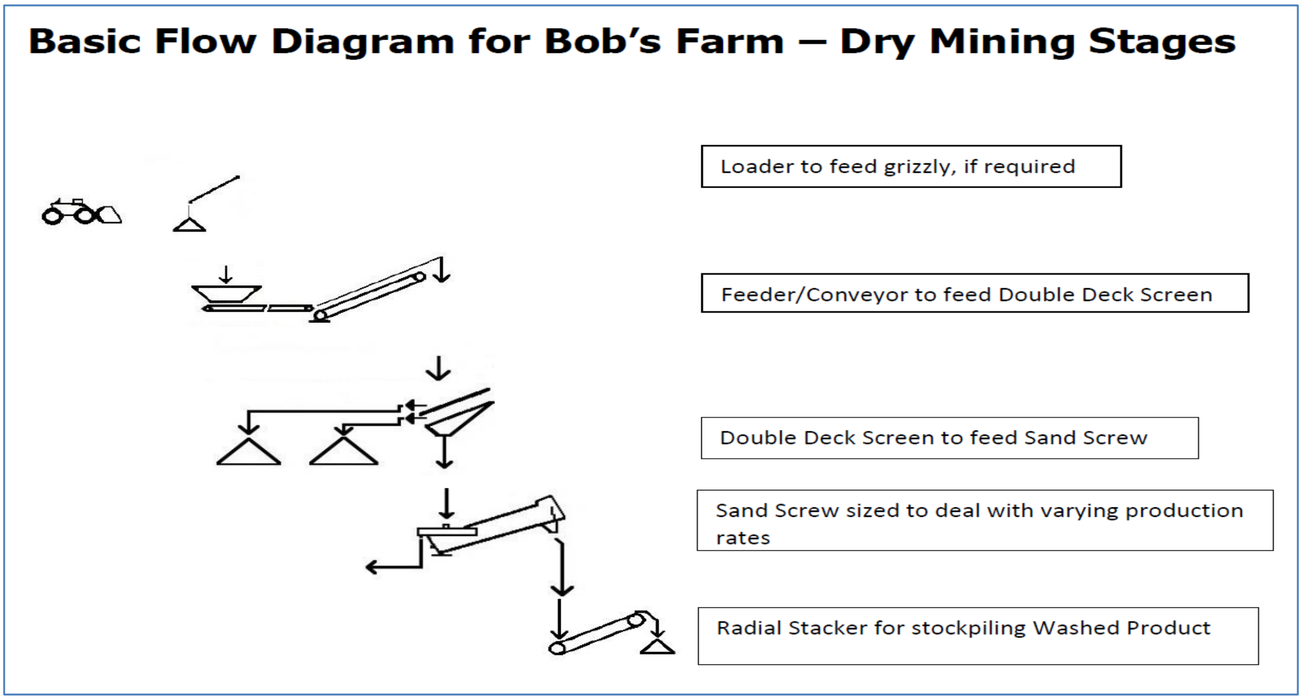


Figure 2: Dry Mining Stages

b. Wet Mining Option 1

- Dredge to pump box
- Pump to double deck vibrating wet screen
- Dewatering classifying tank
- Sand screws to radial stackers and final product

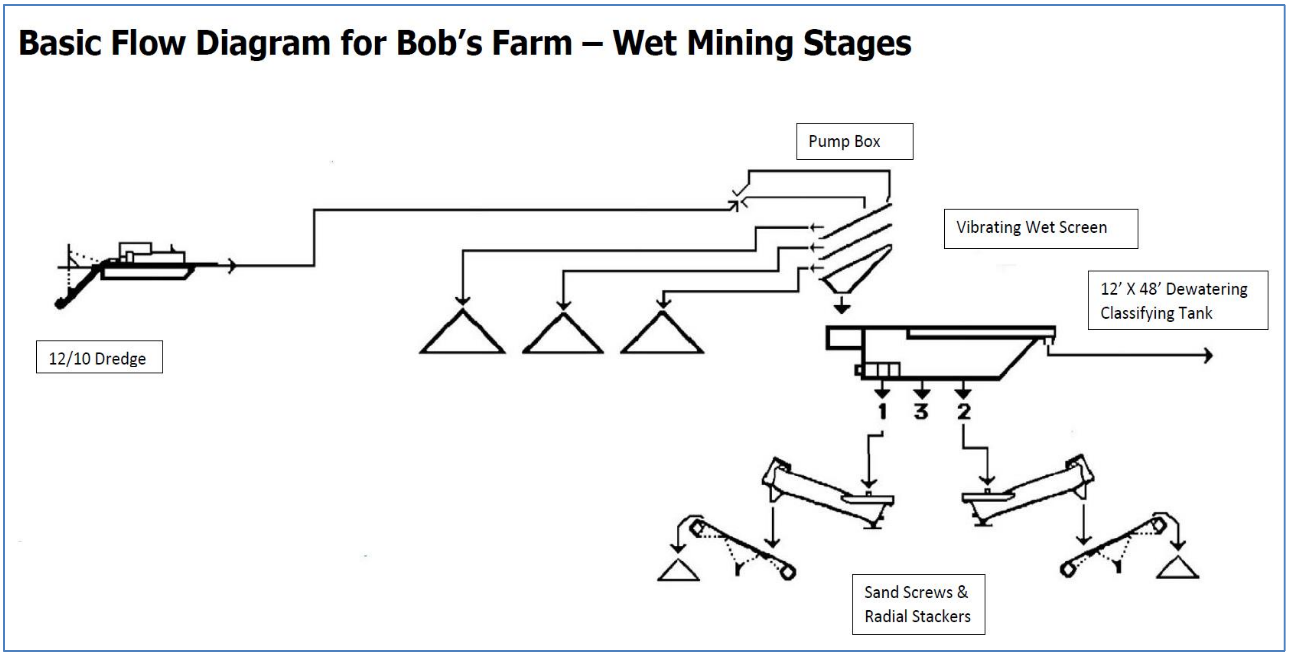


Figure 3: Wet Mining Stages

c. Possible Additional Plant Option 1

- Spirals for glass sand manufacture
- Attrition cells to remove stubborn adhering contaminants if required for higher market return on products

Details to be included in QMS stage 4 as a full plant design and further testing will be required to accurately size equipment.

Option 2- (McLanahan)

a. Dry Mining- Option 2

- Winning of feed
- Feed delivered to processing plant by haul truck
- Haul truck tips into feed stockpile / hopper
- Loader feeds grizzly if oversize present then onto a feed conveyor
- Feed conveyor to double deck screen (maybe a wash screen as required by product)
- Fines to treatment sump

b. Wet Mining Option 2

i) Process 1- Physical wash screening separation (screened sand)

- Sand feed to dump hopper via dredge
- Pump to double deck vibrating wet screen
- Screened oversize to ground as product

ii) Process 2- Cyclone and Hydrosizer (scrubbed and sized sand)

- Screened undersize to sump and pumped to cyclones 1 and 2 in parallel for separation
- Cyclone 1 and 2 and sump1 undersize to waste
- Cyclones 1 and 2 oversize to attrition cells 1 and 2 (to remove bonded contaminants)=> then Hydrosizers 1 and 2 for particle sizing

Process 3- Sump => Cyclone (Glass Sand)

- Hydrosizer 1 and 2 undersize=> to sump=> to cyclone 3=> dewatering screen and final washed/scrubbed/dewatered fine sand
- Hydrosizer oversize to sump 2 to pump2 to Spirals1 and 2 in parallel =>to dewatering screen and final product = glass sand

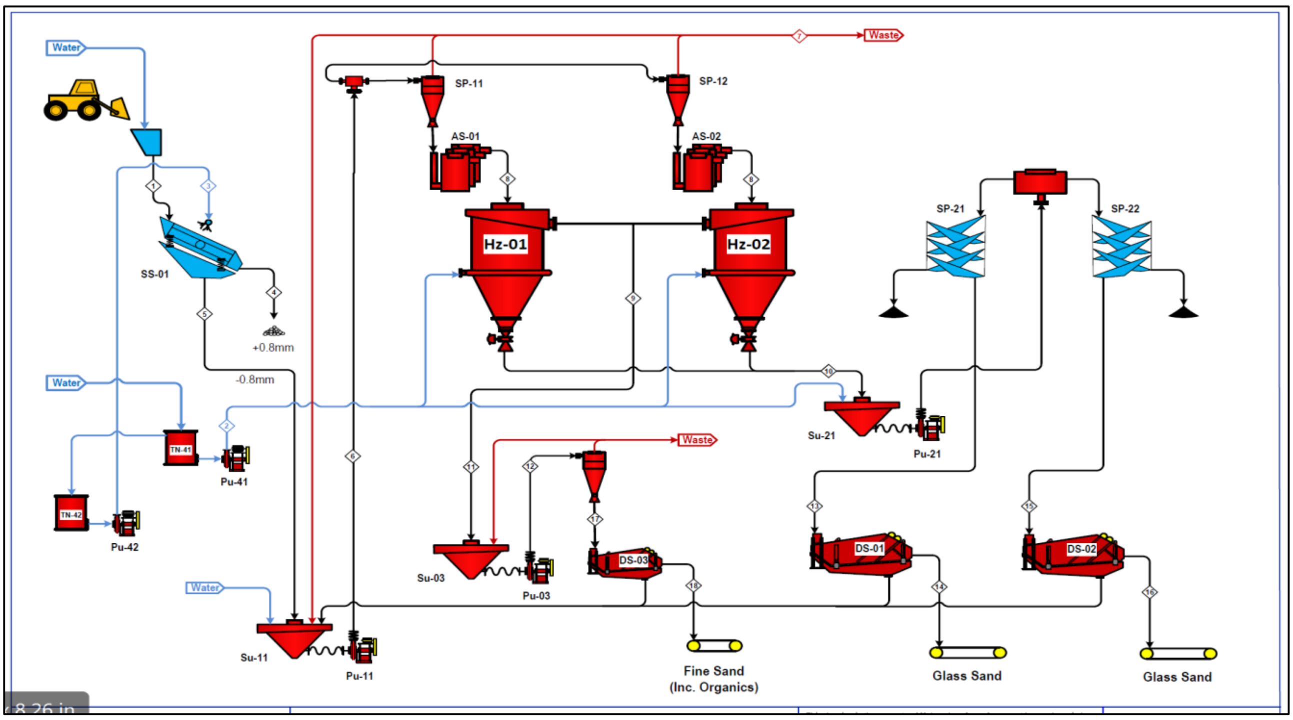


Figure 4: McLanahan Complete Plant Option 2

Project B140725

Quarry Mining Systems- Glass sand Plant

Initial Equipment Supply

Equip No	Description	Model	Supplier	Qty		Ex Works UK
TBA	*Dump Hopper/ Feeder*		*Client*	*1*	*0*	*By Others*
TBA	*D ouble deck scalping screen*		*CLient*	*1*	*0*	*By Others*
TN-41	Clean water receiving		MCL	1	*12,332*	
TN-42	Clean water receiving		MCL	1	*10,479*	
PU-41	Clean Water Pump & motor		MCL	1	*23,541*	
PU-42	Clean Water Pump & motor		MCL	1	*16,200*	
SU-11/21/03	Feed regulating sumps		MCL	3	*79,886*	
PU-11/21/03	Slurry Pumps & motors	250/200	MCL	3	*65,136*	
TBA	Separator Feed Manifold		MCL	1	*5,291*	
SP11/12	Separators to feed Attritioners		MCL	2	*41,310*	
AS01/02	*2 x Attition Banks (TO be advised*		MCL	*6 12?*	*466,560*	
HZ01/02	Hydrosizers	4m round	MCL	2	*123,525*	
TBA	Feed manifold for Spiral banks		MCL	1	*5,291*	
SP21/22	*12 bank 5 turn SC21 Spirals (TBA)*		MCL	*3 ?*	*94,770*	
SP03	Fines Separator		MCL	1	*16,200*	
DS-03	Fines dewatering screen	VD6	MCL	1	*20,250*	
DS-03	Underpan		MCL	1	*5,670*	
DS-03	Discharge chute		MCL	1	*5,822*	
DS-01/02	Glass sand dewatering screens	VD18	MCL	2	*81,000*	
DS-01/02	Underpans		MCL	2	*19,440*	
DS-01/02	Discharge chutes		MCL	2	*15,795*	
FS03/0102	*Finished product conveyors*		*Client*	*3*	*0*	*By Others*
MCC 0526	Central control cabinet complete		mcl	1	*202,500*	
SSTR 0526	Structural design		mcl	1	*50,625*	
SSTR 0526	Structure, stairways and platforms		mcl	1	*202,500*	
	Process pipe-work & Hoses		*Local Fabricator*	*1*	*0*	*By Others*
	Erection		*Local team*	*1*	*0*	*By Others*
			TOTAL Estimate AUD		**1,564,124**	

Figure 5: McLanahan Complete Plant Option 2- Budget price.

It is the opinion of this report author Option 2 from McLanahan appears overly conservative and it is proposed that during stage 4 a detailed plant design be undertaken to accurately size the plant and its application.

The above option 2 plant is more likely suitable where sand feed contains high fines content or clay minerals that are required to be vigorously scrubbed and removed. Further testing will refine this process and likely the number of cyclones and Hydrosizers will be reduced.

It is the opinion of QMS that, due to the single-sized nature of the sand lenses across the site, washing and separation by hydro-cyclone may not the best option in this case, and less effective than flatbed classifiers or other methods, in separating fines from the larger sand product.

Hydro-cyclones rely on cut points within the sand and remove the fines from the cut point down by changing the vacuum pump pressures/flow and weir design at the return sump. Where the sand feed is very single sized, as in the case of Bob's farm, the cut point will be very small and narrow and there is a risk that potential final sand product volume will be lost to waste if this cannot be controlled.

The use of Attrition cells and Hydrosizers to process the sand to higher end applications should be confirmed by additional trialling in stage 4. It may well be that they are not required and classifiers and spirals may be adequate.
In addition further plant options should be considered as a more detailed analysis in Stage 4 will lead to a more refined processing solution and a more accurate purchase price.

Estimated Concept Processing and Budget Plant Costs

1. General:
   - A new 12/10 dredge will be: $2,500,000
   - A reconditioned dredge would be $300,000*

2. **Option 1**- Estimated by *Rivergum* - plant supplier

   Dry Process

   - Dry Fixed Plant-sand wash only not high end processing. $850,000 - $1,000,000

5. Wet Process
   - Wet plant to match the dredge capacity: $2,200,000
   - Spiral system $1,000,000*

   Estimated Sub Total (AUS) $3,200,000

3. **Option 2**- Estimated by *McLanahan* - plant supplier

   Dry Process

   - Dry Fixed Plant-sand wash only not high end processing. $1,200,000

6. Wet Process
   - Wet plant to match the dredge capacity + Spirals: $1,500,000
   - US=>2,000,000AUD + feeders, chutes etc

   Estimated Sub Total (AUS) $3,000,000

2. MINING PLAN BACKGROUND

The proposed Bobs Farm deposit is situated on the northern end of the Stockton Bight Dunal system, approximately 200km north of Sydney, in Port Stephens, NSW Australia.

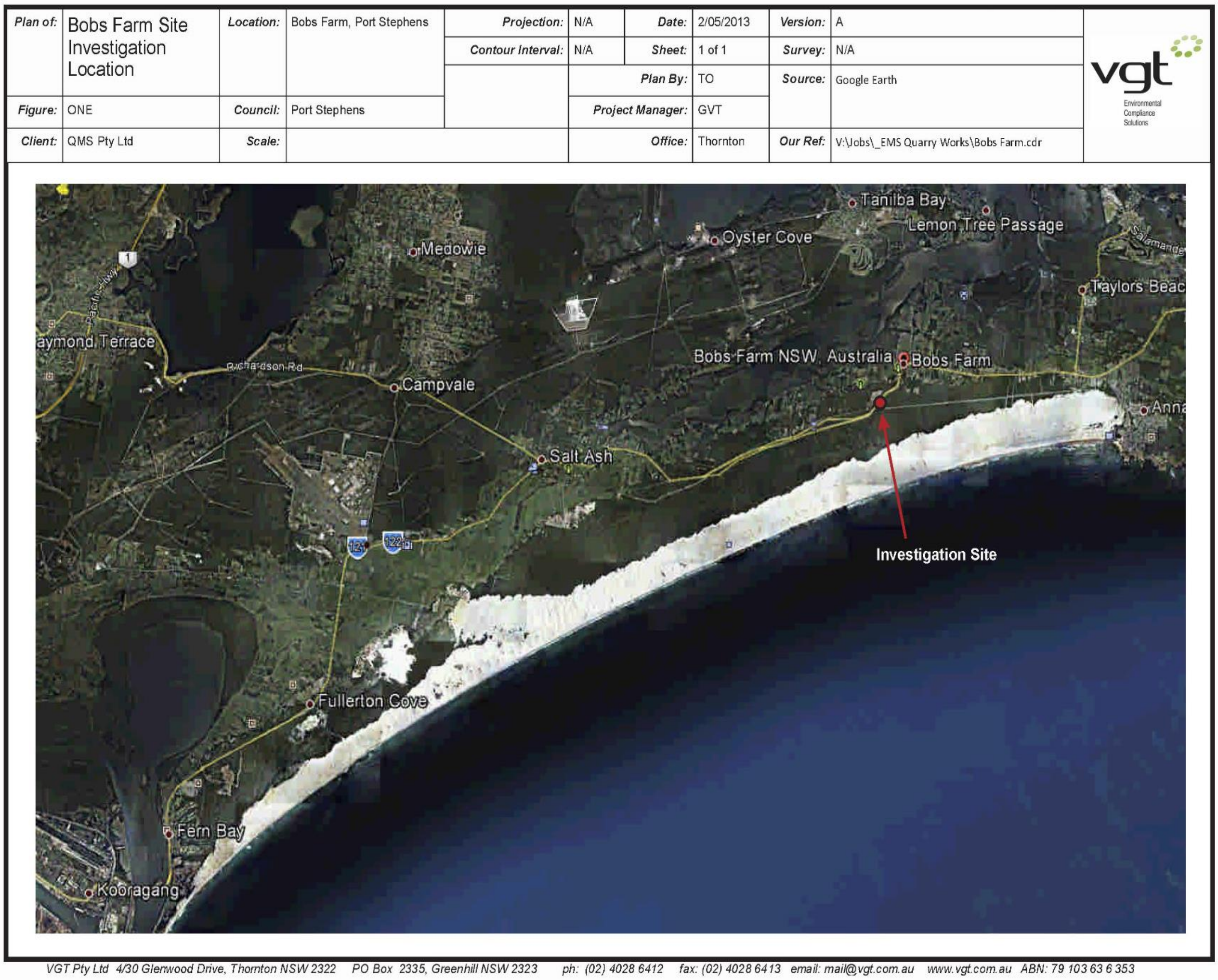


Figure 6: Bobs Farm Investigation Site- Stockton Bight NSW

The Bobs Farm site is an undulating property positioned between Nelson Bay Rd on the east and Marsh Rd in the north. The proposed deposit to be mined falls entirely within Deposited Plans DP753204 (40.9ha) and DP1015671 (6.63ha) with associated land at DP1071458 (2.53ha) outside the proposed extraction limit but also available for support of site mining activities, for potential fuel storage, plant maintenance etc. See Figure 7.

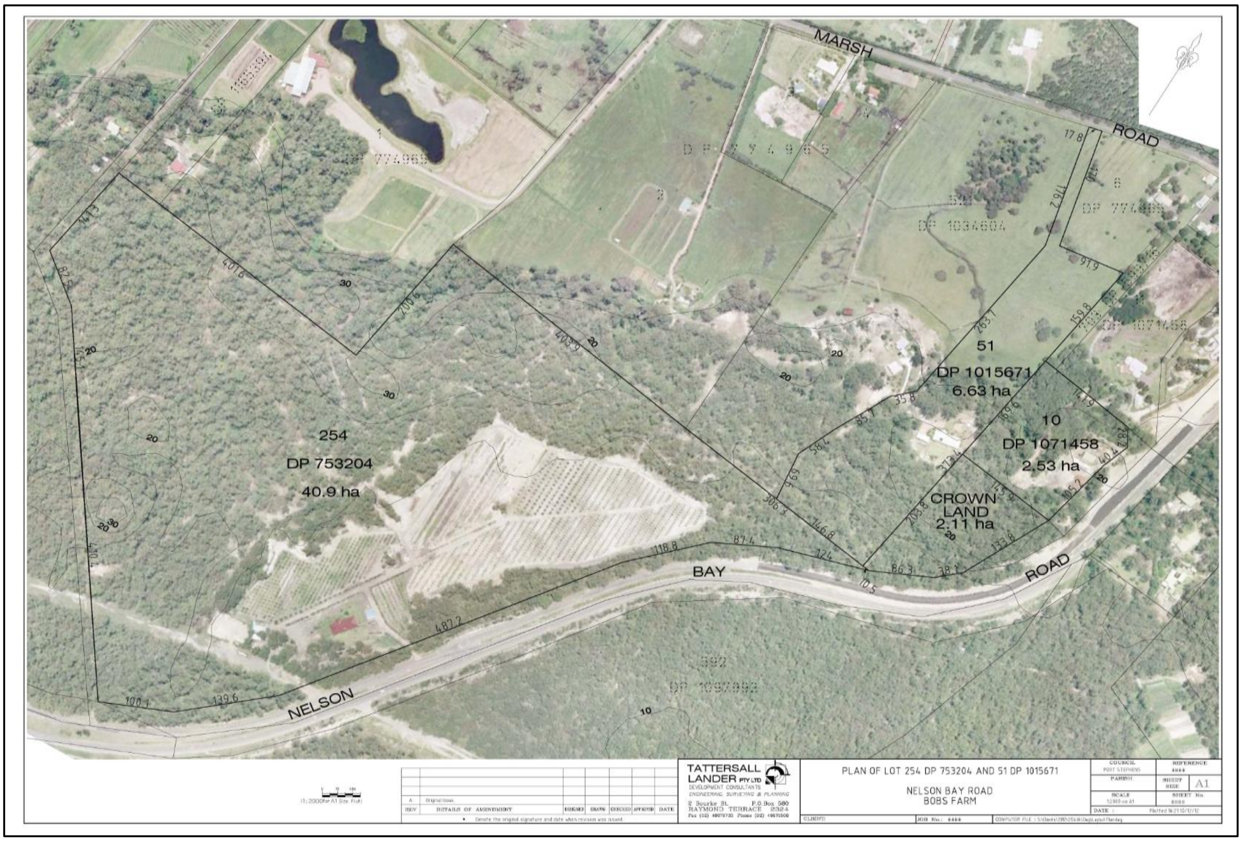


Figure 7: Bobs Farm Site

Entry to the mine site is proposed to be via Nelson Bay Road via a decelerating lane and entry for road truck vehicles, truck/trailer and truck and dog configurations. Exit from site is proposed via a dedicated route to Marsh rd. see SECA Solutions transport study (2)

As presented in the QMS stage 2 report the sand within the proposed Bobs Farm site area 2, Figure 8 is one of a number of sand deposits within the Stockton Bight region and comprises deposited dune and windblown sands found in the Holocene Epoch approx. 7000 years ago. Fanning (3) noted the two main landforms on the Bobs farm site were elevated dune ridge crest units to north and west and low relief sand plains to east with estimated formation at 4,500 to 7,000 years ago.

Note: Greg Thomson of VGT was utilised by Quarry Mining Systems as a specialist sub consultant in development of the Bobs Farm site proposed mining plan, reported here, providing advice on all aspects required for mine development. With significant experience in new mine start –ups Greg has provided significant support to this project.

Regional and site geology

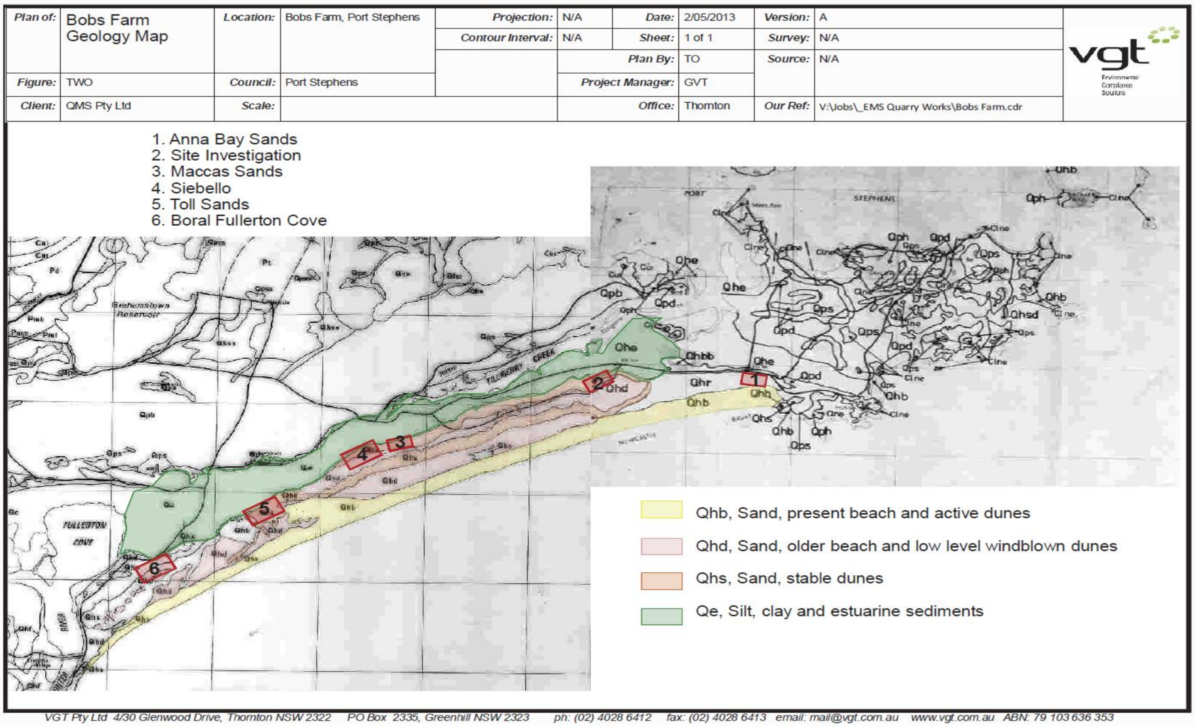


Figure 8: Comparable Geology within the region

Resource Exploration Results and Reserve Estimates

The QMS stage 2 drilling program confirmed that from the five (5) boreholes sunk, the following sand layer thicknesses were estimated.

Bobs Farm Site Stage 2 - Sand Volume Estimates					
Resource Type	**Borehole- Hole Depth (m) / Layer Thickness (m)**				
	1	**2**	**3**	**4**	**5**
Top soil / Root zone	0 – 3.8	0 – 3.5	0 - 1	0 – 0.2	0 - 1
Sand- Mottled / Upper Grey Sand	-	3.5 – 5 (1.5)	1 – 4 (3)	0.2 – 3 (2.8)	1 – 5.5 (4.5)
Sand– Blonde	-	5 – 10.5 (5.5)	4 – 14.5 (10.5)	3 – 5.6 (2.6)	5.5 – 17.5 (12)
Black Dark Mud /Sand	3.8 – 4.5	10.5 - 12	14.5 - 16	5.6 – 6.5	17.5 -20
Water Table- Hole Depth	3.5	10.2	13.2	7.3	15.4
Coloured Grey bands	-	-	-	6.5 – 11.5	20 – 22.6
Lower Grey Sand	4.5 – 19 (14.5)	12 – 26.5 (14.5)	16 – 26.5 (10.5)	11.5 – 24 (12.5)	22.6 – 26.5 (3.9)

Table 6: Sand Volume Estimates across the site

<u>Note:</u> Top Soil (is at or below existing surface), Dark Sand (at Orchard RL), Variable sand quality Mixed in BH2 (near Dump site), Mottled (across site, see Stage 1Test Pits), Blonde (above water table), Black Mud or sediment (normally just beneath water table), Grey sand with black fleck (deeper beneath water table)

Slope stability assessment

To ensure excavated batter slopes remain intact and safe before during and after extraction a slope stability assessment was undertaken by Martens. Based upon the Martens specified batter slopes the reserve estimates have been adjusted to 6,760,737m3 of mineable sand, (approx. 8,788,958 -10,817179 T depending on in situ compacted state between 1.3 to 1.6T/m3). This is also based upon the profile noted below in Figures 12 to 14 with a flatter beach zone located around the main deposit. See Figure 19.

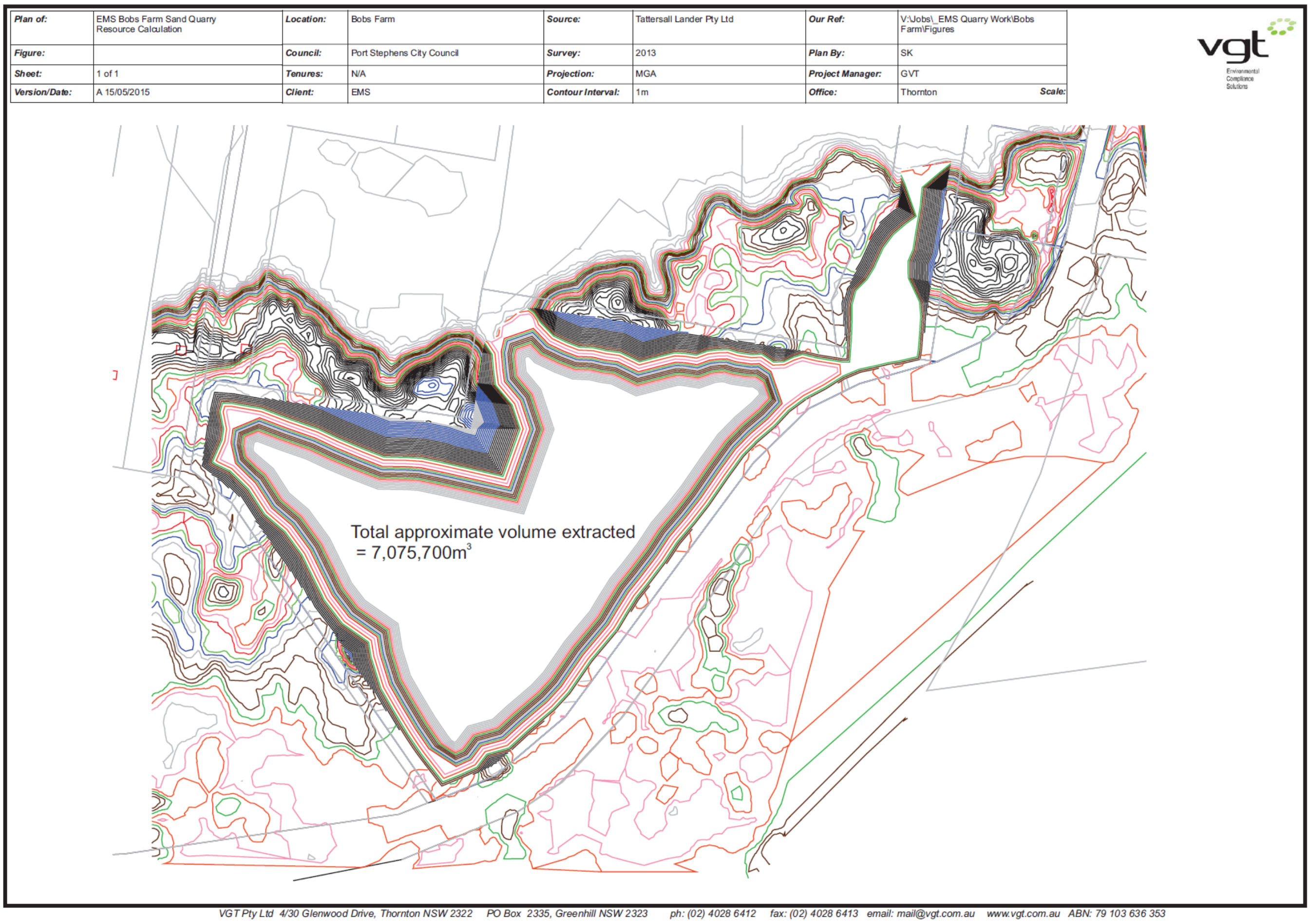


Figure 9: Proposed final resource volume based upon cross-sections provided by Martens and TL

Acid sulphate soils

Within the Bobs Farm site it was identified that during formation and deposition vegetation had grown at the approximate level of the then water table later to be over-topped by new deposition of sand. This vegetated layer, between the sand layers, had broken down over time and has been identified by testing from Martens to have the potential for acid sulphate soil formation, (PASS), if untreated and allowed to freely mix with oxygen overtime (oxidise). To address this the mud layer in question will be selectively removed by excavator and treated with lime to increase the pH to above 5 as per Martens requirements. This will be done by dosing the sand water mixture in a contained bunded area. Testing will validate the treated sand pH before any water will be returned to the site water table. In this way the PASS will be managed overtime.

The dry mining option provides an opportunity to extract the black clay layer with, a high PASS, and treat this material without potentially impacting the whole water body.

Structural features

From reported Geomorphological Assessments made (1)"The Bobs Farm site comprises two main landform units: elevated dune ridge crests to the North east and low relief sandplain to the east." The dune crests are believed to have remained stable since formation while the transgressive dune has been significantly disturbed overtime and incorporates the current orchard and residence and work areas.

Compaction characteristics of resource (in situ)

The sand on the Bobs Farm site is predominantly packed sand which has interlocked overtime to form the current deposit. Based upon the QMS Stage 1 and 2 investigations the sand appears to be easy to extract with little clay or mud layers to cause issues with soil cohesion. Induration hardening of soft sediments has not been encountered to date in the QMS Investigation Stages 1 and 2. The sand deposit is readily rippable and expected to be easy to win and transport by haul truck or later with suction/cutter dredge.

Topsoil

The sand onsite is believed to have been deposited approx. 4,500 to 7,000 years ago with podsoil profiles noted to approx. the top 2 metres of the site. It is this soil that will be reclaimed and stored as much as operationally possible to be reused for later rehabilitation of the site post mining.

Nature of Fines

Based upon the QMS stage 1 and 2 investigations the sand within the Bobs Farm deposit does not contain significant levels of clay or silt within the finer fractions and as such it is anticipated that the by-product silts produced from processing are expected to be low and easily managed within the site operations. Where fines are produced they will be regularly tested for chemical and physical properties such that they may be re-used in future saleable products or in site rehabilitation. PASS fines will be treated as per Martens specified requirements and lime dosed to ensure pH remains >5

Overburden characteristics

From previous QMS stage 1 and 2 investigations it was clear there was little overburden present across the Bobs Farm site, up to 2 metres depth in places. The process of clearing and stripping of surface vegetation will be expected to remove most of the overburden of root zone contaminated sand; but this will be stored onsite for later reuse to save the valuable seed stock of natives. In addition this material will be important for formation and vegetation of permanent bunds and berms onsite.

Unique landforms (e.g. geodiversity, cultural significance)

Unique landforms within the site had been identified by others with the mining envelope developed by Tattersall Lander ensured mining operations do not impact on these protected areas.

Water table/ groundwater

The water balance has been developed by Martens and incorporates the water level rise and fall with season and the staged mining approaches proposed. See later in report.

Statutory Requirements, Licensing and Tenure Factors

The following factors are to be addressed by TL and other sub-consultants:

- Climate change impacts – sea level, GHG emissions
- Consent uses, prohibited uses
- Contour plans and aerial photos
- Excavation limits
- Forestry / agriculture and other resource values and land uses
- Land tenure
- Mining tenure v extractive tenure
- Planning scheme intent – extractive industry?
- Real property descriptions, property boundaries
- State and local government planning policies/ environmental licencing
- Ownership
- Royalties payable
- Zoning of lands, land use; existing and surrounding

Fuel / chemical storage

Fuel or chemicals are not to be stored within the area of extraction and any handling of fuels or re-fuelling of mobile equipment is to be done in conjunction with operational requirements for the site and all relevant legislation.

Hours of operation

During construction of the mine the proposed operating hours will be for 12 hours per day, 6am to 6pm, Monday to Saturday with no Sundays or Public Holidays.

During initial operation of the mine 12hrs will be available however it is estimated that production will commence as a single shift of 8 hours, with provision for an additional 10 hour shift if production and or sales demands require it.

Production is based upon 11 months per year, 19 days per month and 8 hours per day. This allows adequate time for plant and equipment maintenance, staff leave, shutdowns and miscellaneous unforseen stoppages etc.

Leases, easements, rights of way, encumbrances etc.

Within the Bobs Farm site there exists a 33kV (TML) Power line easement which cuts the site in the south-eastern corner of the extraction zone. It is proposed that dry mining would commence in this area no earlier than year two and the access along the easement will remain trafficable with maximum slopes of 2.5:1 to the mining face to maintain pole stability as per Martens slope stability determinations. Longer term it is proposed that the Ausgrid easement would be moved into the post-mine batter along Nelson Bay road. Upon relocation of the power poles this area will be wet mined to the final batter slope approved by Martens.

Access and right of way has been determined by SECA as part of the traffic management plan for the site outside of the extraction areas. This including entry to the site via Nelson Bay Road and egress onto Marsh road. Within the extraction zone and bunded area dedicated haul roads will be established to minimise travel times from extraction to processing plant.

Within the site there exists current dwellings and sheds which will remain as a caretakers quarters and are outside the extraction zone.

The road easement within the northern area of the site will remain to allow east-west access across this area. The area north of the road easement will be dry mined only to the final Martens approved batter slope. This is noted as Pit 3 in Figure 10 of this report.

Within the site there are 5 permanent wells which are located at the previous 5 boreholes sunk in the QMS stage 2 drilling. Data was collected by Martens as part of their earlier groundwater studies and the bores with the exception of BH4 will be removed during the mining operation and will need to be relocated to become long term monitoring bores – refer Martens Groundwater Management Plan Report.

Electricity to run the fixed processing plant will be available onsite via underground cables within a controlled services area of the site.

Noise

During the construction, operation and maintenance of the mine site there will be noise generated from mobile equipment and fixed processing plant.

Dry mining above the site water table will produce noise from extraction and processing, while wet mining is to be by suction/cutter dredge and once in operation will significantly reduce overall site noise.

Noise impact across the site will be minimised by locating the processing operations close to Nelson Bay road where the existing traffic noise will lessen impacts. In addition a dedicated permanent vegetated bund will be provided to Nelson Bay road to provide an audible and visible barrier between the travelling public and the mining operation. See Vipac report (Appendix 8). Temporary noise bunds will be constructed in accordance with VIPAC reported requirements to the 2.5:1 slope stability design provided by Martens. These bunds will only be required for dry mining, will be made of existing sand material and when mining is finished will be removed, again under the construction activity noise guidelines. Stripped timber will be used for poles and fence posts where possible. Any remaining material will be mulched under the noise activity document requirements.

Air

Dust from mobile equipment will be minimised by sealing the main haul roads with sprayed bituminous seal and minor roads with suitable gravel etc. A water cart will ensure haul road dust levels are controlled and the use of processing water and natural dust supressing agents will be incorporated as required to minimise dust level within the processing areas. Upon commissioning and operation of the suction/cutter dredge dust levels onsite are expected to reduce significantly. See Vipac report.

Surface and groundwater

The water balance and management cycle for site water has been designed by Martens with consideration made to the required water to wash and process the sand feed to saleable products. Upon establishment of the suction /cutter dredge the demand for water drawn from the site water table increases and the operational aspects are detailed later in this report.

Water delivered with the sand feed will be tested at the processing plant for pH and in accordance with Martens Groundwater Management Plan, water with a pH < 4 will be treated prior to discharge into the lake. This process water will not be returned to the site water table until the pH has been confirmed to be 4 or greater as per Martens requirements for PASS material. See Martens report

Flooding

During construction surface water flows will be encouraged to flow into controlled drainage areas that will not negatively impact the site or its surrounds. Permanent vegetated bunds or berms are to be in place with significant freeboard to accommodate rainfall and counteract evaporation of water from site. This forms part of the overall water balance designed by Martens. Refer Martens Surface Water Management Plan.

Waste management

Waste onsite is expected to be predominantly the silt/fines remaining after the washing and processing of the sand feed. These fines will be tested for chemical and physical properties and will be incorporated into saleable products where possible or used in site rehabilitation or if unsuitable removed from site using appropriate waste management processes.

Energy efficiency

Within the site energy efficiency will be maximised to reduce operating costs and the carbon footprint for the site. This will form part of the overall operational sustainability plan for the site.

Rehabilitation, post-mining land use

Mining of sand across the site is to develop under an active extraction cell process. Upon opening of a cell the rehabilitation process is to commence such that the Martens approved maximum batter slopes are maintained and slope stability risk minimised. The use of soft slope stabilisation such as plants or hard stabilisation such as rock/rip rap, gabion, or larger spalls or amour stone will be directed by TL to suit final post mining landforms.

Safety – public, employees, contractors, visitors

The safety of employees, contractors, visitors and the general public will be maintained overtime by control measures implemented across the site. Controlled access to specific areas of the site along with physical separation of the public from the mining operations by bund walls, berms, gates or fences will assist in this area.

Staging plans

The development of the proposed Bob Farm site will be broken into a construction phase, operation and maintenance phase and at end of mine life a final land use phase.
Each of these phases will form part of the overall use for the site and will need to be flexible enough to service the required market need, social, environmental, economic and operational requirements for the site and the region in which it is located.

Transport routes

Site access is to be via Nelson Bay road and site visitors are to report to the site office located at this entrance. Trucks entering the mine site are generally going to travel to the stockpile/ sales area for product load-out and ticketing unless they have a specific product or service for the site approved and supervised by management. The site transport plan has been provided by SECA with exit onto Marsh road once trucks are loaded, ticketed and cleared to leave site.

Vibration effects from activities

Vibration from site has been modelled by VIPAC and will be minimised by operating a lean fleet of mobile equipment. Controlled haul road speed limits and driver behaviour. Better efficiency in processing of sand feed, including use of water and controlled feed rates to ensure consistent plant workload rather than unnecessary operational peaks etc.

3. EXTRACTION OF PLANT FEED

Mining of the Bobs Farm deposit will be dictated by the market demand for the final sand products in each market. Given the variable sand layers within the deposit the mining plan proposed for the site is flexible enough to take advantage of this variability to allow different sand markets to be exploited.

If all sand was mixed in together and processed niche markets may be lost and the overall profitability of the operation put at risk.

It is believed, by QMS, that a mining plan that incorporates dry and wet winning of feed allows the opportunity to exploit niche markets as the sand is dry mined down towards and below the water table. In this way the maximum end use can be achieved for the benefit of the deposit and the community using this valuable construction material resource.

To minimise slope stability issues in dealing with large faces of exposed and unconsolidated sand it is proposed that extraction of feed is undertaken in stages such that the working face of sand is as low as possible and controlled at all times, in accordance with Martens slope stability determinations. This significantly reduces risk with operation of mobile plant and allows selective mining as required to service different markets.

Dry mining of feed is expected to involve excavator and haul truck to processing plant while wet winning of feed is to occur with a suction/cutter dredge established on a pond at the water table surface. This dredge once established will remain within the pond for the life of the deposit and is expected to mine to the final landform below the water table.

3.1 METHODOLOGY

Extraction and Infrastructure Factors (Operations)

The extraction and operational factors will be finalised within the site operational and sustainability plan, which will be developed in subsequent stages of investigation.

Ancillary activities and Weighbridge.

Additional activities and weighbridge / loader bucket load cell details will be confirmed in the aforementioned Operational plans.

Proposed Operations

Within the eastern side of the Bobs Farm site, adjacent to Nelson Bay road will be the proposed processing stockpiling and sales areas. Within this location the processing plant will be positioned to accept the sand feed from which saleable sand products will go to ground and be stored in stockpiles or for higher end products potentially within a dedicated enclosed shed to maintain a controlled moisture content for specialist client applications.

The footprint and detail of the plant will be confirmed in the QMS stage 4 when a full plant design will be established.

Sales load out from stockpiles is to be conducted by dedicated sales loader(s). These Front End Loaders (FELs) should ideally be sized to match the intended road truck sizes used to transport the saleable sand products with the minimum of loading passes required.

The rate of sales load out will be determined by the sales demand for the final sand products and hours of operation.

During the sales loading process, to confirm the quantity of material loaded onto individual road trucks the buckets of the FELs will have load cells attached which will be calibrated to weigh, record and ticket each truck individually. A dedicated weighbridge is not proposed for the site at this stage unless production dictates it is needed at which point this will be fully investigated and constructed in accordance with all relevant legislation and sustainable site practices.

The delivery docket/ticket for each truck delivery will be printed at a dedicated pick up point where the driver of that truck will retrieve the ticket from the printer.

All truck movements will need to comply with the SECA transport management plan and NSW legislation for truck transport weights for given axle/body configurations.

Pumps

Pumps will be used extensively across the Bobs farm site as a means of transporting and processing sand material, washing and mine development. During wet mining phase of this mine the main means of winning feed will be by pumping, from a suction cutter dredge to processing plant, so pump efficiency will be of utmost importance.

Pumping operations will be optimised to minimise power requirements for the site and associated fuel spend as part of the sustainable operation procedures. Pumps will have protective liners fitted to reduce internal wear and prolong the operating pump life, where possible practical or economically feasible.

Waste dumps

Waste generated from site is mainly expected to come as by-products from earlier processes, including washed sand tailings and rejects, unwanted vegetation, PASS which will be treated as part of the Martens designed process. Fuels, and chemicals etc. will be handled offsite in accordance with sustainable operation procedures and relevant legislation.

Bench / batter widths, face heights, orientation

Any benches, batters or exposed sand faces to be established within the Bob farm site will be done within safe mine operating practice to suit the mobile plant and equipment under use and the overall site operational plan, in accordance with Martens slope stability guidelines. Where they are to be regularly trafficked by light vehicle, truck or other vehicle, benches and batters will be appropriately designed by a suitably qualified geotechnical engineer for the expected loading they are likely to receive overtime.

Benches, batters, berms and exposed sand faces will be oriented to minimise site noise and visual impacts and minimal wind-blown sand across or off site. All batter designs are provided by Martens.

Electricity supply

Electricity will be supplied to the site from an operating main and will be utilised onsite to run lighting, pumps, processing plant, and amenities. Where electrical cables are run underground they will be clearly sign posted and noted within the site operational plan. Where electrical power is to be run above ground any overhead wires will be supported in accordance with all legislative requirements, including height above ground in trafficable and non-trafficable areas, isolation and on-site labelling or identification etc.

Fuel, lubricants, chemical storage

There will be no fuel, lubricants or chemicals stored within the site extraction zones. All storage of such items will be offsite and in accordance with relevant requirements for the material being stored, including suitable hardstand and bunded areas as required.

Future planned development

Final landform and future planning for the site is to be completed by TL and others.

Haul truck fleet

Haul trucks within the Bobs farm site are to be matched for size and capacity with the loading equipment and the processing to allow the required quantity of feed and saleable product to meet production requirements and potential sales demand.

The number and capacity of mobile equipment will increase and decrease over the life of the deposit depending on what stage of development the site is at a given time. This is discussed in more detail later in this report.

Internal road system

Roads outside of the site mining operation are modelled and reported by SECA and the haul roads within the mine site are to consist of dedicated haul and localised access roads to assist extraction and processing. As stated earlier in this report to minimise dust and noise the major haul roads will be sealed with a bituminous seal while minor haul and access ways established with a prepared gravel base. All roadways are to be constructed within accepted mining standards to be trafficable by loaded and unloaded haul truck(s), maintenance vehicles and light vehicles as required.

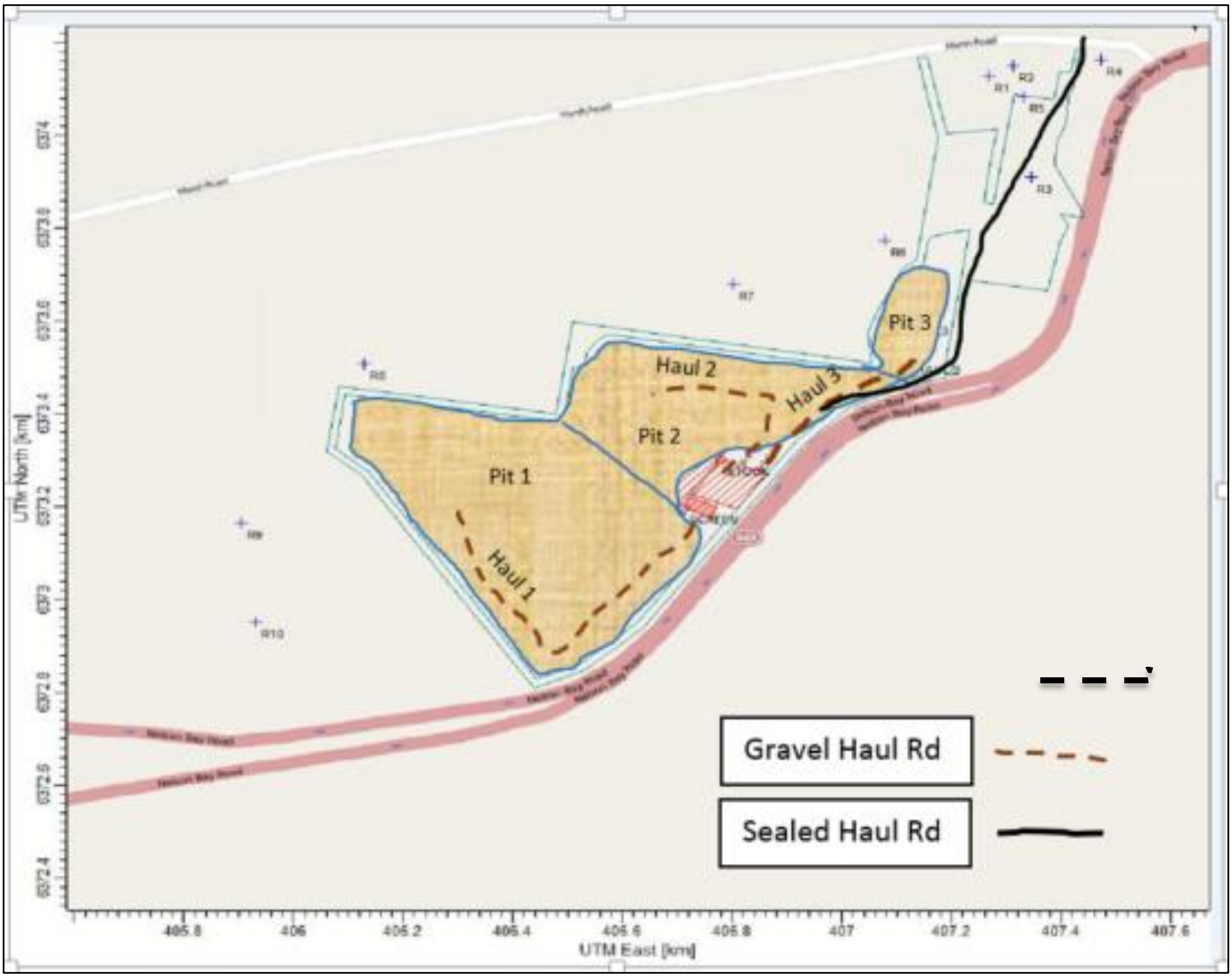


Figure 10: Proposed Haul Roads Onsite

Limits of extraction; other constraints

The extraction limits for the site are based upon a 15m offset from site boundaries and easement from identified flora and fauna and provide a working envelope with batter slope as determined by Martens for slope stability before during and after mining operations. The site is broadly categorised into three sections: Pit 1, Pit 2 and Pit 3. Each area will be opened as part of the site operational plan and closed as part of the site rehabilitation plan provided by others.

Figures 11 to 14 show an overview of the site including batter slopes, lot areas and site cross-sections through the mining envelope.

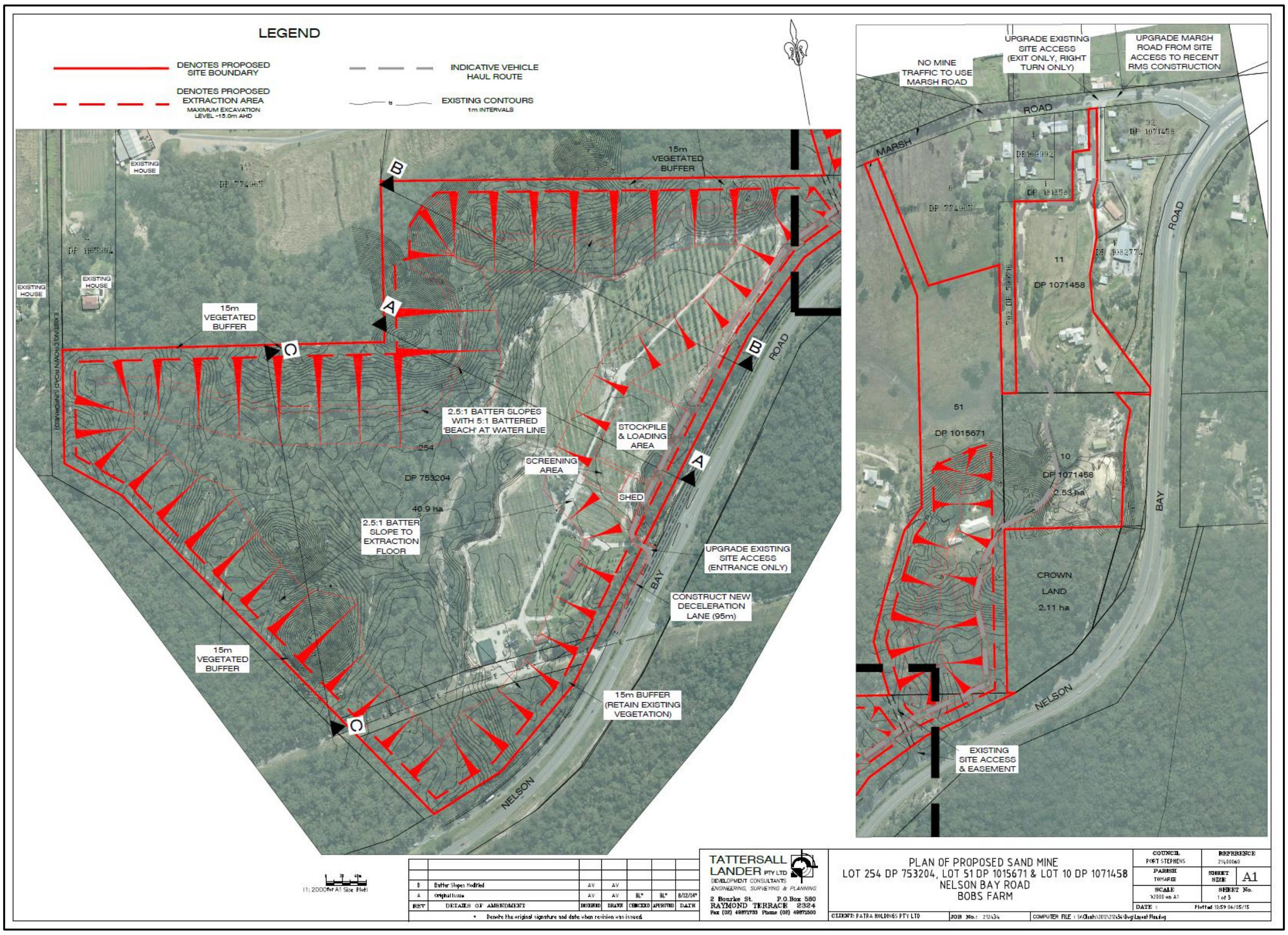


Figure 11: Overview of Extraction envelope for Bobs Farm Site

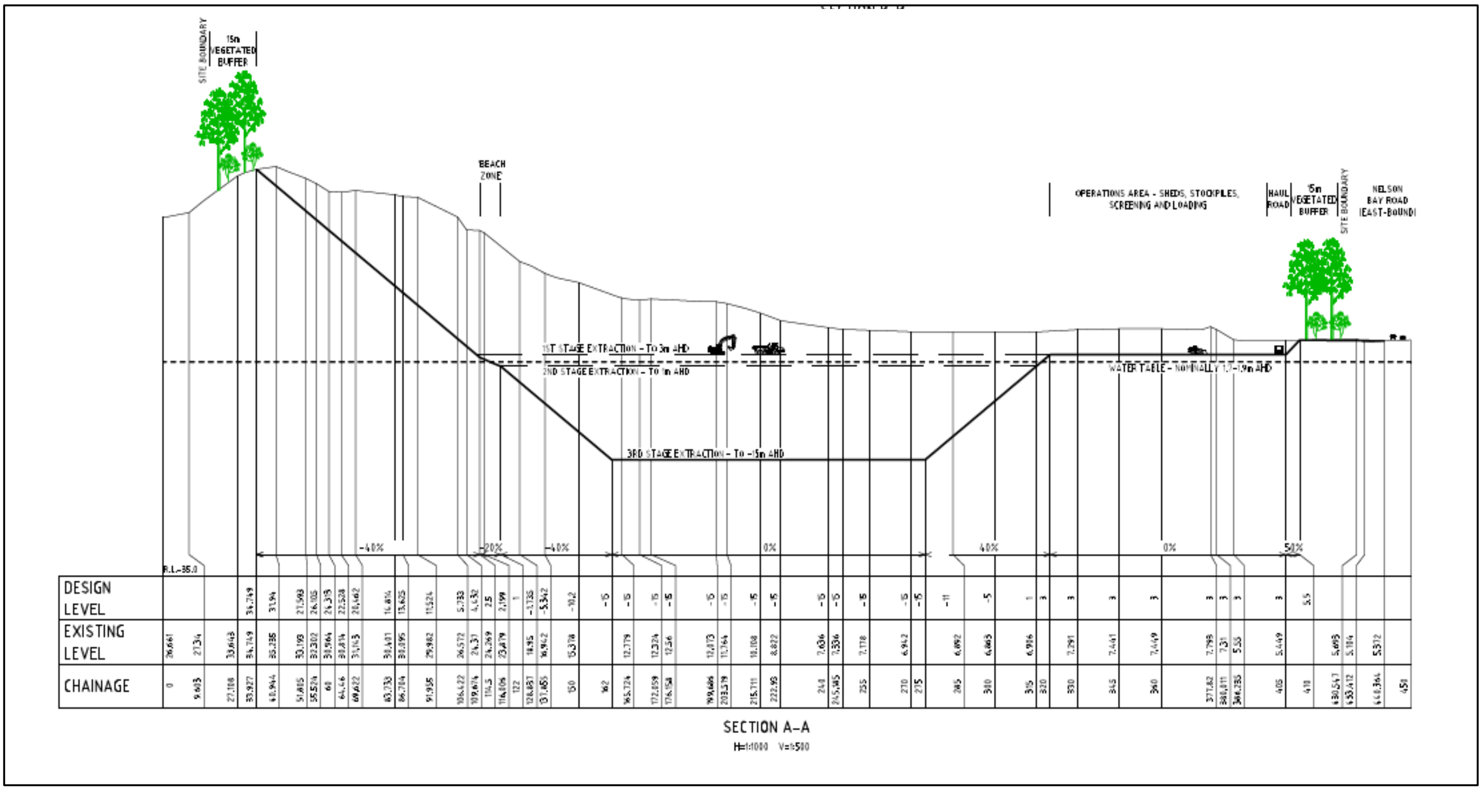


Figure 12: Section A-A through the proposed mining envelope

As can be seen from the proposed cross-sections depending on the location within the site extraction zone the final landform cross-section will be different. The final batter slopes, as discussed earlier in this report, are determined by Martens as part of an overall geotechnical investigation of the site.

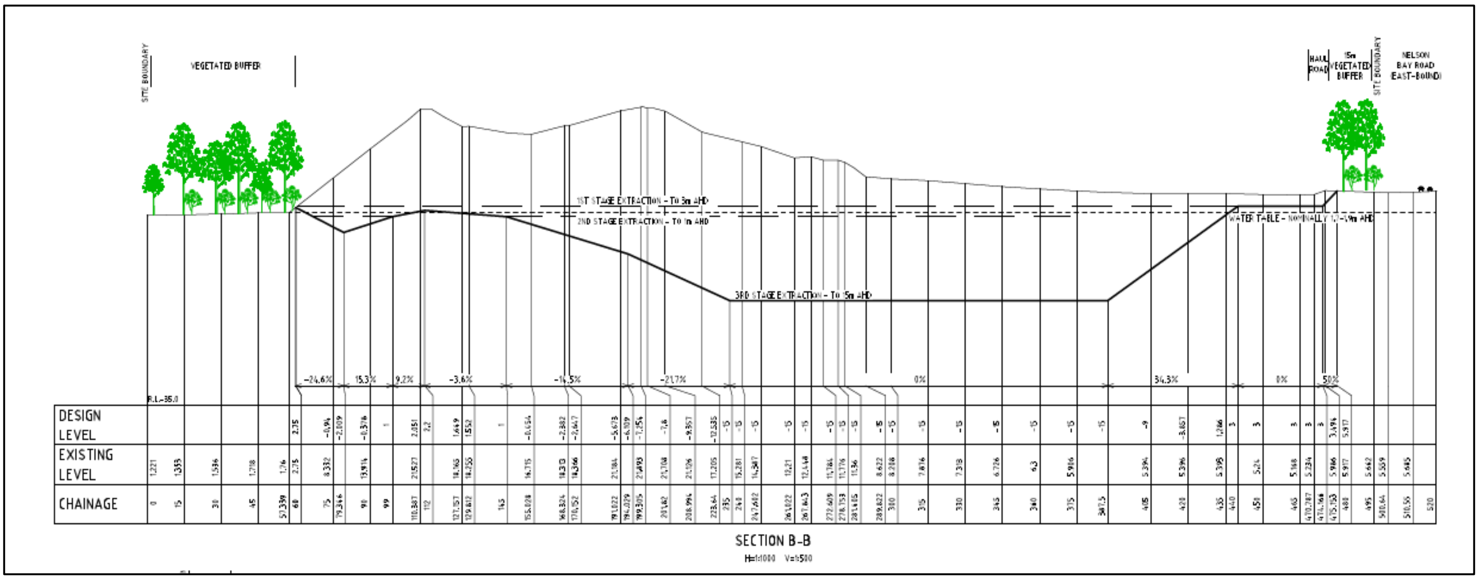


Figure 13: Section B-B through the proposed mining envelope

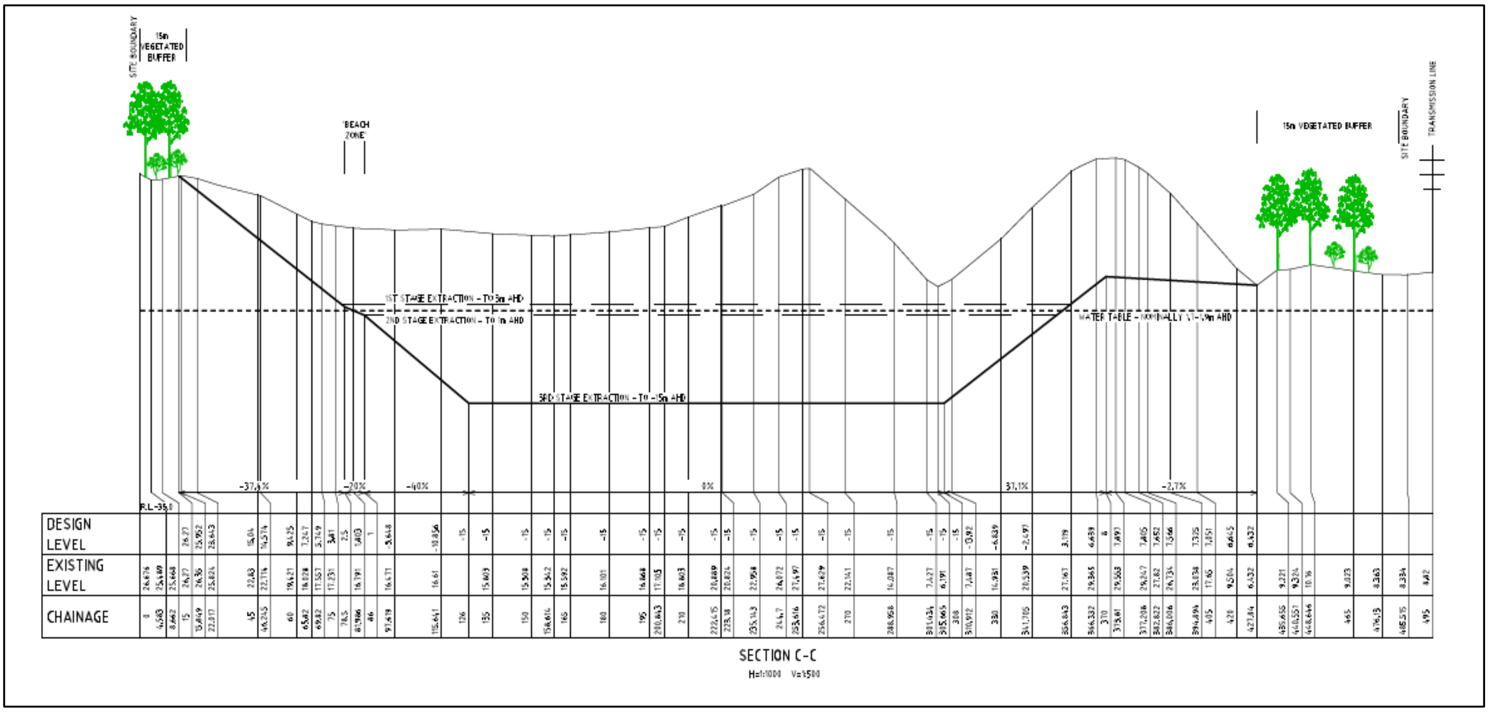


Figure 14: Section C-C through the proposed mining envelope

3.2 Mining method (s) - Active Extraction Cells

As the sand within the Bobs Farm deposit is very single sized it is important that the exposed areas of sand are minimised, at any given time, to avoid windblown sand across the site. To achieve this the concept of active extraction cells was introduced by QMS; which provides a small area of deposit which is stripped mulched and prepared for mining then after extraction is rehabilitated and closed off (inactive) before commencing the next production cell.

Over time the extraction cells will be active when ready for mining production and inactive once extraction has been exhausted and rehabilitation has been commenced. The extraction cells will follow a pre-determined route across the Bobs Farm site based upon a point of entry at the most convenient entry point and a point of exit via Marsh road at end of mine life. See Figures 15 and 16.

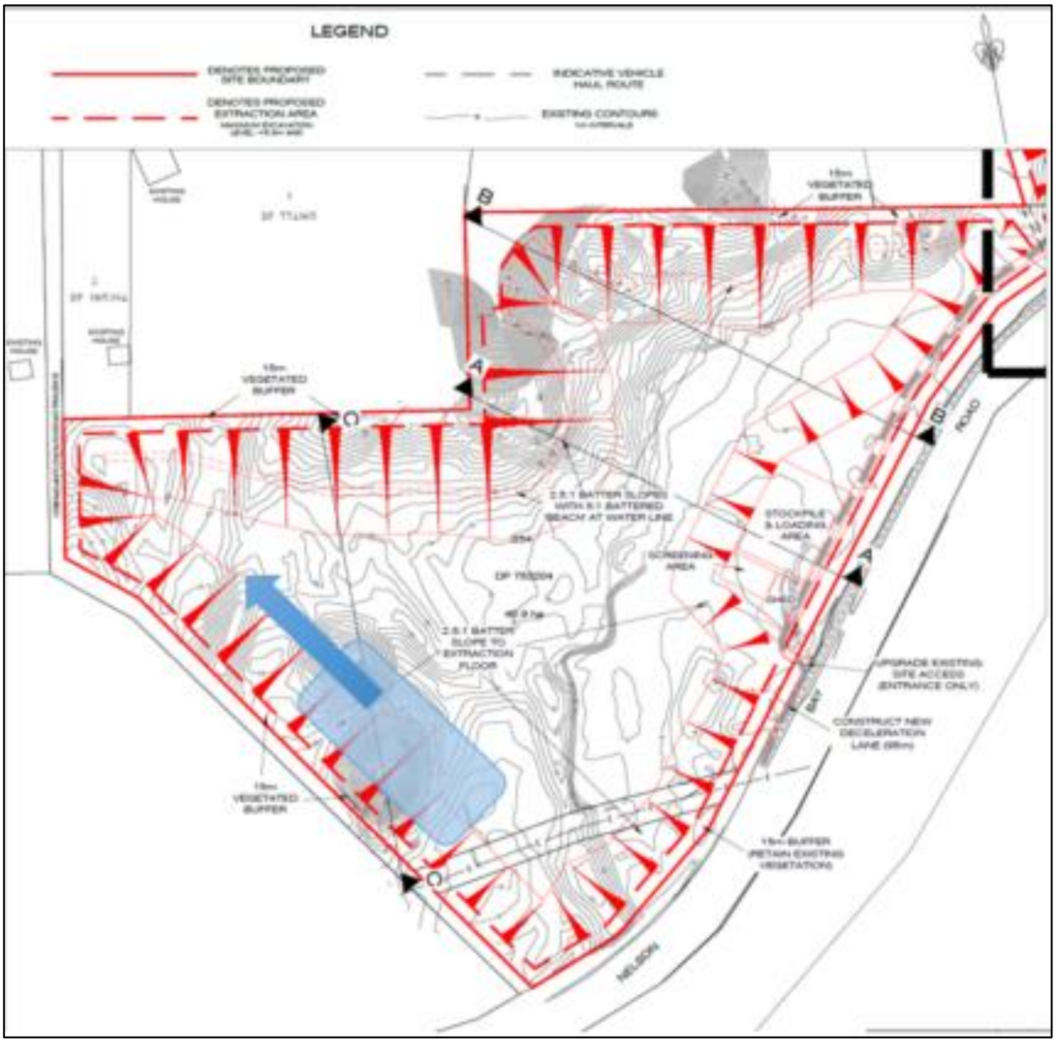


Figure 15: Active Extraction cells

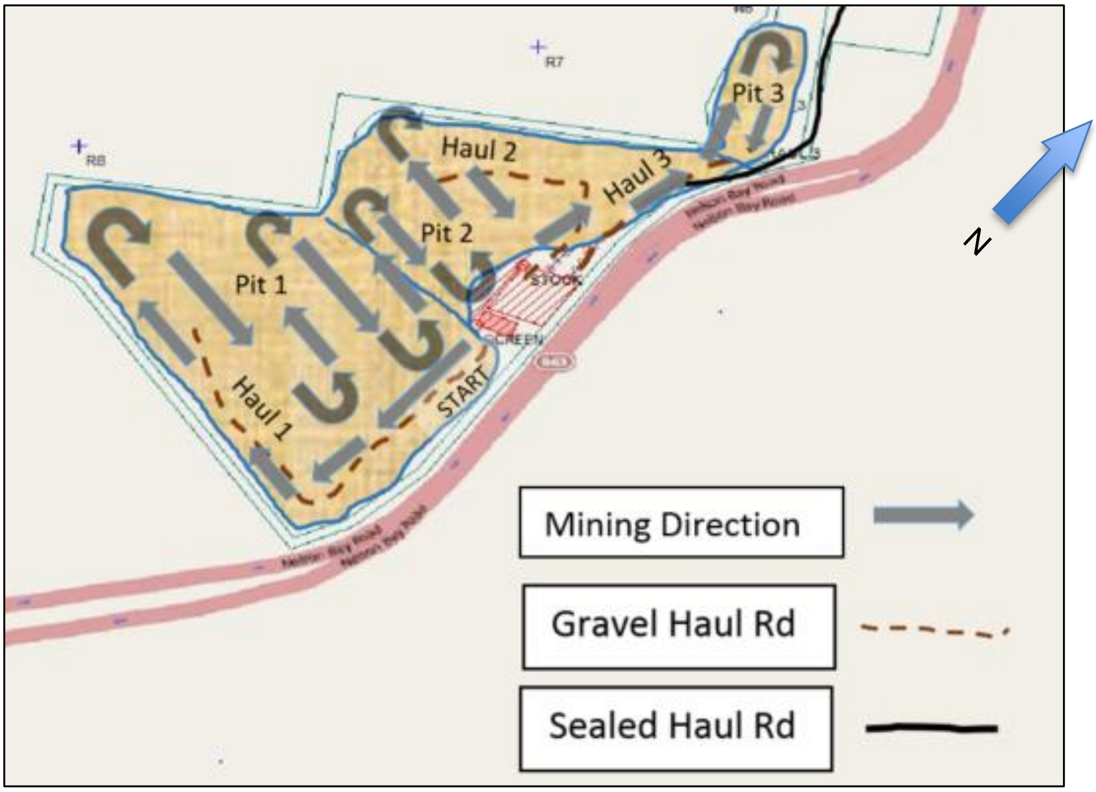


Figure 16: Active Extraction cells move across the site for controlled extraction of feed-

As can be seen the active cell extraction is planned to commence in the south eastern corner of the site extending west then returning east as per the illustrated extraction flow direction

Mining method (s) – Beneath Existing Power lines

Existing power lines stretch across the south eastern corner of the site and dry mining of sand is to commence from existing ground level to 2m AHD under controlled conditions. There will be (1) one only under-pass / cross-under area beneath the overhead lines which will accommodate traffic in two directions. This will be established and maintained to all relevant safety and operational requirements. All other existing easements and buffers to the power lines will be maintained until later stages where the existing lines will be relocated into the permanent bund near the site boundary in conjunction with Ausgrid and relevant council requirements etc.

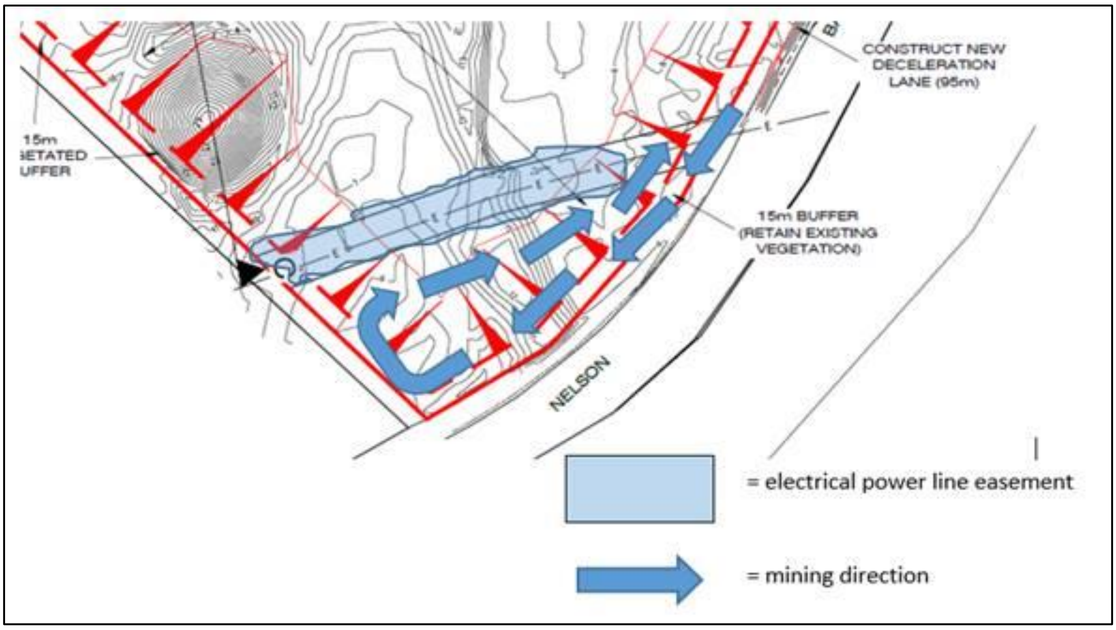


Figure 17: Existing overhead power line easement to be maintained with one cross-under as shown.

Each active cell is to be stripped of existing vegetation in turn and prepared for mining. It will then be dry mined to within 2 metres of the water table, before switching to wet mining. Main haul road 3 will be constructed and maintained with a bituminous seal to minimise dust generation; with haul roads 1 and 2 gravel during mining operation. See Figure 16.

3.3 Dry Mining

Dry mining of the Bobs Farm deposit will commence with stripping of existing vegetation from the surface by excavator with a grab and bulldozer. The vegetation that can be saved will be stored onsite to provide the required seed stock of natives for rehabilitation while the remainder would be processed into mulch and stockpiled onsite in a location that will not cause problematic leachate discharge during rain events. This mulch material will be needed throughout the life of the deposit to vegetate the final bund profiles so should be easily accessible for this future re-use.

Temporary acoustic bunds will be required during this phase of extraction. These 6 metre high bunds will be required to attenuate noise emitted from the mining and hauling equipment at the locations shown in the Vipac Noise assessment see Appendix 8. The construction and design of these bunds have not been geo-technically assessed and the authors recommend this occur, prior to construction to ensure stability. It is also recommended that these bunds will be vegetated with grasses to reduce nuisance dust. The construction of these bunds where the topography allows, as illustrated below will be created using the natural landforms. Where the topography is not conducive to this the bunds will be constructed using local sand materials and will be built within the construction noise criteria, specified by Vipac, refer to Appendix 8. As mining progresses to the 15 metre vegetated buffer the bunds will be removed also within the construction noise criteria, specified by Vipac, refer to Appendix 8. These bunds will not be required during wet mining.

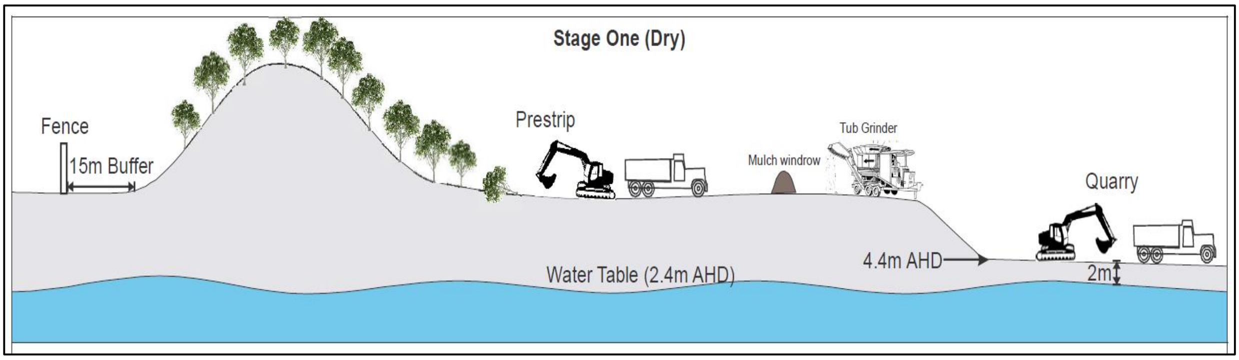


Figure 18: Dry Mining Schematic

The final stages of dry mining will involve removal of the PASS black mud layer, for treatment or disposal, reducing the acid sulphate soil risk for that portion of the site. In accordance with the Martens acid sulphate management plan for the site this removal will be done by excavator which will operate at or just below the water table in removing this layer. If testing confirms pH of the sand has dropped below 5 pH points it will be treated with Lime in accordance with a PASS treatment plan to be provided by Martens.

3.4 Wet Mining

Wet mining is to commence upon establishment of the dedicated suction cutter dredge upon the water table.

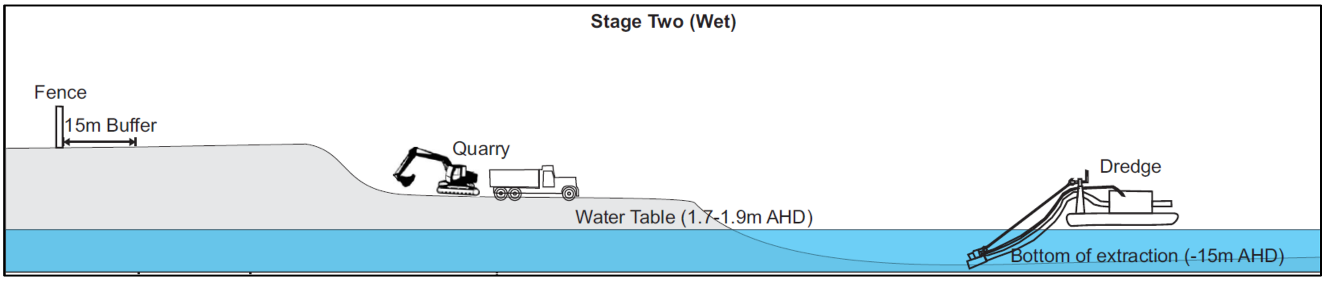


Figure 19: Wet Mining Schematic

Wet mining will involve the winning of sand feed by suction cutter dredge. Sand remaining above the water table will be placed into the dredge pond by excavator with a bulldozer feeding the excavator to assist the process. The operation of the dredge will be such that it will mine the sand feed below the water table to a final profile as provided by Martens.

3.5 Final Landform

The final landform will be a bunded water pond with a geotechnically approved batter slope to eliminate slope instability issues as designed by Martens.

Note: QMS have not undertaken geotechnical analysis of the site and as such are not providing advice on suitable batter slopes but relying on the advice provided by Martens on slope stability and final landform. See Figure 20.

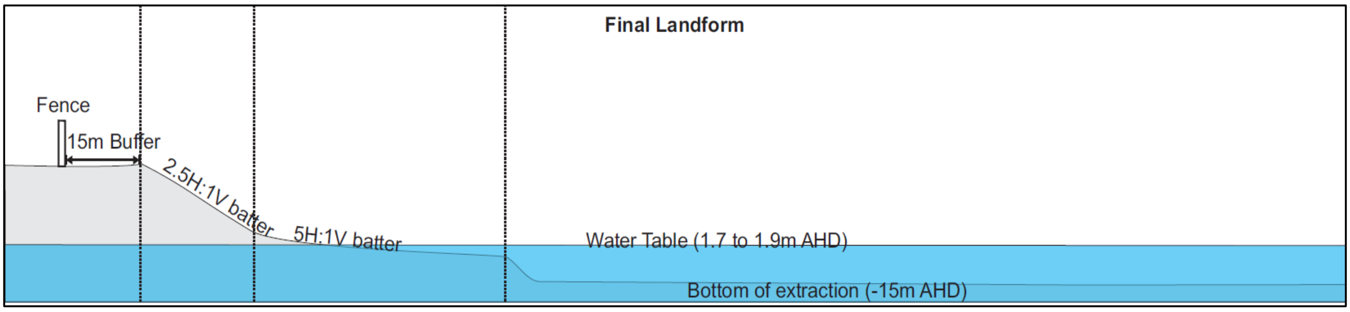


Figure 20: Proposed Final Landform Schematic

Batter slopes as provided by Martens are summarised in Table 7 below.

Unit	Maximum Slope Batter[1]
Unit 1: Organic Sand	1:3.0
Unit 2: Aeolian Sand	1:3.0
Unit 3: Aeolian Sand	1:2.5
Unit 4: Marine Organic Sand	1:2.5
Unit 5: Marine Sand	1:2.5

Table 7: Final batter slopes proposed by Martens.

Stabilisation of final slopes will be as provided by Martens, or others, and are expected to include soft stabilisation (dedicated planting to retain sand locally) and hard stabilisation by rock wall, spalls, riprap, gabion basket or other means as designed and specified by Martens or others. As can be seen for the different sand layers across the site a different maximum slope is recommended by Martens.

3.6 Rates of extraction - Projected

The Director General requirements for the Bobs Farm site outlined at peak production a maximum of 750,000 TPA of sand feed may be extracted for processing. This would equate to approx. 450 Tonnes per hour based on 11 months of sand production at 19 days per month and 8 hours per day (=> 750,000 /11/19/8 = 448.56t /hr => ~ 450t/hr of extracted feed). That estimate allows enough time for plant maintenance, shutdowns and production interruptions.

The build-up of sand production volume up to the specified maximum of 750,000TPA depends on the market take up of sand products. A conservative approach for build-up of sand product volumes and sales is estimated in Tables 1 to 4, achieving maximum at year 4 onward.

Bobs Farm Mine Development- Staged Mine Construction Summary- Conservative						
Year	Sales	Mining Operation	Winning of feed	Sales Load Out	**Dry**	**Washed**
1	150,000 Tpa, ~13,636T/mth, ~717 T/day, ~90 T/hr	**Dry feed system**: - Excavator to Dump Truck -> dump truck tips feed into hopper -> hopper to a conveyor -> conveyor to wet screen -> wet screen to sump -> sump to spirals -> spirals to de-watering screens -> de-watering screens to stackers (final product). A wash / recovery plant to handle tonnage required, a 6/4 pump would handle this volumes, with limited room for increased tonnages on a 6/4, an 8/6 would handle this capacity and into the next phase. Assume 8/6 pump & plant.	**Winning plant feed**- Excavator and dumper: 2 x 22 tonne tracked excavators with an oversize mud bucket would be utilised to win sand feed with 1 x 44 tonne articulated dumper used to transport the raw feed along dedicated haul roads to the processing plant on site. (Note: The 22 tonne excavator is a miss match with the dump trucks size, however it is believed to be within existing fleet of potential quarry operator and should work in the initial phase).	**Sales loading:** 2 x 23 tonne loaders for sales load-out, (bladed bucket) (Note: If selling to ship bound consignments, each = 10,000 tonnes per consignment, => 3 x 11 hour days to load each consignment = 3,333 tonnes per day divided by 11 hours per day = 303 tonnes per hour, divided by 32 tonne per load = 9.4 loads per hour, The existing loader will not be capable of loading this volume, an additional loader of similar size would be required.	Construction sands, Native landscape soils & top dress, Golf fairway, mulch sands	Washed Golf sands, specialist construct sands, coloured glass, foundry etc.- (demand dependent)

Table 8: Conservative Staged Mine Construction Summary- Year 1

Year	Sales	Mining Operation	Winning of feed	Sales Load Out	Dry	Washed
2	250,000 Tpa, ~22,727 T/mth, ~1,196T/day, ~150 T/hr	Dry Only with process washing Production continued as per year 1 with 2 x 44 tonne articulated dumpers (1 from year 1 + 1 additional from year 2 on). Replace the 1 x 22 tonne excavator with a 1 x 35 to 40 tonne excavator to load articulated dump trucks or for a defined period utilise the second 22 tonne excavator to load the 2nd truck on each cycle as a short term compromise to engage existing equipment. An 8/6 pump should still handle this tonnage, and if required the pump may be sped up on revolutions per minute (R.P.M.) to achieve extraction targets.	Production continued as per year 1 , Dry mining only Winning plant feed- Excavator and dumper:	Dry mining is to continue until a sufficient size pond is constructed to float and engage the dredge for winning material, to feed the plant. This is more likely in year 3 of mine life. 2 x 22 tonne loader with bladed bucket for sales.	Construction sands, Native landscape soils & top dress, Golf fairway, mulch sands	Washed Golf sands, specialist construct sands, coloured glass, (demand dependent)

Table 9 : Conservative Staged Mine Construction Summary- Year 2

Year	Sales	Mining Operation	Winning of feed	Sales Load Out	Dry	Washed
3	450,000 Tpa, ~40,909 T/mth, ~2,153 T/day, ~269 T/hr	Dry and Wet Mining Production should have transitioned to dredging, direct coupled to a processing plant, using a 12 / 10 cutter suction dredge would suit, coupled to a 10" I.D. Poly / Rubber pipeline, (negating the dependence on the articulated dump trucks and excavators),	Excavator and haul trucks and suction/cutter dredge. 1 excavator should remain as a utility machine, while noise and dust emissions should be greatly reduced. The dredge should effectively be sitting at or around the water table below the surrounding natural levels also reducing noise even further.	The loaders will need to be increased in size and probably in numbers. The minimum requirement would be 2 wheel loaders with a capacity to carry and load 7 tonnes per cycle, the next most suitable size would be 12 tonne capacity per cycle.	Construction sands, Native landscape soils & top dress, Golf fairway, mulch sands	Washed Golf sands, specialist construct sands, coloured glass, (demand dependent)

Table 10: Conservative Staged Mine Construction Summary- Year 3

Year	Sales	Mining Operation	Winning of feed	Sales Load Out	Dry	Washed
4 onwards	697,500 Tpa, ~63,409T/mth, ~3,337 T/day, ~417 T/hr	Dry and Wet Mining The dredge as described above should have the capacity to extract up to 300 tonne per hour with capacity to spare. The dredge should be capable of pumping 40% solids in this material (375 T.P.H.) (not the 30% used in this assumption). In addition tonnages could be won by increasing the R.P.M. of the pump, which should deliver approx. 400 T.P.H.	Excavator and haul trucks and suction/cutter dredge. Options at this point are to work additional hours to deliver the shortfall on 8 hours production, hot seat the dredge for morning tea, lunch etc., pump at a higher density, increase the R.P.M. on the pump or a mix of these options. Also could change out the 12/10 pump and replace it with a 14/10, in doing so the entire process on the back end of the dredge, the pipeline, the wash plant, the screens, spirals etc.. all have to be capable of handling this increase. This will be determined in QMS stage 4 when a complete plant analysis will be undertaken	The loaders will need to be increased in size and probably in numbers. The minimum requirement would be 2 wheel loaders with a capacity to carry and load 12 tonne capacity per cycle.	Construction sands, Native landscape soils & top dress, Golf fairway, mulch sands	Washed Golf sands, specialist construct sands, coloured glass, (demand dependent)

Table 11: Conservative Staged Mine Construction Summary- Year 4

3.7 Mining Plan Operational Plan- (Conservative Sales)

Bobs Farm- Est. Conservative Rate of Extraction & Sales with Time			
Year	Extraction (TPA)	Product Sales (TPA)	Assumed Product Yield from Feed
1	162,000	150,000	93
2	268,000	250,000	93
3	483,000	450,000	93
4	750,000	700,000	93
5	750,000	700,000	93

Table 12: Conservative Sales and Production Estimates

Note: This may vary depending on market demand especially if exporting sand to Asia

3.8 Mining Operational Plan- (Aggressive Sales)

Bobs Farm- Est. Aggressive Extraction & Sales with Time					
Year	Extraction (TPA)	Product Sales (TPA) Road/Other	No. of 10,000T Export Shipments pa/ Tonnes	Estimated Total Sales	Assumed Product Yield from Feed
1	290,322	150,000	12 / 120,000	270,000	93
2	440,860	250,000	16/ 160,000	410,000	93
3	741,935	450,000	24/240,000	690,000	93
4 Onwards	750,000	460,000	24/240,000	697,500	93

Table 13: Aggressive Sales and Production Estimates

Note: This may vary depending on market demand

The above aggressive sales strategy assumes a combination of road transported sand, and sales and export shipments via the Port of Newcastle. Dependent on demand for sand products the export shipment requirements could ramp up from one 10,000T ship per month to 1.5 to 2 per month, depending on processing production capacity, available storage and site load-out facility. The maximum extraction under the DGR's would still be 750,000 Tonnes per annum and as such an expected maximum of 700,000Tpa of saleable product is expected based upon a 97% production efficiency.

Alternative from Year 1

If proposing to sell to ships from year 1, there will need to be a rapid ramp up of production to have sufficient stock on the ground to feed the ships at 10,000T minimum per ship load.

The entire design process should then be based around peak production, under this condition, and at that time the operator could use the assumptions from year 4 and onwards, for the remainder of deposit life to accommodate the approx. 450 tonne per hour, with room for service, breakdowns etc.

Bobs Farm Mine Development- Staged Mine Construction Summary- Aggressive Sales						
Year	Sales	Mining Operation	Winning of feed	Sales Load Out	Dry	Washed
1	270,000 Tpa, ~24,545/mth, ~1,292 T/day, ~161 T/hr	**Dry feed system**: - Dry Only with process washing Production continued as per year 1 with 2 x 44 tonne articulated dumpers (1 from year 1 + 1 additional from year 2 on). Replace the 1 x 22 tonne excavator with a 1 x 35 to 40 tonne excavator to load articulated dump trucks or for a defined period utilise the second 22 tonne excavator to load the 2nd truck on each cycle as a short term compromise to engage existing equipment. An 8/6 pump should handle tonnage, if required the pump may be sped up on RPM to achieve extraction targets.	**Winning plant feed**- Excavator and dumper: Dry Mine only 2 x 22 tonne tracked excavators with an oversize mud bucket would be utilised to win sand feed with 1 x 44 tonne articulated dumper used to transport the raw feed along dedicated haul roads to the processing plant on site. (Note: The 22 tonne excavator is a miss match with the dump trucks size, however it is believed to be within existing fleet of potential quarry operator and should work in the initial phase).	**Sales loading:** 2 x 23 tonne loaders for sales load-out, (bladed bucket) (Note: If selling to ship bound consignments, each = 10,000 tonnes per consignment, => 3 x 11 hour days to load each consignment = 3,333 tonnes per day divided by 11 hours per day = 303 tonnes per hour, divided by 32 tonne per load = 9.4 loads per hour, sales loader.	Construction sands, Native landscape soils & top dress, Golf fairway, mulch sands	Washed Golf sands, specialist construction sands, coloured glass, foundry etc.- (demand dependent)

Table 14: Sales Projections Aggressive-Year 1

Year	Sales	Mining Operation	Winning of feed	Sales Load Out	Dry	Washed
2	410,000 Tpa, ~37,272T/mth, ~1,962T/day, ~245 T/hr	Dry and Wet Mining Production should have transitioned to dredging, direct coupled to a processing plant, using a 12 / 10 cutter suction dredge would suit, coupled to a 10" I.D. Poly / Rubber pipeline, (negating the dependence on the articulated dump trucks and excavators),	Excavator and haul trucks and suction/cutter dredge. 1 excavator should remain as a utility machine, while noise and dust emissions should be greatly reduced. The dredge should effectively be sitting at or around the water table below the surrounding natural levels also reducing noise even further.	The loaders will need to be increased in size and probably in numbers.	Construction sands, Native landscape soils & top dress, Golf fairway, mulch sands	Washed Golf sands, specialist construction sands, coloured glass, (demand dependent)

Table 15: Sales Projections Aggressive-Year 2

Year	Sales	Mining Operation	Winning of feed	Sales Load Out	Dry	Washed
3	690,000 Tpa, ~62,727T/mth, ~3,301 T/day, ~413 T/hr	Dry and Wet Mining Production should have transitioned to dredging, direct coupled to a processing plant, using a 12 / 10 cutter suction dredge would suit, coupled to a 10" I.D. Poly / Rubber pipeline, (negating the dependence on the articulated dump trucks and excavators).	Excavator and haul trucks and suction/cutter dredge. 1 excavator should remain as a utility machine, while noise and dust emissions should be greatly reduced. The dredge should effectively be sitting at or around the water table below the surrounding natural levels also reducing noise even further.	The minimum requirement would be 2 wheel loaders with a capacity to carry and load 7 tonnes per cycle, the next most suitable size would be 12 tonne capacity per cycle.	Construction sands, Native landscape soils & top dress, Golf fairway, mulch sands	Washed Golf sands, specialist construction sands, coloured glass, (demand dependent)

Table 16: Sales Projections Aggressive-Year 3

Year	Sales	Mining Operation	Winning of feed	Sales Load Out	Dry	Washed
4 onwar[illegible]ds	697,500 Tpa, ~63,409T/mth, ~3,337 T/day, ~417 T/hr	Dry and Wet Mining The dredge as described above should have the capacity to extract up to 300 tonne per hour with capacity to spare. The dredge should be capable of pumping 40% solids in this material (375 T.P.H.) (not the 30% used in this assumption). In addition tonnages could be won by increasing the R.P.M. of the pump, which should deliver approx. 400 T.P.H.	Excavator and haul trucks and suction/cutter dredge. Options at this point are to work additional hours to deliver the shortfall on 8 hours production, hot seat the dredge for morning tea, lunch etc., pump at a higher density, increase the R.P.M. on the pump or a mix of these options. Also could change out the 12/10 pump and replace it with a 14/10, in doing so the entire process on the back end of the dredge, the pipeline, the wash plant, the screens, spirals etc.. all have to be capable of handling this increase. This will be determined in QMS stage 4 when a complete plant analysis will be undertaken	The loaders will need to be increased in size and probably in numbers. The minimum requirement would be 2 wheel loaders with a capacity to carry and load 12 tonne capacity per cycle.	Construction sands, Native landscape soils & top dress, Golf fairway, mulch sands	Washed Golf sands, specialist construction sands, coloured glass, (demand dependent)

Table 17: Sales Projections Aggressive-Year 4

3.9 Mine planning for site water management.

During the Initial stages of mine development water will be required to wash and process the sand, for dust suppression and wheel wash. Town water or rainwater tanks will supply water to amenities on site.

Preliminary site works will largely revolve around clearing, movement, storage and re-use of vegetation and overburden sand. This will also involve mulching operations which would be conducted alongside the Nelson Bay road side of the site to minimise noise, dust and vibration. The establishment of a sump will be needed, below the site water table, to access ground water for processing, dust suppression etc. This will be in a suitable location using excavators and dump trucks, (probably within the 1st cell for extraction). Stockpiling of won sand feed material should be done as close to the proposed processing plant location as practical.

Martens Surface water assessment requires a swale (Page 30) to be installed on the haul road between Nelson Bay road and the proposed processing plant to capture any sediment generated from site. It is noted that 184 m2 area is also required for sewer spray and filtration onsite.

Water requirements for sand transport and washing:

Depending on the rate of production and involved processes, the sand transport and washing water requirements will vary with time for the Bobs Farm operation. It is expected that the maximum water is likely to be between 1050m3/hr to 1350m3/hr based on production output when the dredge is in full operation and wash water is used in processing the sand feed. If the quarry ramps up to full production of 450t/hr of extraction in the first year the water requirements will be at the maximum in year 1 of 1350 cubic metres per hour of water.

Dredge Efficiency Estimates

The expected water usage for the wet mining process depends on the dredge efficiency and arte summarised in Table 18.

Bobs Farm Mine Development- Staged Mine Construction Summary- Conservative				
Sand Extraction T/hr	Solids content %	Total Water + Sand Slurry = Sand Extraction/Solid% T/hr	Water = Slurry*(100% - %solids) T/Hr	Water m3/Hr
450	25%	=> 450/25%=1800	1350	1350
450	30%	=> 450/30%=1500	1050	1050
Density = Mass/Volume	Particle Density= 2.65	450T/hr => 450/2.65= 170m3/hr solids		

Table 18: Dredge Solids Content and Water Demands

It is QMS understanding that both 25 and 30% solids density are achievable in pumping this type of sand/water slurry.

Water Considerations

To extract 750,000 TPA, by dredge, there will need to be up to 1800T/hr of slurry pumped and 1350m3/hr of water for the required 450t/hr sand feed. The majority of the water required on site, will be for sand dredge transport, washing and processing purposes, at the designated processing plant location.

Water Quality.

As the ground water will form the wash water required, QMS see no issues with the ground water for washing purposes. As the development progress's, the water for washing will be supplied from the 1st cell under extraction, once it is large enough, in this application the dirty water from the wash plant will be delivered back to the same cell, this will be possible as such a small percentage of reject will be returned to the ponds. QMS mining plan follows the recommendations from Martens on the treatment of the PASS material as per the agreed strategy once near the water table.

Recycling Water.

The wash water required and used within the sand washing process will be recycled on this project, with minimal losses, as it is basically a closed loop operation. The water will be pumped (with sand) via the dredge to the wash plant. The wash / processing plant will separate recoverable sand, from the reject waste. The "dirty" water will be sent back to the ponds / cells with the unwanted reject materials settling out and the water used again, and again. The only losses will be evaporation and minor spills or splashing around the plant on start-up or blockages, if and when they occur, delivering >98% return, not including evaporation on the cells / ponds.

The agreed treatment of PASS from Martens will be incorporated here in water recycling.

Water Treatment.

The only water expected to require treatment on this development is the PASS layer, which when encountered, will be processed as per agreed Martens procedures.

Water Losses.

Water will be recycled for washing, with expected minimal losses of approx. 2% in this process, other water loss will be with dust suppression of trafficable areas, and water loss due to evaporation on the cells / ponds as they are progressively developed.

Landscape Irrigation.

No specific allocation has been allowed for landscape irrigation and development. No final Landscape detail has been agreed, however the quantities of water required would still fall well within the 10% of total process water for the year 2, allowance nominated. This would constitute > 98% of total water requirements, on site for the life of the development.

As soon as the dredge is commissioned, dust emissions from on-site dump trucks and excavators will almost cease, dredging and washing alone do not generate any dust.

The main long term area for dust suppression will be road going tip trucks entering and departing the sales loading area, as we believe the larger portion of this trafficable area is to be sealed, resulting in little or no dust being generated. An allowance of 10% of the nominated water requirements for Year 2, listed below would be more than sufficient for all other water requirements.

3.10 Heavy Machinery and Equipment

Mining Plan:

- Stripping- Bull dozer / excavator with grab etc.
- Dry Mine- Excavator / haul trucks / sales loader(s)
- Establish dredge- excavator / haul trucks- once dredge established haul trucks limited use.
- Feed dredge with excavator (Dredge retracts excavator drops sand into pond-> dredge marches over sand and repeat)
- Push up sand with small dozer- D7 or D8 to feed excavator to feed dredge
- Move dredge once cell exhausted.

Location/description of all buildings, offices, workshops, amenities, etc. are identified on Figure 21 below.

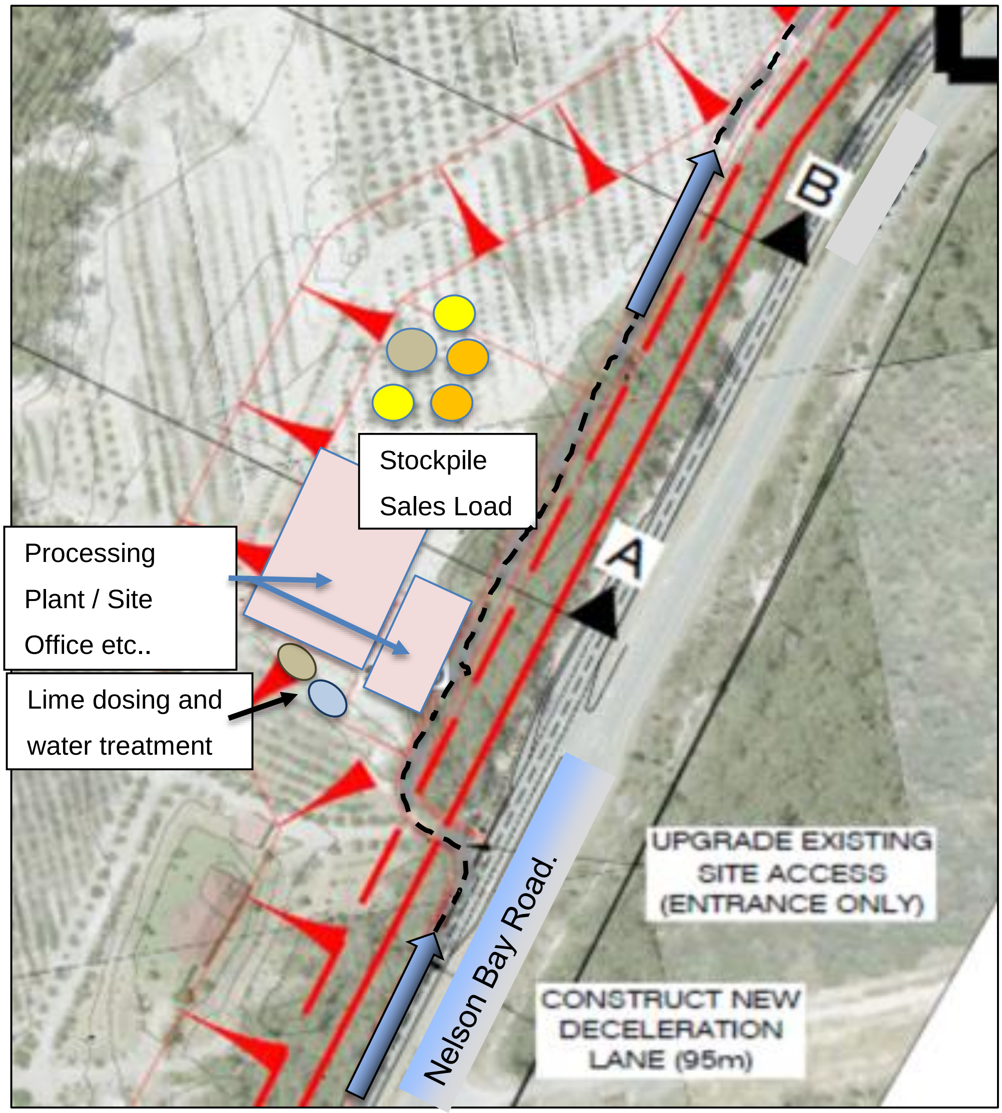


Figure 21: Site building location

As can be seen from Figure 21 the plant processing area requires a significant footprint to allow for washing/ screening/ attrition/ spirals/ dewatering and then to final stockpile product. Provision for enclosed processing and sand storage is made where controlled moisture content is required for export sand requirements or other.

Other land uses on site

There will be no alternate land uses for agriculture, grazing or forestry applications however a caretaker residence will be maintained onsite to ensure site security is maintained at all times.

Other manufacturing plant on site – eg Concrete, asphalt

There are no plans to process the sand products from site into concrete, asphalt or any other product on site.

Parking and marshalling area

Visitor parking will be provided at the site office off Nelson Bay Road and site access will be restricted to only authorised personnel, with boom gate or similar vehicular obstacle to prevent unplanned site entry.

Employees and site staff will have designated parking area onsite outside of the extraction area.

In case of emergency or evacuation a muster point will be located at the site office and or front gate as deemed appropriate by quarry management.

To facilitate efficient and fast loading of road trucks onsite there will be a designated waiting area within the stockpile / sales area and a marshalling area where trucks can be parked up onsite overnight if required.

Safety and security measures

The safety and security of the Bobs farm site will be maintained at all times through compliance with the site operational plan, which will ensure the mine site is kept isolated from the public at all times, other than by controlled and authorised access.

Service utilities and infrastructure

The location of all related services for the site will be clearly identified and marked within the site operational plan to be developed in stages 4 and 5 of the QMS investigations. This will include any above and below ground power, telecoms, water, fibre optic, gas etc.

Processing and Stockpiling Factors (Operations)

Finished product specifications

Stockpiled products located onsite will be clearly signposted to identify what material is within a given stockpile and a current record of what product are within the stockpiled/sales area will also be available at the site office. Testing and validation of quarry product quality will be done by customised Inspection and Test Plans (ITPs) which will be developed and maintained by QMS based upon the market into which the individual product is to be sold.

Future product compliance and specification suitability will be handled by regular and periodic review of ITPs by QMS, keeping track of new opportunities to value add sand product won from site when feed quality improves or new markets open up for individual products available from site.

Stockpile methods & requirements

Stockpiling of sand products will be utilised to make best use of available area and will include trestle conveyors capable of luffing (up/down) and slewing (side to side) to develop large stockpiles / windrows of finished saleable sand product as required for production / sales demand. .

Conveyor design will be matched to the likely production capacity required, including belt speed and width.

Dewatering screens are to be incorporated in the processing operation to minimise the time required in stockpile to reach an acceptable material moisture content for transport as agreed by management or in conjunction with clients.

The stockpile areas will be prepared to be flat durable working surfaces with adequate cross fall to encourage controlled surface drainage of water. Under no circumstances will the stockpile floor be picked up during sales load-out and this will be clearly outlined in the operational plan for the Bobs farm quarry site.

4. Economic and Market Factors

A local and export sand market report is presented in Appendix 8 of this report.

While QMS have endeavoured to cover all required site aspects in this mining plan the following have not been addressed in this report:

- Business cycles for products
- Commercial and economic need - level of need
- Critical success factors for products in target market segments
- Demand and supply analysis – usage / consumption trends
- External contingency analysis (social, legal, cultural, environmental etc.)
- Industry and competitor analysis
- Market area, size – radius of economic distribution; exports
- Market segmentation by product type, application/ customer type
- Population growth
- Pricing
- Reliance on particular customers/suppliers, export markets
- Sales forecasts/ projections / sensitivities
- Social Cost Benefit Analysis
- Value-adding opportunities – ease of implementation/ impact on sales targets

Haulage and Distribution Factors (e.g. Off-site heavy vehicle movements)

Costs of transportation to markets

The transport cost of final saleable sand products to the associated material markets will be included in delivered prices under an accepted socially responsible market pricing strategy, in compliance with the requirements of the Trades Practice act of Australia. Ex-bin sand product prices will also be available where customers wish to pick up material from the Bobs Farm site in line with the site operational plan with site safety firmly in mind. This may restrict the sale of small sand volumes by box trailer and may be restricted to tip truck load minimums as decided by mine management.

Entrance and exit - configuration, surfacing

As discussed, earlier in this report, main haul roads will be surfaced with sprayed bituminous seal to minimise dust and noise including the exit road from the stockpile area; with loaded trucks to pass over a drive-over wheel wash and grate to liberate sand from tyres and wheel guards before exiting onto public roads.

The following transport areas will be addressed by TL or others:

- Noise, dust, vibration impacts from off-site truck movements on neighbours
- Pavement impacts
- Public safety – traffic safety impacts TL
- Road maintenance levy fees TL
- Road network usage/ transport routes – current, proposed
- Truck types and configurations

Volume of truck movements

The daily, peak, average traffic movements within the mine site will be determined by the production and sales requirements. Traffic management entering and leaving the Bobs Farm site is modelled by SECA and outside the scope of this report.

Weighbridge

As discussed earlier in this report weighing and ticketing of loads will be via load cells within the sales loader buckets and dedicated wireless ticketing system. A weighbridge is not planned to be introduced onsite unless production demands warrant its use and this will be addressed at that stage.

Traffic management on site

Traffic management on site is to be controlled via the site operational plan. Quarry management will ensure haul trucks have right of way within the mining extraction zone and intersections where light vehicles or other site traffic interact with haul trucks will be minimised to encourage optimal safety outcomes. This will form part of the traffic management plan for the site.

The following Environmental, Social and Cultural Factors (Impacts) will be addressed by TL and others:

- Acid sulphate soils (PASS)
- Agricultural land (eg GQAL)
- Archaeological, cultural and historical heritage and values
- Buffer areas - internal, external
- Community consultation, feedback
- Contaminants – pre, during and post mining
- Climate change – sea level effects
- Discharges to water – water quality
- Drainage, bores, dams, watercourses, springs, wetlands, flood impacts and frequencies, groundwater impacts
- Dust emissions
- Existing services / utilities
- Exposed vs screened areas – landscaping/ barriers TL- Sound and visual barriers
- Fauna/ flora
- Flooding, bunding
- Fire controls
- Groundwater
- Neighbours names, addresses, details of adjoining landholders - expectations and views / submissions
- Natural features
- Noise, light and vibration emissions – operations and off site transport
- Permit and licence conditions – history of operator, reference sites, proposed conditions Public safety and amenity – incl. school safety / amenity of students/staff

- Rehabilitation – prior, during and post extractive landform
- Sewage and effluent
- Site and surrounding land uses - current and future
- Slope stability, ground control
- Soil quality, quantity, fertility, re-use
- Surrounding land uses – impacts and their mitigation
- Sustainable development (energy efficiency, greenhouse gas emissions etc.)
- Sediment and erosion controls
- Vegetation - existing, native, ecosystems, disturbed, authorised tree cleari
- Visual amenity, views into and out of the site over time
- Wastes generated and management
- Weeds and pests

The following Governmental / Other Factors will be addressed by TL:

- State and local government policy,
- Views and attitudes of public officers

Disclaimer: The Quarry Due Diligence Index that has been used in compiling this Mining Plan was compiled by ECOROC Pty Ltd to assist in the project and risk management of quarries or quarry-related projects. The index is adapted from the 'modifying factors' in the Minerals Industry JORC Code (2014) and is intended as a guide only. The index is not exhaustive and other site-specific issues not listed in the index may be relevant for a particular resource, quarry site or project.

5. CONCLUSIONS

The Bobs Farm Site has minable lenses of sand that are suitable for a number of applications including; foundry sand, industrial moulding sand, fire furnace sand, coloured glass sand, construction sand(s), turf sands etc. The mine plan that is reported here will form the basis of the site processes, however a specific site operational plan will need to be developed to run the site as a dedicated quarry resource.

6. RECOMMENDATIONS

It is recommended that the next stage of QMS investigations focusses on a full and detailed plant design to allow accurate budgets to be developed for fixed plant establishment and process development. This work will allow a more accurate operational plan to also be established as accurate flow rates, feed rates and production rates will be known and mobile equipment may be more accurately sized to the defined operation(s).

7. APPENDICES

Appendix 1 to 5	Frac sand test results
Appendix 6 to 7	Geochempet reports
Appendix 8	Vipac Noise Assessment Reports
Appendix 9	Sand Market Reports

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McLanahan Frac Sand Testing Results

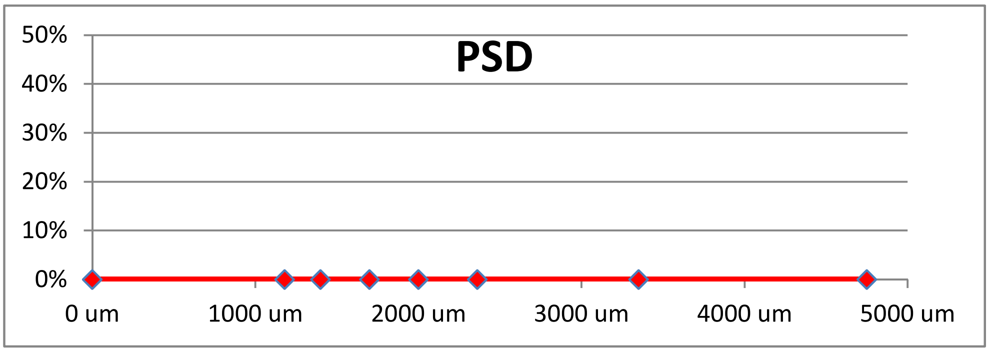
Job #: B140725

Customer: QMS
Contact: Mark Philpot
Address: TBA
Date: 31/07/2014
Tested by: Bevan McLachlan
Sample Location: BH2-22.5-23.5-G-ML

6/12 (3350-1700µm) Primary Frac Sand Size Testing Results

Product Size Distribution

4750 um	0 g
3350 um	0 g
2360 um	0 g
2000 um	0 g
1700 um	0 g
1400 um	0 g
1180 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test	20
Average Roundness	0.1	Average crush test Fines Generated (%)	0.0
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail	N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)	

		Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Tested Acid solubility	xxxxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	**Fail**	xxx	xxx	xxx	xxx	xxx

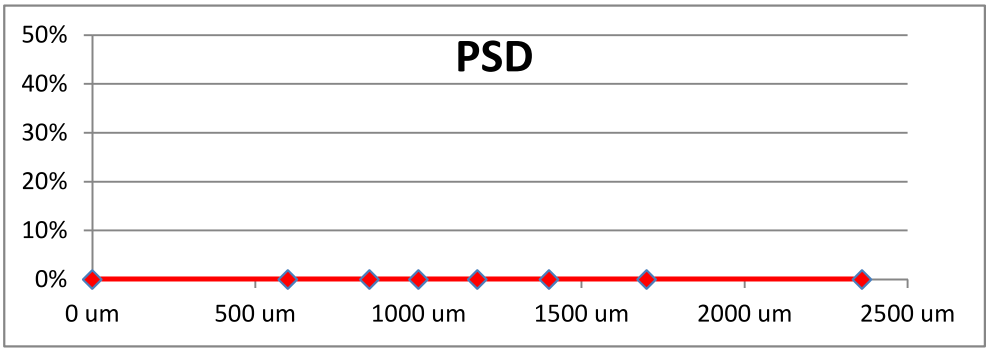
Warnings: **Size 6/12 Sphericity < 0.6 , Size 6/12 Roundness < 0.6 , , ,**

Comments: **Not enough sand at this size.**

12/20 (1700-850µm) Primary Frac Sand Size Testing Results

Product Size Distribution

2360 um	0 g
1700 um	0 g
1400 um	0 g
1180 um	0 g
1000 um	0 g
850 um	0 g
600 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test	16
Average Roundness	0.1	Average crush test Fines Generated (%)	0.00
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail	N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)	

		Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Tested Acid solubility	xxxxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	**Fail**	xxxx	xxx	xxx	xxx	xxx

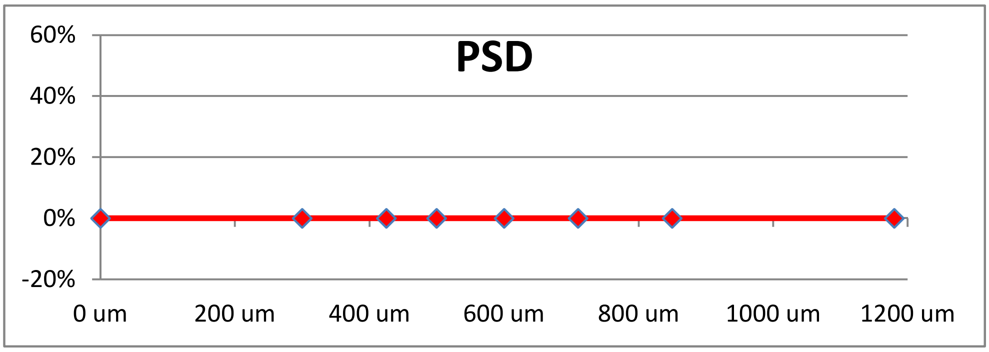
Warnings: **Size 12/20 Sphericity < 0.6 , Size 12/20 Roundness < 0.6 , , ,**

Comments:	**Not enough sand at this size.**

20/40 Primary (850-425µm) Frac Sand Size Testing Results

Product Size Distribution

1180 um	0 g
850 um	0 g
710 um	0 g
600 um	0 g
500 um	0 g
425 um	0 g
300 um	0 g
Pan	0 g

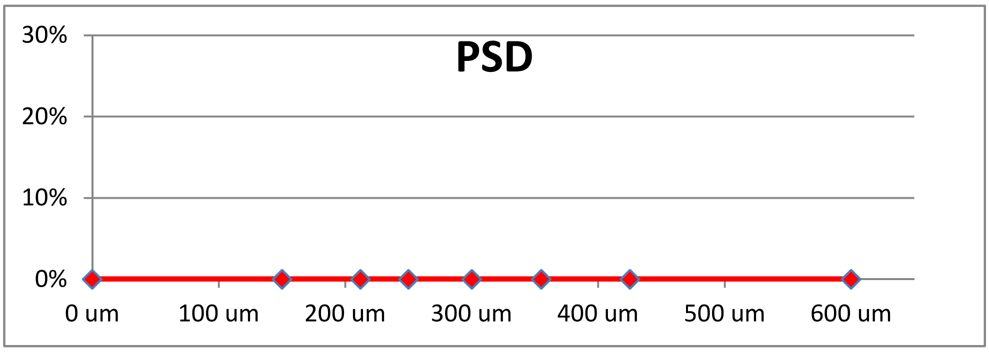


Average Sphericity	0.1	% Fines Allowed for Crush test				14
Average Roundness	0.10	Average crush test Fines Generated (%)				0.0
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail				N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxxxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	**Fail**	xxx	xxx	xxx	xxx	xxx
Warnings:	**Size 20/40 Sphericity < 0.6 , Size 20/40 Roundness < 0.6 , , ,**					
Comments:	**Not enough sand at this size.**					

40/70 (425-212µm) Primary Frac Sand Size Testing Results

Product Size Distribution

600 um	0 g
425 um	0 g
355 um	0 g
300 um	0 g
250 um	0 g
212 um	0 g
150 um	0 g
Pan	0 g



Average Sphericity	0.64	% Fines Allowed for Crush test				8
Average Roundness	0.535	Average crush test Fines Generated (%)				28.3
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail				**Fail**
Acid Solubility limit	3%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	Fail	xxx	xxx	xxx	xxx	xxxx
Warnings:	**, Size 40/70 Roundness < 0.6 , , , 8% Fines by weight exceeded for 40/70 Crush test**					
Comments:	**Sand Roundness Fails. Acid test and mineralogical analysis not conducted.**					

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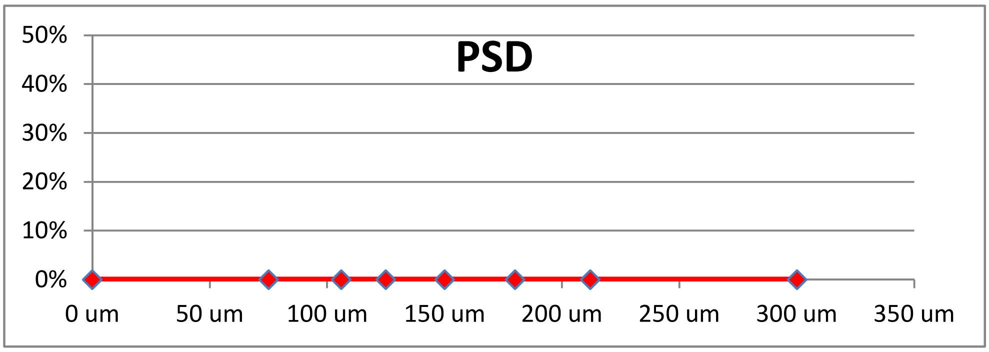
70/140 (212-106µm) Primary Frac Sand Size Testing Results

Product Size Distribution

300 um	0 g
212 um	0 g
180 um	0 g
150 um	0 g
125 um	0 g
106 um	0 g
75 um	0 g
Pan	0 g



Average Sphericity	0.645	% Fines Allowed for Crush test	6
Average Roundness	0.53	Average crush test Fines Generated (%)	0.0
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail	N/A
Acid Solubility limit	3%	Mineralogical Analysis Results (Mineral by Mass %)	
Tested Acid solubility	xxx		
Acid test Pass/ Fail	**Fail**		

Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
xxx	xxx	xxx	xxx	xxx

Warnings:	**, Size 70/140 Roundness < 0.6 , , ,**
Comments	**Sand Roundness Fails. Acid test, crush test and mineralogical analysis not conducted.**

Mineralogical Analysis Notes

The quantitative results shown in the mineralogical analysis results table have been normalised to 100%, and it should be noted that the values shown represent the relative proportion of the crystalline material in the sample. Totals greater or smaller than 100% are due to rounding errors. Negative results in the table indicate normally a larger than usual uncertainty in regard to the quantity of the phase reported; for some of the minor and trace phases it might also indicate an uncertainty in regard of the phase itself, or both.

Notes

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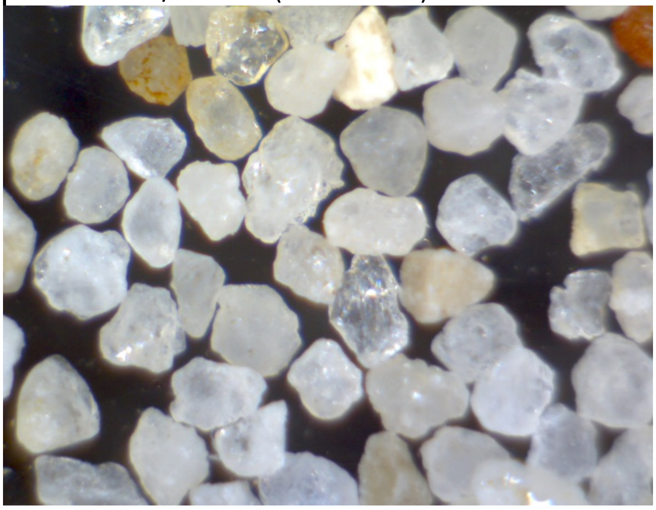
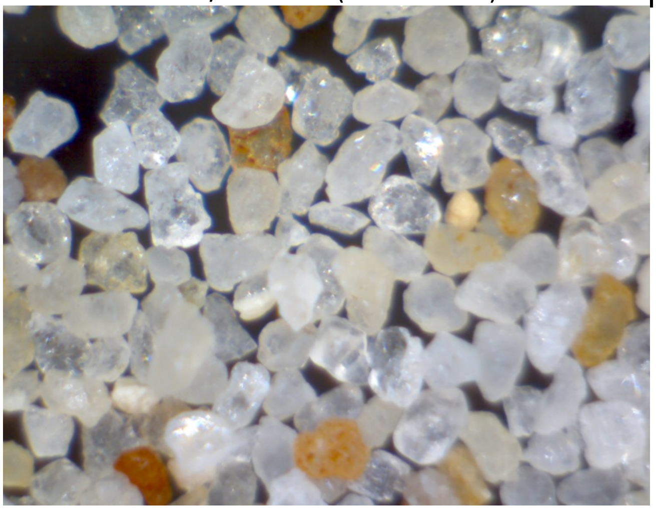
40/70 sand (425-212um)	70/140 sand (212-106 um)
	

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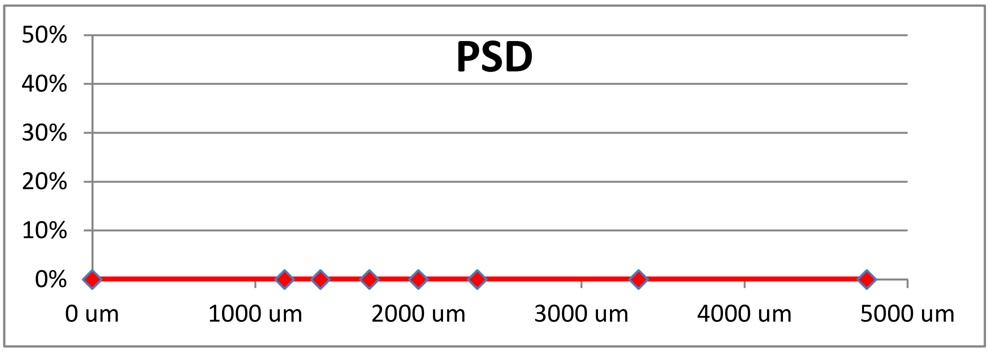
McLanahan Frac Sand Testing Results   Job #: B140725

Customer: QMS   Contact: Mark Philpot
Address: TBA
Date: 31/07/2014   Tested by: Bevan McLachlan
Sample Location: BH3 BL B ML

6/12 (3350-1700µm) Primary Frac Sand Size Testing Results

Product Size Distribution

4750 um	0 g
3350 um	0 g
2360 um	0 g
2000 um	0 g
1700 um	0 g
1400 um	0 g
1180 um	0 g
Pan	0 g

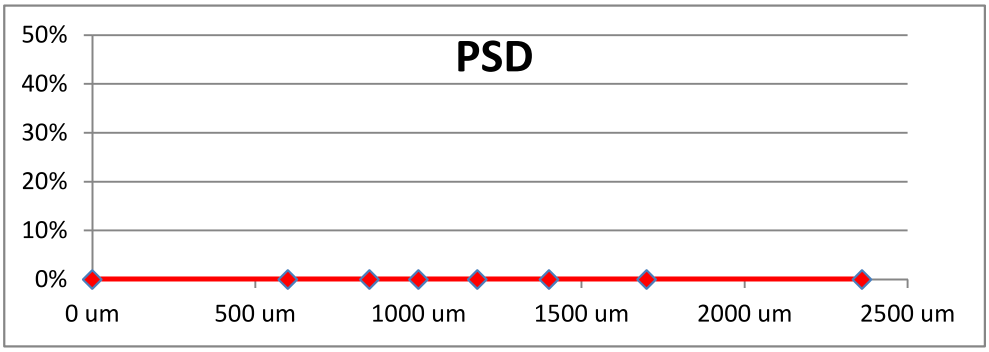


Average Sphericity	0.1	% Fines Allowed for Crush test				20
Average Roundness	0.1	Average crush test Fines Generated (%)				0.0
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail				N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxxxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	Fail	xxx	xxx	xxx	xxx	xxx
Warnings:	Size 6/12 Sphericity < 0.6 , Size 6/12 Roundness < 0.6 , , ,					
Comments:	xxxxxxxx					

12/20 (1700-850µm) Primary Frac Sand Size Testing Results

Product Size Distribution

2360 um	0 g
1700 um	0 g
1400 um	0 g
1180 um	0 g
1000 um	0 g
850 um	0 g
600 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test				16
Average Roundness	0.1	Average crush test Fines Generated (%)				0.00
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail				N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxxxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	Fail	xxxx	xxx	xxx	xxx	xxx
Warnings:	Size 12/20 Sphericity < 0.6 , Size 12/20 Roundness < 0.6 , , ,					

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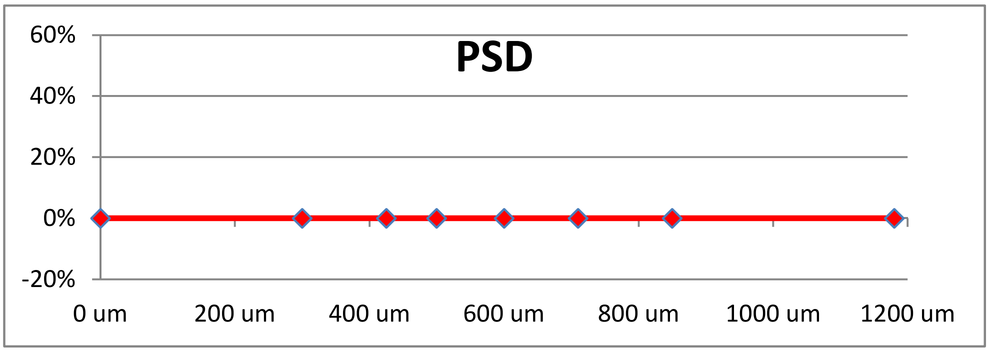
Comments:	**xxxxxxx**

20/40 Primary (850-425µm) Frac Sand Size Testing Results

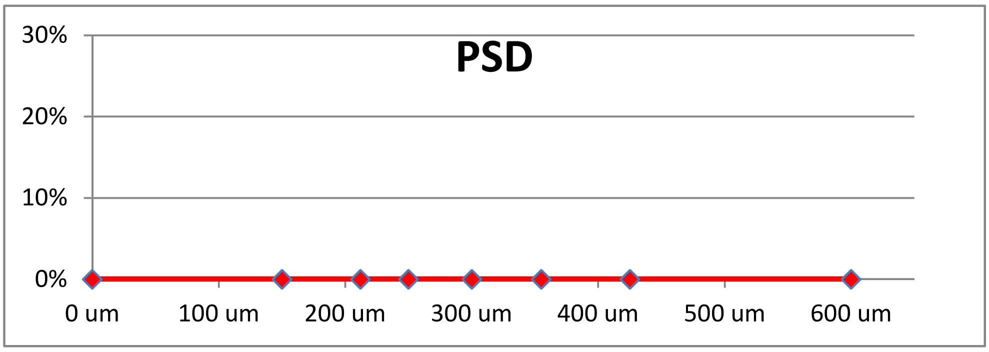
Product Size Distribution	
1180 um	0 g
850 um	0 g
710 um	0 g
600 um	0 g
500 um	0 g
425 um	0 g
300 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test				14
Average Roundness	0.10	Average crush test Fines Generated (%)				0.0
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail				N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxxxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	**Fail**	xxx	xxx	xxx	xxx	xxx
Warnings:	**Size 20/40 Sphericity < 0.6 , Size 20/40 Roundness < 0.6 , , ,**					
Comments:	**xxxxxxx**					

40/70 (425-212µm) Primary Frac Sand Size Testing Results

Product Size Distribution	
600 um	0 g
425 um	0 g
355 um	0 g
300 um	0 g
250 um	0 g
212 um	0 g
150 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test				8
Average Roundness	0.1	Average crush test Fines Generated (%)				18.0
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail				**Fail**
Acid Solubility limit	3%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	Fail	xxx	xxx	xxx	xxx	xxxx
Warnings:	**Size 40/70 Sphericity < 0.6 , Size 40/70 Roundness < 0.6 , , , 8% Fines by weight exceeded for 40/70 Crush test**					
Comments:	**xxxxxxxxxxxxx**					

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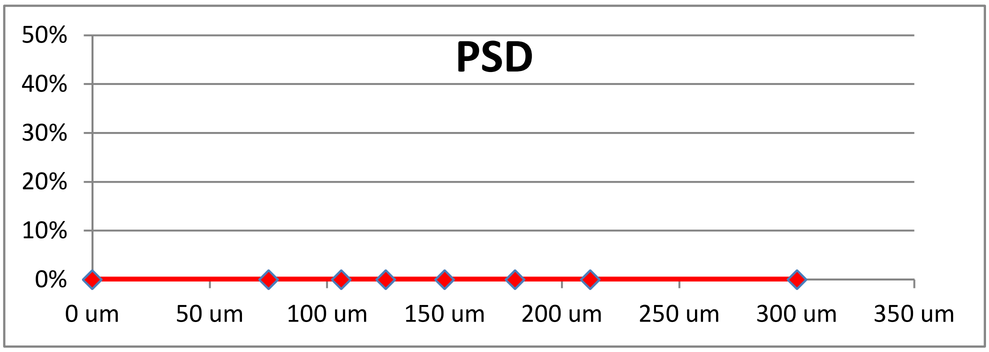
70/140 (212-106µm) Primary Frac Sand Size Testing Results

Product Size Distribution

300 um	0 g
212 um	0 g
180 um	0 g
150 um	0 g
125 um	0 g
106 um	0 g
75 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test				6
Average Roundness	0.10	Average crush test Fines Generated (%)				0.0
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail				N/A
Acid Solubility limit	3%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	**Fail**	xxx	xxx	xxx	xxx	xxx
Warnings:	**Size 70/140 Sphericity < 0.6 , Size 70/140 Roundness < 0.6 , , ,**					
Comments	**xxxxxxxx**					

Mineralogical Analysis Notes

The quantitative results shown in the mineralogical analysis results table have been normalised to 100%, and it should be noted that the values shown represent the relative proportion of the crystalline material in the sample. Totals greater or smaller than 100% are due to rounding errors. Negative results in the table indicate normally a larger than usual uncertainty in regard to the quantity of the phase reported; for some of the minor and trace phases it might also indicate an uncertainty in regard of the phase itself, or both.

Notes

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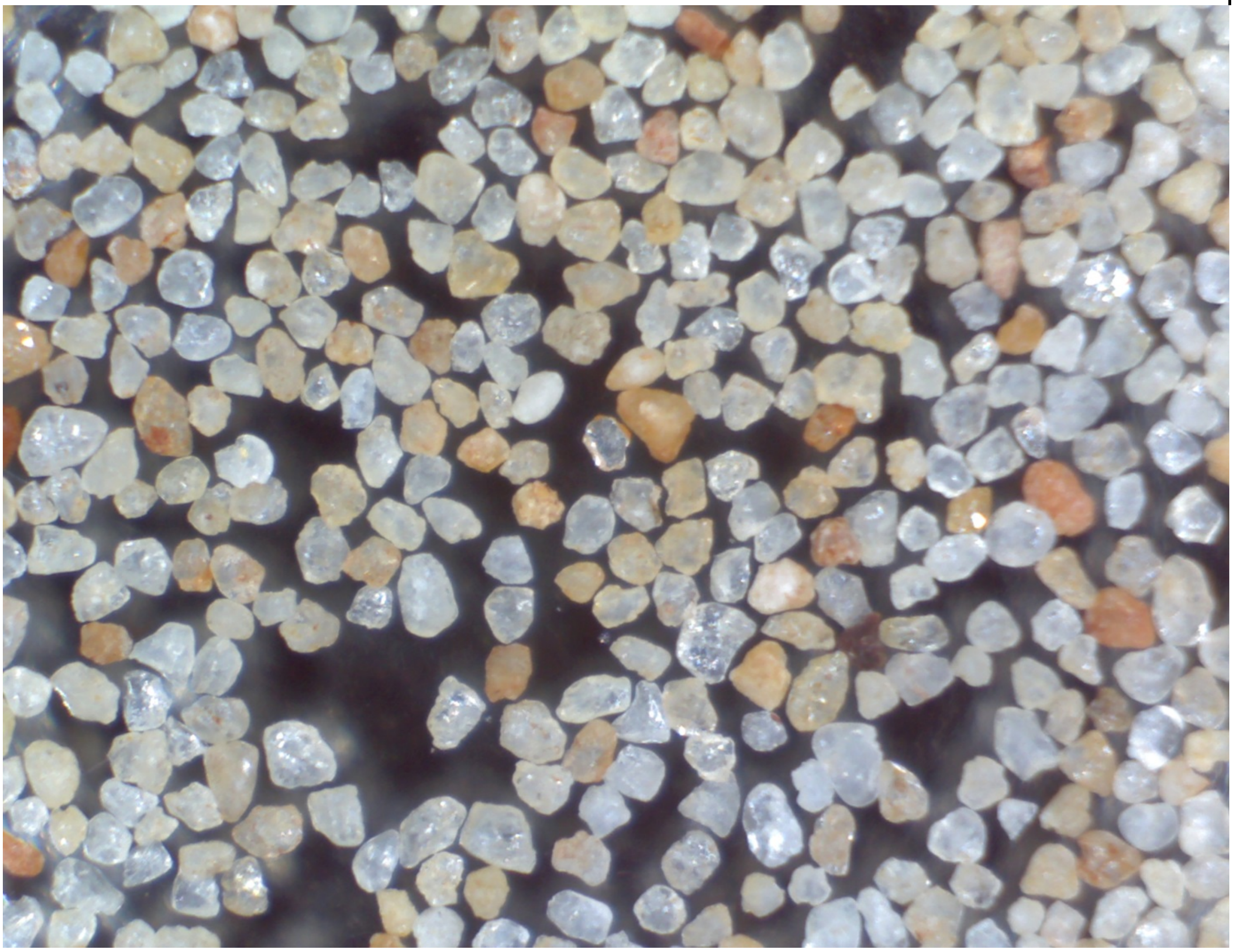

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McLanahan Frac Sand Testing Results

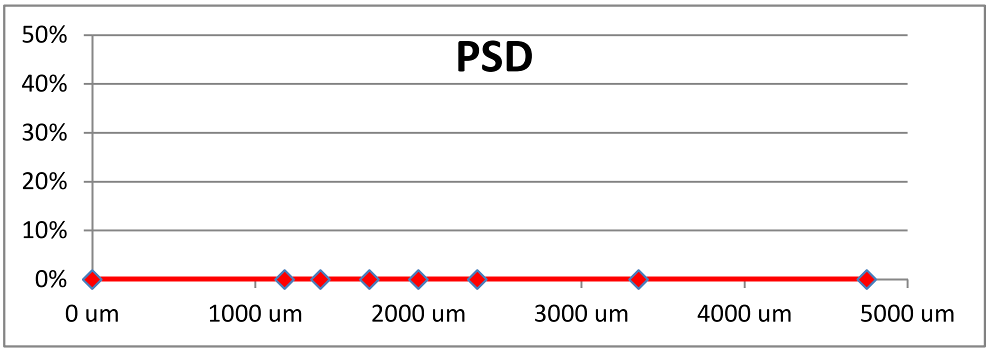
Job #: **B140725**

Customer: QMS
Contact: Mark Philpot
Address: TBA
Date: 31/07/2014
Tested by: Bevan McLachlan
Sample Location: BH3 BL G ML

6/12 (3350-1700µm) Primary Frac Sand Size Testing Results

Product Size Distribution

4750 um	0 g
3350 um	0 g
2360 um	0 g
2000 um	0 g
1700 um	0 g
1400 um	0 g
1180 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test	20
Average Roundness	0.1	Average crush test Fines Generated (%)	0.0
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail	N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)	

		Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Tested Acid solubility	xxxxx					
Acid test Pass/ Fail	Fail	xxx	xxx	xxx	xxx	xxx

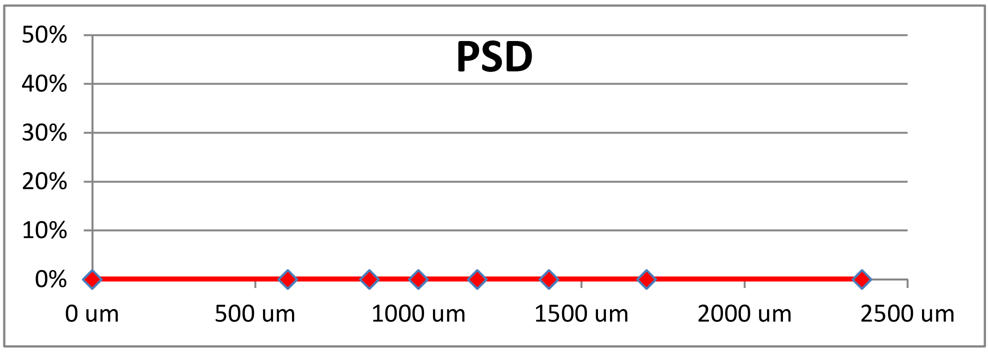
Warnings: **Size 6/12 Sphericity < 0.6 , Size 6/12 Roundness < 0.6 , , ,**

Comments: **xxxxxxxx**

12/20 (1700-850µm) Primary Frac Sand Size Testing Results

Product Size Distribution

2360 um	0 g
1700 um	0 g
1400 um	0 g
1180 um	0 g
1000 um	0 g
850 um	0 g
600 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test	16
Average Roundness	0.1	Average crush test Fines Generated (%)	0.00
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail	N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)	

		Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Tested Acid solubility	xxxxx					
Acid test Pass/ Fail	Fail	xxxx	xxx	xxx	xxx	xxx

Warnings: **Size 12/20 Sphericity < 0.6 , Size 12/20 Roundness < 0.6 , , ,**

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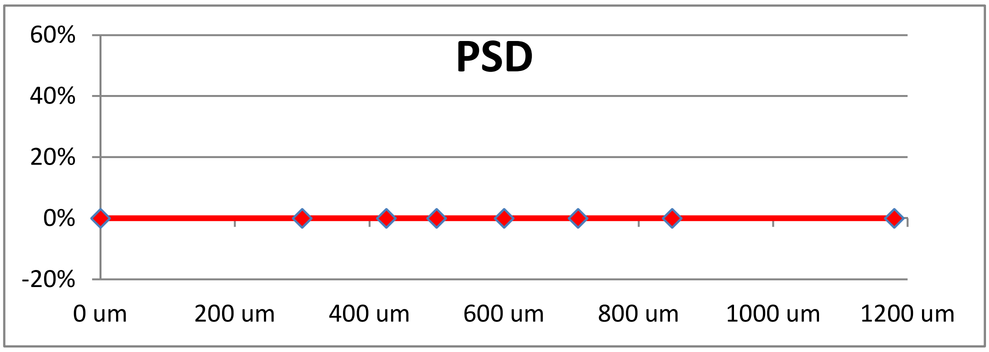
Comments:	**xxxxxxx**

20/40 Primary (850-425µm) Frac Sand Size Testing Results

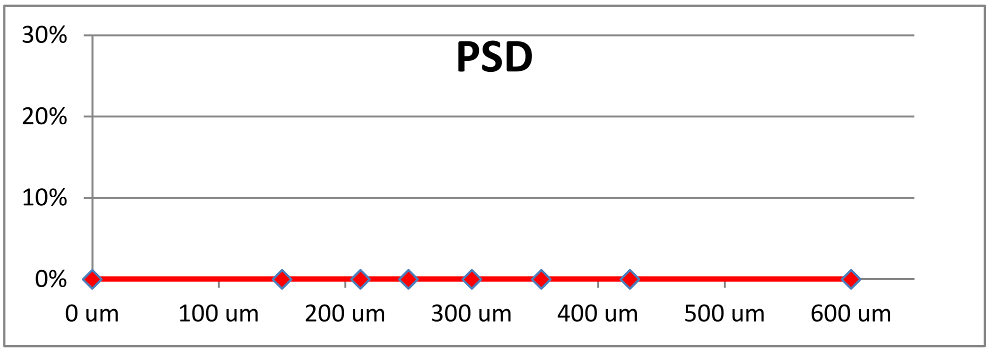
Product Size Distribution	
1180 um	0 g
850 um	0 g
710 um	0 g
600 um	0 g
500 um	0 g
425 um	0 g
300 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test				14
Average Roundness	0.10	Average crush test Fines Generated (%)				0.0
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail				N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxxxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	**Fail**	xxx	xxx	xxx	xxx	xxx
Warnings:	**Size 20/40 Sphericity < 0.6 , Size 20/40 Roundness < 0.6 , , ,**					
Comments:	**xxxxxxx**					

40/70 (425-212µm) Primary Frac Sand Size Testing Results

Product Size Distribution	
600 um	0 g
425 um	0 g
355 um	0 g
300 um	0 g
250 um	0 g
212 um	0 g
150 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test				8
Average Roundness	0.1	Average crush test Fines Generated (%)				18.3
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail				**Fail**
Acid Solubility limit	3%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	Fail	xxx	xxx	xxx	xxx	xxxx
Warnings:	**Size 40/70 Sphericity < 0.6 , Size 40/70 Roundness < 0.6 , , , 8% Fines by weight exceeded for 40/70 Crush test**					
Comments:	**xxxxxxxxxxxxx**					

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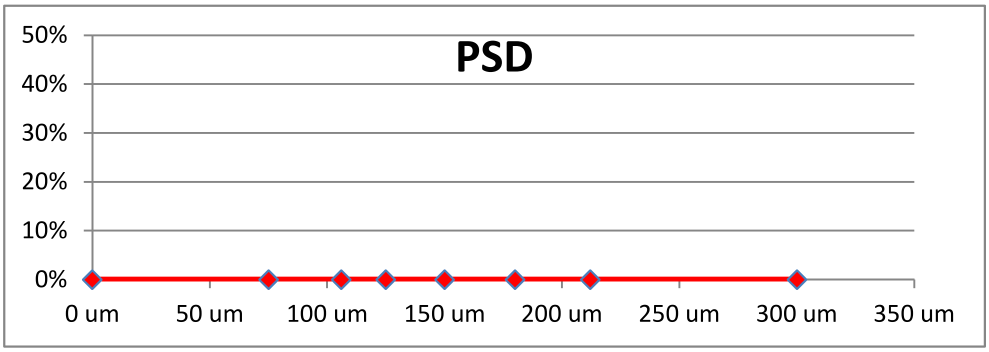
70/140 (212-106µm) Primary Frac Sand Size Testing Results

Product Size Distribution

300 um	0 g
212 um	0 g
180 um	0 g
150 um	0 g
125 um	0 g
106 um	0 g
75 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test	6
Average Roundness	0.10	Average crush test Fines Generated (%)	0.0
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail	N/A
Acid Solubility limit	3%	Mineralogical Analysis Results (Mineral by Mass %)	
Tested Acid solubility	xxx	Zeolite / Mica / Amphibole / Serpentine / Alpha Quartz	
Acid test Pass/ Fail	**Fail**	xxx / xxx / xxx / xxx / xxx	

Warnings:	**Size 70/140 Sphericity < 0.6 , Size 70/140 Roundness < 0.6 , , ,**
Comments	**xxxxxxxx**

Mineralogical Analysis Notes

The quantitative results shown in the mineralogical analysis results table have been normalised to 100%, and it should be noted that the values shown represent the relative proportion of the crystalline material in the sample. Totals greater or smaller than 100% are due to rounding errors. Negative results in the table indicate normally a larger than usual uncertainty in regard to the quantity of the phase reported; for some of the minor and trace phases it might also indicate an uncertainty in regard of the phase itself, or both.

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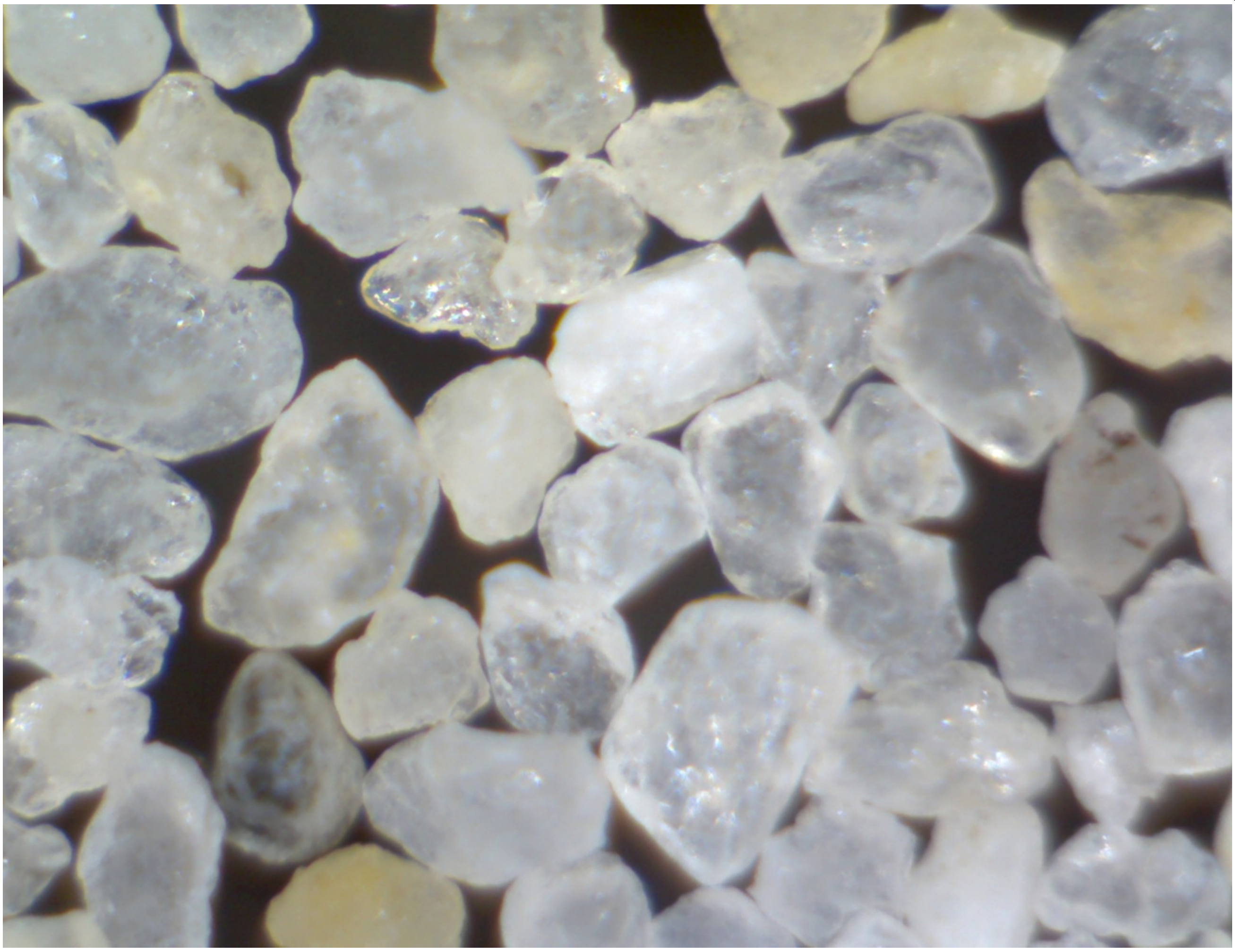

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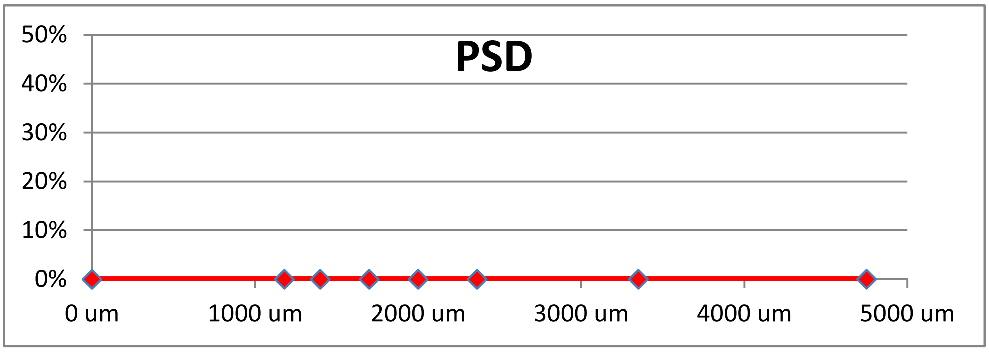
McLanahan Frac Sand Testing Results   Job #: B140725

Customer: QMS   Contact: Mark Philpot
Address: TBA
Date: 31/07/2015   Tested by: Bevan McLachlan
Sample Location: BH5 BL B ML

6/12 (3350-1700µm) Primary Frac Sand Size Testing Results

Product Size Distribution

4750 um	0 g
3350 um	0 g
2360 um	0 g
2000 um	0 g
1700 um	0 g
1400 um	0 g
1180 um	0 g
Pan	0 g

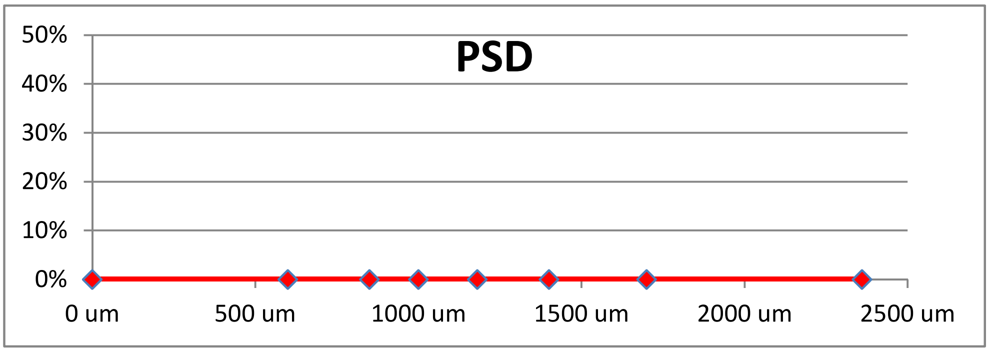


Average Sphericity	0.1	% Fines Allowed for Crush test				20
Average Roundness	0.1	Average crush test Fines Generated (%)				0.0
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail				N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxxxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	Fail	xxx	xxx	xxx	xxx	xxx
Warnings:	Size 6/12 Sphericity < 0.6 , Size 6/12 Roundness < 0.6 , , ,					
Comments:	xxxxxxxx					

12/20 (1700-850µm) Primary Frac Sand Size Testing Results

Product Size Distribution

2360 um	0 g
1700 um	0 g
1400 um	0 g
1180 um	0 g
1000 um	0 g
850 um	0 g
600 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test				16
Average Roundness	0.1	Average crush test Fines Generated (%)				0.00
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail				N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxxxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	Fail	xxxx	xxx	xxx	xxx	xxx
Warnings:	Size 12/20 Sphericity < 0.6 , Size 12/20 Roundness < 0.6 , , ,					

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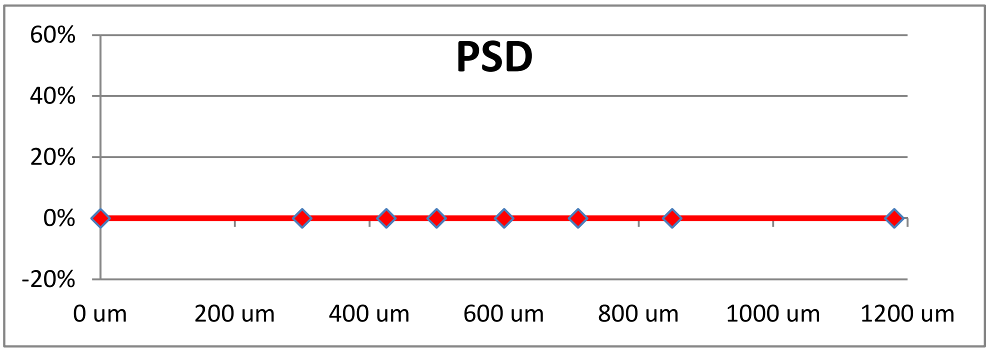
Comments:	xxxxxxx

20/40 Primary (850-425µm) Frac Sand Size Testing Results

Product Size Distribution

1180 um	0 g
850 um	0 g
710 um	0 g
600 um	0 g
500 um	0 g
425 um	0 g
300 um	0 g
Pan	0 g

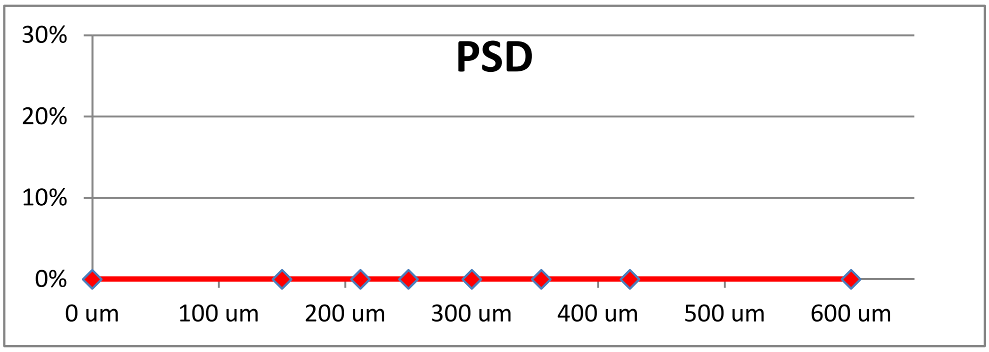


Average Sphericity	0.1	% Fines Allowed for Crush test	14
Average Roundness	0.10	Average crush test Fines Generated (%)	0.0
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail	N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)	
Tested Acid solubility	xxxxx	Zeolite / Mica / Amphibole / Serpentine / Alpha Quartz	
Acid test Pass/ Fail	**Fail**	xxx / xxx / xxx / xxx / xxx	
Warnings:	**Size 20/40 Sphericity < 0.6 , Size 20/40 Roundness < 0.6 , , ,**		
Comments:	xxxxxxx		

40/70 (425-212µm) Primary Frac Sand Size Testing Results

Product Size Distribution

600 um	0 g
425 um	0 g
355 um	0 g
300 um	0 g
250 um	0 g
212 um	0 g
150 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test	8
Average Roundness	0.1	Average crush test Fines Generated (%)	18.1
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail	**Fail**
Acid Solubility limit	3%	Mineralogical Analysis Results (Mineral by Mass %)	
Tested Acid solubility	xxx	Zeolite / Mica / Amphibole / Serpentine / Alpha Quartz	
Acid test Pass/ Fail	Fail	xxx / xxx / xxx / xxx / xxxx	
Warnings:	**Size 40/70 Sphericity < 0.6 , Size 40/70 Roundness < 0.6 , , , 8% Fines by weight exceeded for 40/70 Crush test**		
Comments:	xxxxxxxxxxxx		

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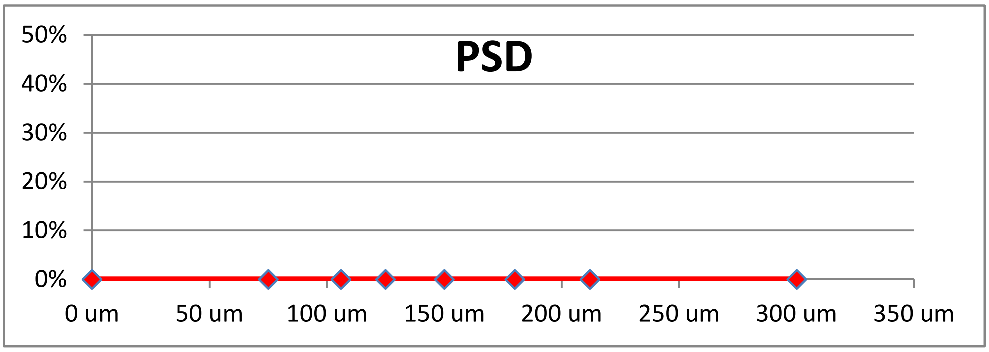
70/140 (212-106µm) Primary Frac Sand Size Testing Results

Product Size Distribution

300 um	0 g
212 um	0 g
180 um	0 g
150 um	0 g
125 um	0 g
106 um	0 g
75 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test	6
Average Roundness	0.10	Average crush test Fines Generated (%)	0.0
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail	N/A
Acid Solubility limit	3%	Mineralogical Analysis Results (Mineral by Mass %)	

Tested Acid solubility	xxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	**Fail**	xxx	xxx	xxx	xxx	xxx

Warnings: **Size 70/140 Sphericity < 0.6 , Size 70/140 Roundness < 0.6 , , ,**

Comments **xxxxxxxxx**

Mineralogical Analysis Notes

The quantitative results shown in the mineralogical analysis results table have been normalised to 100%, and it should be noted that the values shown represent the relative proportion of the crystalline material in the sample. Totals greater or smaller than 100% are due to rounding errors. Negative results in the table indicate normally a larger than usual uncertainty in regard to the quantity of the phase reported; for some of the minor and trace phases it might also indicate an uncertainty in regard of the phase itself, or both.

Notes

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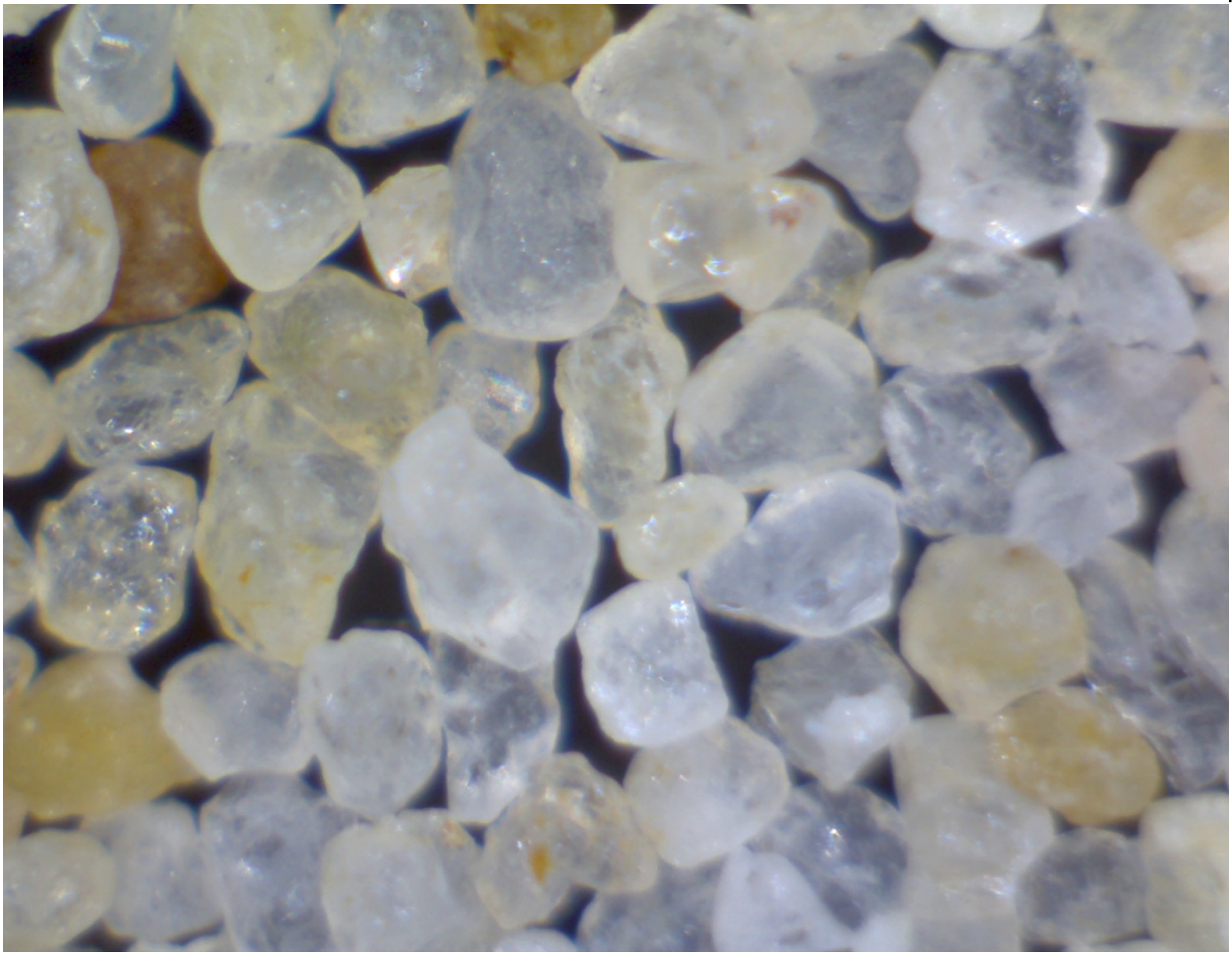

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McLanahan Frac Sand Testing Results

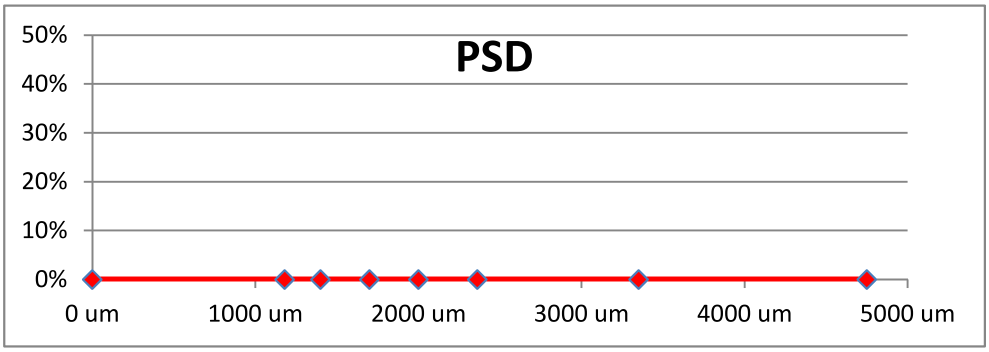
Job #: **B140725**

Customer: QMS
Contact: Mark Philpot
Address: TBA
Date: 31/07/2014
Tested by: Bevan McLachlan
Sample Location: HA ML 1

6/12 (3350-1700µm) Primary Frac Sand Size Testing Results

Product Size Distribution

4750 um	0 g
3350 um	0 g
2360 um	0 g
2000 um	0 g
1700 um	0 g
1400 um	0 g
1180 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test	20
Average Roundness	0.1	Average crush test Fines Generated (%)	0.0
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail	N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)	
Tested Acid solubility	xxxxx	Zeolite / Mica / Amphibole / Serpentine / Alpha Quartz	
Acid test Pass/ Fail	Fail	xxx / xxx / xxx / xxx / xxx	

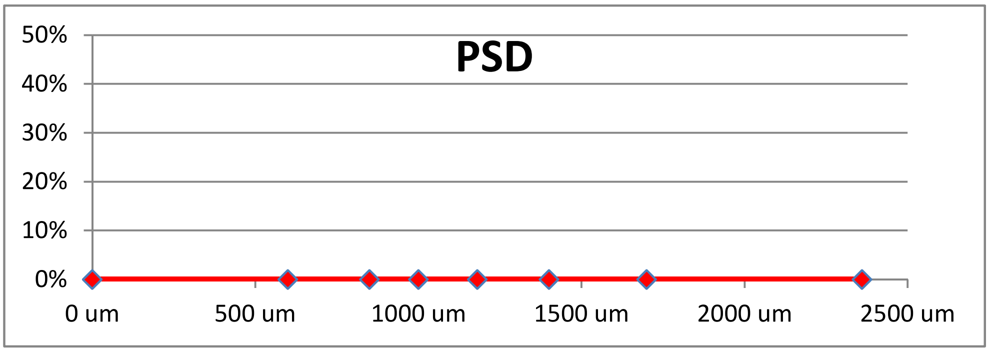
Warnings: Size 6/12 Sphericity < 0.6 , Size 6/12 Roundness < 0.6 , , ,

Comments: xxxxxxxx

12/20 (1700-850µm) Primary Frac Sand Size Testing Results

Product Size Distribution

2360 um	0 g
1700 um	0 g
1400 um	0 g
1180 um	0 g
1000 um	0 g
850 um	0 g
600 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test	16
Average Roundness	0.1	Average crush test Fines Generated (%)	0.00
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail	N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)	
Tested Acid solubility	xxxxx	Zeolite / Mica / Amphibole / Serpentine / Alpha Quartz	
Acid test Pass/ Fail	Fail	xxxx / xxx / xxx / xxx / xxx	

Warnings: Size 12/20 Sphericity < 0.6 , Size 12/20 Roundness < 0.6 , , ,

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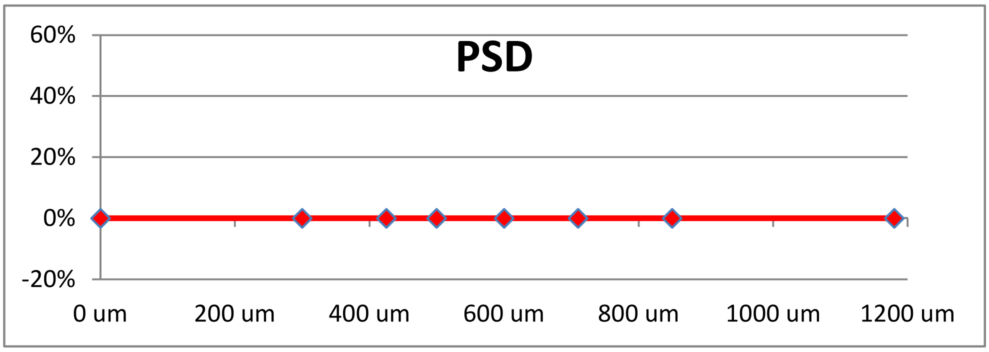
Comments:	**xxxxxxx**

20/40 Primary (850-425µm) Frac Sand Size Testing Results

Product Size Distribution

1180 um	0 g
850 um	0 g
710 um	0 g
600 um	0 g
500 um	0 g
425 um	0 g
300 um	0 g
Pan	0 g

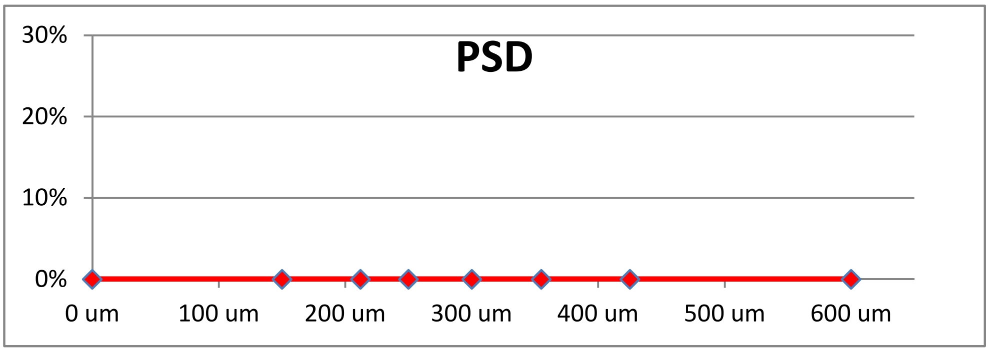


Average Sphericity	0.1	% Fines Allowed for Crush test	14
Average Roundness	0.10	Average crush test Fines Generated (%)	0.0
Round/ Sphere Pass	**Fail**	Crush Test Pass/ Fail	N/A
Acid Solubility limit	2%	Mineralogical Analysis Results (Mineral by Mass %)	
Tested Acid solubility	xxxxx	Zeolite / Mica / Amphibole / Serpentine / Alpha Quartz	
Acid test Pass/ Fail	**Fail**	xxx / xxx / xxx / xxx / xxx	
Warnings:	**Size 20/40 Sphericity < 0.6 , Size 20/40 Roundness < 0.6 , , ,**		
Comments:	**xxxxxxx**		

40/70 (425-212µm) Primary Frac Sand Size Testing Results

Product Size Distribution

600 um	0 g
425 um	0 g
355 um	0 g
300 um	0 g
250 um	0 g
212 um	0 g
150 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test	8
Average Roundness	0.1	Average crush test Fines Generated (%)	33.8
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail	**Fail**
Acid Solubility limit	3%	Mineralogical Analysis Results (Mineral by Mass %)	
Tested Acid solubility	xxx	Zeolite / Mica / Amphibole / Serpentine / Alpha Quartz	
Acid test Pass/ Fail	Fail	xxx / xxx / xxx / xxx / xxxx	
Warnings:	**Size 40/70 Sphericity < 0.6 , Size 40/70 Roundness < 0.6 , , , 8% Fines by weight exceeded for 40/70 Crush test**		
Comments:	**xxxxxxxxxxxxx**		

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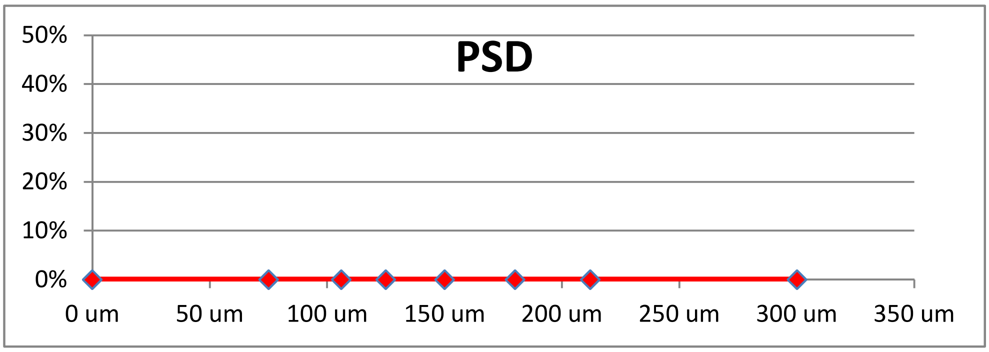
70/140 (212-106µm) Primary Frac Sand Size Testing Results

Product Size Distribution

300 um	0 g
212 um	0 g
180 um	0 g
150 um	0 g
125 um	0 g
106 um	0 g
75 um	0 g
Pan	0 g



Average Sphericity	0.1	% Fines Allowed for Crush test				6
Average Roundness	0.10	Average crush test Fines Generated (%)				0.0
Round/ Sphere Pass	Fail	Crush Test Pass/ Fail				N/A
Acid Solubility limit	3%	Mineralogical Analysis Results (Mineral by Mass %)				
Tested Acid solubility	xxx	Zeolite	Mica	Amphibole	Serpentine	Alpha Quartz
Acid test Pass/ Fail	Fail	xxx	xxx	xxx	xxx	xxx
Warnings:	**Size 70/140 Sphericity < 0.6 , Size 70/140 Roundness < 0.6 , , ,**					
Comments	**xxxxxxxxx**					

Mineralogical Analysis Notes

The quantitative results shown in the mineralogical analysis results table have been normalised to 100%, and it should be noted that the values shown represent the relative proportion of the crystalline material in the sample. Totals greater or smaller than 100% are due to rounding errors. Negative results in the table indicate normally a larger than usual uncertainty in regard to the quantity of the phase reported; for some of the minor and trace phases it might also indicate an uncertainty in regard of the phase itself, or both.

Notes

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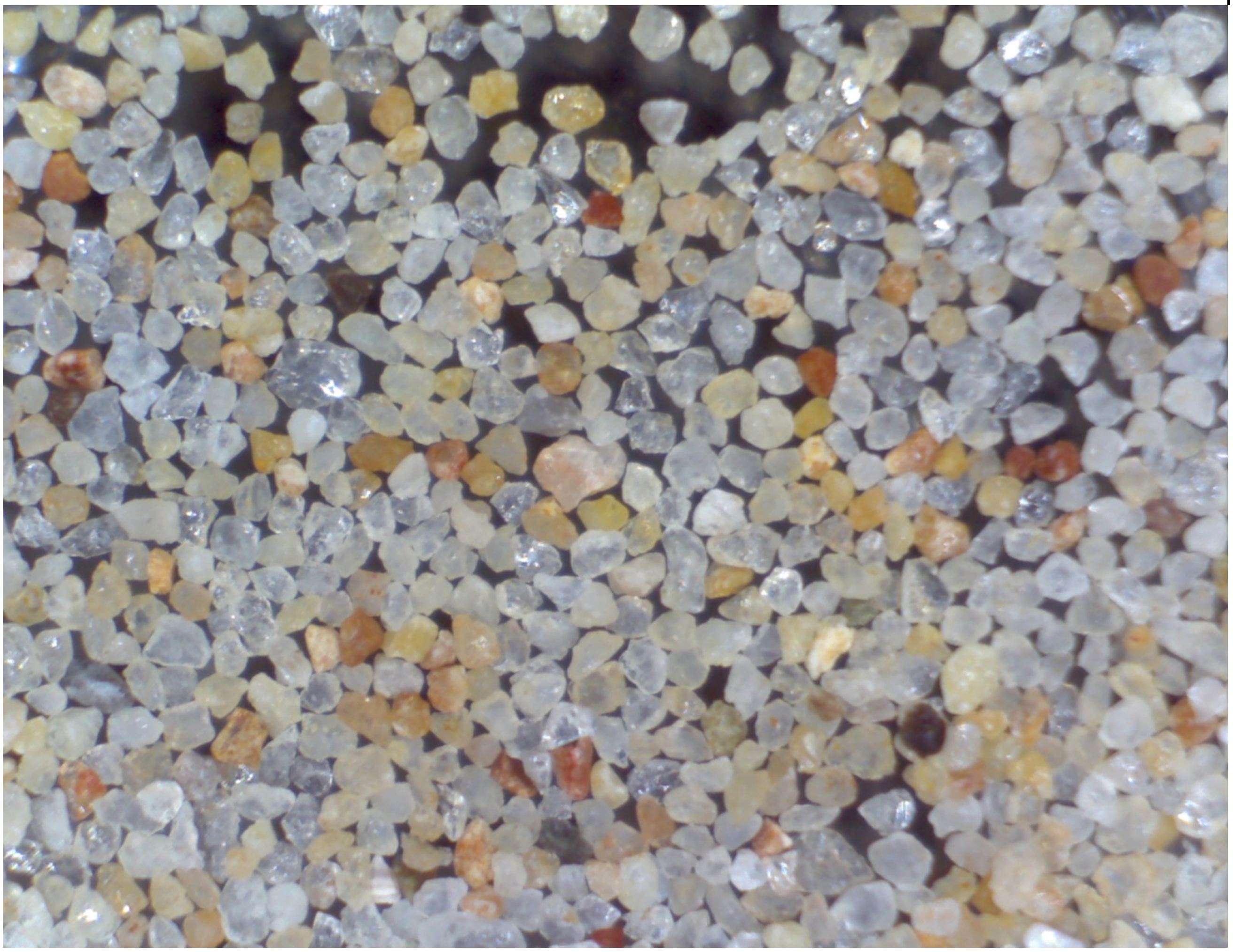

STAGE 2 REPORT

GEOCHEMICAL TESTING ON 9 RAW BLENDED SAND SAMPLES TAKEN FROM SILICA SAND DEPOSIT AT BOBS FARM, NELSON BAY ROAD, PORT STEPHENS, NSW AND RECOMMENDATIONS FOR FURTHER STAGE 2 INVESTIGATION AND STAGE 3 CONSIDERATIONS

prepared for

QUARRY MINING SERVICES PTY LTD
RED HEAD, NSW

By

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Date: **8th October, 2014**

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1.0 OVERVIEW

1.1. INTRODUCTION

Geochempet Services (Geochempet) has been requested by Quarry Mining Services Pty Ltd (QMS) on 31/07/14 to conduct some targeted geochemical testing on 9 raw blended sand samples to explore commercial opportunities for the use of silica sand materials contained within the dune and beach sand sequences within the Bobs Farm area at 51 Nelson Bay Road as part of Stage 2 investigations.

Geochempet Services contracted out the XRD, XRF and LECO analytical testing to QUT and ALS, Brisbane on 07/08/14.

1.2. OBJECTIVES OF GEOCHEMICAL INVESTIGATIONS

The overall objective of this investigation is to assess if silica products of added value could be potentially processed from the silica sand by testing for:

- elements and oxides using XRF analysis on the 9 raw blended sand samples (SiO2, Na2O, K2O, CaO, MgO, Al2O3, TiO2, Fe2O3, Cr2O3 and LOI as well as Cu, Co, Cr, Cu, Fe, Mn, Ni, Ti, V and Zn)
- carbon and sulphides impurities using LECO analysis on the 9 raw blended sand samples
- and using Quantitative XRD analysis on three sand samples (BH2-BL-B-PL, BH3-BL-G-PL, BH5-BL-G-PL) with lowest free silica contents to identify if any impurities are in mineral form

2.0 GEOCHEMICAL ANALYSIS

Nine raw blended sand samples were selected as suitable for further geochemical testing to identify any potential for value-added uses. Terminology of blonde or dune sands and grey or beach sands are used inter-changeably. The sand samples are labelled as follows:

BH1-BL-G1-PL	blended lower grey beach sand from 12 - 19 m
BH2-BL-B-PL	blended blonde dune sand from 4.2 – 9.5 m
BH2-BL-G-PL	blended grey beach sand from 13.5 – 26.5 m
BH3-BL-B3-PL	blended blonde dune sand from 4 - 10 m
BH3-BL-G-PL	blended grey beach sand from 17 – 26.5 m
BH4-BL-B-PL	blended blonde dune sand from 1.5 – 5.7 m
BH4-BL-G-PL	blended grey beach sand from 13.5 – 24 m
BH5-BL-B-PL	blended blonde dune sand from 5.5 – 14.5 m
BH5-BL-G-PL	blended grey beach sand from 23 – 25.6 m

The four blonde (B) sand samples are interpreted to be from the upper dune sand sequence capped by a mottled soil profile. The five grey sand samples are interpreted to be from the barrier beach sand sequence below a black organic-rich mud and silt marker horizon.

Nine petrographic reports issued by Geochempet Services which characterise the properties of the selected sand samples are shown below in Table 1.

Sample Number	BH2-BL-B-PL	BH3-BL-B3-PL	BH4-BL-B-PL	BH5-BL-B-PL
Composite depth	4.2-9.5 m	4-10 m	1.5-5.7 m	5.5-14.5 m
Sample Type	Quartz Sand	Quartz Sand	Quartz Sand	Quartz Sand
Free Silica Content	91%	94%	99%	99%
Grainsize	Fine to medium	Fine to medium	Fine to medium	Fine to medium
Grain Shape	Sub-rounded to sub-angular	Sub-rounded to rounded	Sub-rounded to sub-angular	Sub-rounded to rounded
Mineral grains	4% feldspar	3% feldspar	<1% feldspar	<1% feldspar
Lithic Clasts	4%	3%	1%	1%
Fe_2O_3 coatings	<1%	<1%	<1%	<1%
Heavy minerals	1%	<1%	<1%	<1%

Sample Number	BH1-BL-G1-PL	BH2-BL-G-PL	BH3-BL-G-PL	BH4-BL-G-PL	BH5-BL-G-PL
Composite depth	12-19 m	13.5-26.5 m	17-26.5 m	13-24 m	23-25.6 m
Sample Type	Quartz Sand	Quartz Sand	Quartz Sand	Quartz Sand	Quartz Sand
Free Silica Content	97%	97%	88%	93%	90%
Grainsize	Fine to medium	Fine to medium	Fine to medium	Fine to medium	Fine to medium
Grain Shape	Sub-rounded to sub-angular	Sub-rounded to sub-angular	Sub-rounded to rounded	Sub-rounded to sub-angular	Sub-rounded to rounded
Mineral grains	1% feldspar	1% feldspar	2% feldspar	3% feldspar	2% feldspar
Lithic Clasts	1%	2%	9%	3%	9%
Fe2O3 coatings	<1%	<1%	<1%	<1%	<1%
Heavy mineral Content	1%	<1%	1%	1%	<1%

Table 1. Characteristics of blended borehole sand samples from petrographic examinations.

2.1. XRD RESULTS

Three 3 raw blended sand samples from Bob's farm investigation site were submitted for XRD analysis (see Tables 2 and 3) and powder and clay XRD patterns are shown in Figures 1 and 2.

	BH2-BL-B-PL	BH3-BL-G-PL	BH5-BL-G-PL
Quartz	91.7%	91.8%	89.7%
K-feldspar	1.5%	1.9%	0.9%
Unidentified	6.7%	6.2%	9.3%

Table 2. Mineral identifications - Results in weight% for 3 blended sand samples.

	BH2-BL-B-PL	BH3-BL-G-PL	BH5-BL-G-PL
Kaolinite	minor	minor	minor
Illite/Sericite	minor	minor	minor
Chlorite		trace	trace

Table 3. Clay phase identifications - Results in weight% for 3 blended sand samples.

Note that their concentrations are such that the clays could not be detected in the powder samples.

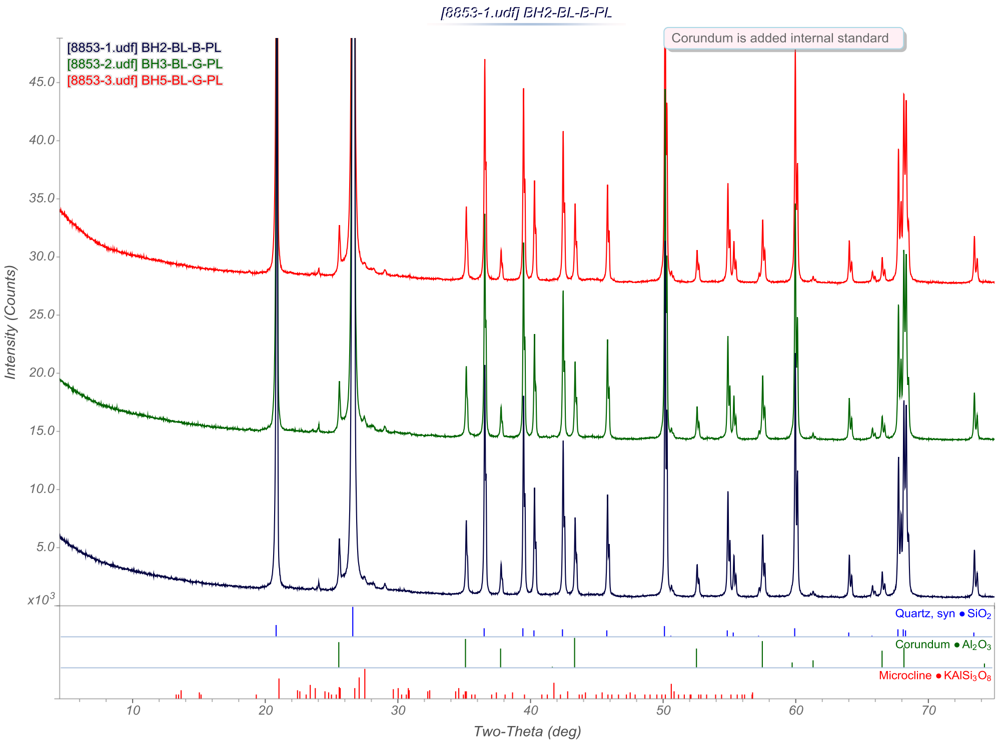

Figure 1. Powder XRD patterns of the three sand samples.

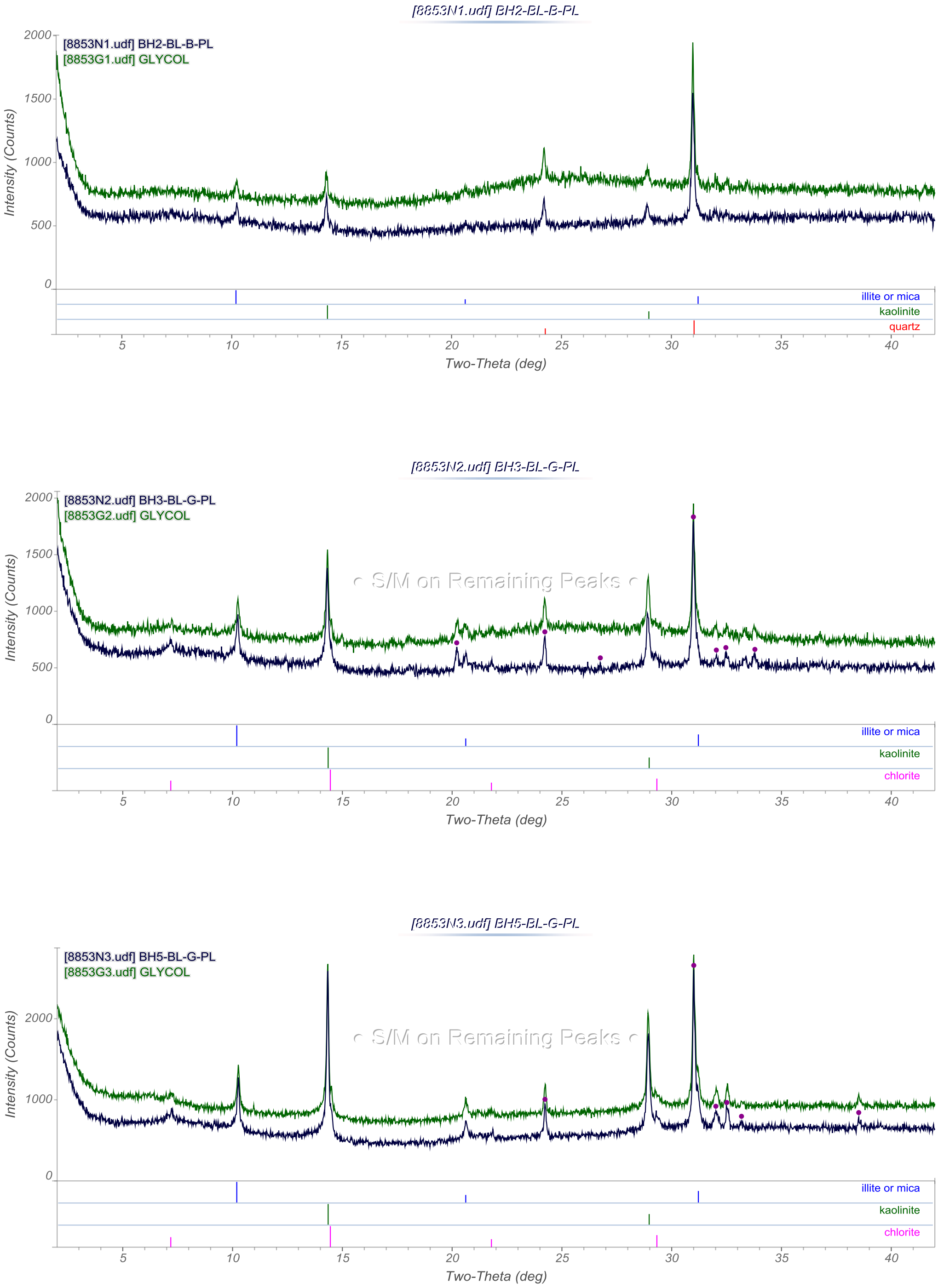

Figure 2. Clay XRD patterns of the three sand samples.

The three raw blended sand samples were selected on the basis of their lower free quartz contents which implied a greater variation in minerals. Only two minerals were identified by XRD analysis of the 3 sand samples, dominantly quartz with minor microcline feldspar, confirming that these sand samples can be identified as clean quartz sands. They contain 91.7wt%, 91.8wt% and 89.7wt% quartz respectively by XRD analysis whereas petrographic examination identified 91vol%, 88vol% and 90vol% respectively. The results show good correlation despite the fact they are estimated by different techniques.

The feldspar contents are 1.5wt%, 1.9wt% and 0.9wt% respectively compared with 4vol%, 2vol% and 2vol% respectively. The usual reason for over counting abundances in petrographic examination is variation in grain size, the smaller the grainsize the more likely it is counted as 1% when in reality it occupy a smaller volume. Also XRD determines composition in weight% and is calculated from a very small sub-sample of the original sand sample which may lead to a bias in sampling. I would regarded the XRD results as more consistent and a better guide of feldspar composition in the sand samples.

The amorphous content of the three sand samples are 6.7%, 6.2% and 9.3% and are probably related to the abundance of lithic clasts within the sands. The meaning of the amorphous/unknown concentration is open to interpretation – it could represent the non-diffracting component, any unidentified phases and/or any short-coming of the models used for the respective phases modelled. In my opinion, the amorphous/unknown content is probably a result of poor fit to modelled phases. This implies that lithic content should be highest in Sample BH5-BL-G-PL and is recorded from petrographic examination as 9vol% of the supplied sample as against 9.3wt%. In sample BH3-BL-G-PL, the lithic content may be slightly over-estimated by petrographic examination (9vol% versus 6.2wt%). The result for sample BH2-BL-B-PL appear to be slightly under-estimated by petrographic examination (4vol% versus 6.7wt%) for lithic clasts.

The presence of very minor amounts of clay (kaolinite) and very fine micas (illite/sericite) are noted in the three sand samples below the detection limit of the quantifiable technique. These contribute traces of aluminium and potassium noticed in the XRF analysis in Section 2.2. Traces of a chlorite phase is also present in the grey sand samples (BH3-BL-G-PL and BH5-BL-G-PL) but is absent in the blonde sand sample (BH2-BL-B-PL).

No heavy minerals or highly aluminous grains were detected by the XRD analyses and if they are present, the abundance is below the detection limit for the technique.

2.2. XRF RESULTS

A total of nine (9) blended sand samples were submitted for XRF and LECO analyses.

The following table shows the elemental oxide analysis results for each sample.

	BH1-BL-G1-PL %	BH2-BL-B-PL %	BH2-BL-G-PL %	BH3-BL-B3-PL %	BH3-BL-G-PL %	BH4-BL-B-PL %	BH4-BL-G-PL %	BH5-BL-B-PL %	BH5-BL-G-PL %
Al203	0.7	0.55	1.0	0.49	0.71	0.53	0.72	0.52	0.6
BaO	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
CaO	0.02	0.02	0.02	0.01	0.03	0.01	0.02	0.02	0.24
Cr2O3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe2O3	0.18	0.17	0.2	0.1	0.21	0.13	0.13	0.14	0.14
K2O	0.22	0.17	0.34	0.17	0.22	0.17	0.24	0.17	0.19
MgO	0.01	<0.01	0.03	0.01	0.03	0.01	0.03	0.01	0.02
MnO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Na2O	0.05	0.03	0.07	0.03	0.06	0.04	0.06	0.04	0.05
P2O5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01
SO3	0.12	<0.01	0.04	<0.01	0.08	<0.01	0.06	<0.01	0.08
SiO2	97.8	97.9	97.6	98.2	97.8	98.3	98.2	98.3	97.3
SrO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO2	0.1	0.16	0.18	0.06	0.39	0.07	0.11	0.12	0.14
LOI	0.6	0.44	0.42	0.38	0.34	0.37	0.36	0.22	0.43
C	0.37	0.17	0.06	0.04	0.03	0.08	0.06	0.02	0.09
S	0.05	0.01	0.02	0.01	0.04	<0.01	0.02	<0.01	0.04

Table 4. – Elemental oxide analyses by fusion XRF using Method ME—XRF26, loss on ignition by ME-GRA05, and total carbon by C-IR07 and total sulphur by S-IR08.

The silica dioxide results for the nine sand samples range from 97.3wt% to 98.3wt% which is quite consistent across the sand samples. When compared to the XRD results for the three sand samples with the lowest quartz content, it implies that the lithic clasts are contributing a significant amount of SiO2 to the overall level of silica.

The Al2O3 content reflects the presence of feldspar, kaolinite and some lithic clasts. The relatively elevated CaO and LOI values in Sample BH5-BL-G-PL are probably a reflection of minor shell content. Otherwise, the LOI values overall are interpreted to represent the carbon levels in these sands and possibly traces of shell fragments. The Fe and Ti oxides are interpreted to be derived from very minor amounts of ilmenite in the sands and some of the Fe2O3 result may also reflected traces of secondary iron oxide coatings on sand grains. The

K content is probably derived from the presence of microcline feldspar as a minor component in the sand samples.

All other elemental oxides are present in trace amounts (generally below 0.07wt%).

The following table shows the elemental analysis results for each sample.

	BH1-BL-G1-PL	**BH2-BL-B-PL**	**BH2-BL-G-PL**	**BH3-BL-B3-PL**	**BH3-BL-G-PL**	**BH4-BL-B-PL**	**BH4-BL-G-PL**	**BH5-BL-B-PL**	**BH5-BL-G-PL**
Co ppm	<1	<1	<1	<1	1	<1	1	1	1
Cr ppm	6	5	7	2	15	3	6	4	8
Cu ppm	1	1	11	1	3	1	5	1	2
Fe %	0.11	0.11	0.13	0.07	0.13	0.08	0.09	0.09	0.09
Mn ppm	10	13	18	5	35	6	12	11	14
Ni ppm	<1	1	2	1	1	1	1	<1	2
Ti %	0.05	0.06	0.08	0.03	0.14	0.03	0.05	0.05	0.06
V ppm	4	4	5	3	8	3	4	4	4
Zn ppm	5	2	23	<2	17	<2	22	2	15
Ctotal%	0.37	0.17	0.06	0.04	0.03	0.08	0.06	0.02	0.09
Cinorganic%	0.24	0.05	0.02	0.03	0.02	0.03	0.03	0.02	0.07
Corganic%	0.13	0.12	0.04	<0.02	<0.02	0.05	0.03	<0.02	0.02
Stotal%	0.05	0.01	0.02	0.01	0.04	<0.01	0.02	<0.01	0.04
Ssulphate%	0.04	<0.01	0.01	0.01	0.03	<0.01	0.02	<0.01	0.02
Ssulphide%	0.01	0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02

Table 5. – Elemental analyses by four acid digestion and ICP-AES using Method ME—ICP61 as well as organic carbon by C-IR17 and sulphate by S-ICP16.

The manganese result in the grey sand (18 ppm) is twice the average for the blonde sand (9 ppm). The average vanadium result is 5 ppm for grey or beach sand and 3.5 ppm for blonde or dune sand and zinc values for the grey sand averages 16 ppm as against an average value of about 1 ppm for the blonde sand. The other elemental results generally follow a similar trend of lower values in the blonde sand which indicates that the upper dune sands are slightly leached of more soluble elements.

The relatively high carbon result in Sample BH1-BL-G1-PL is probably the result of some slight carbonaceous contamination down hole from the overlying carbonaceous layer during auger drilling.

The following figures display trends for oxides and elements in wt%.

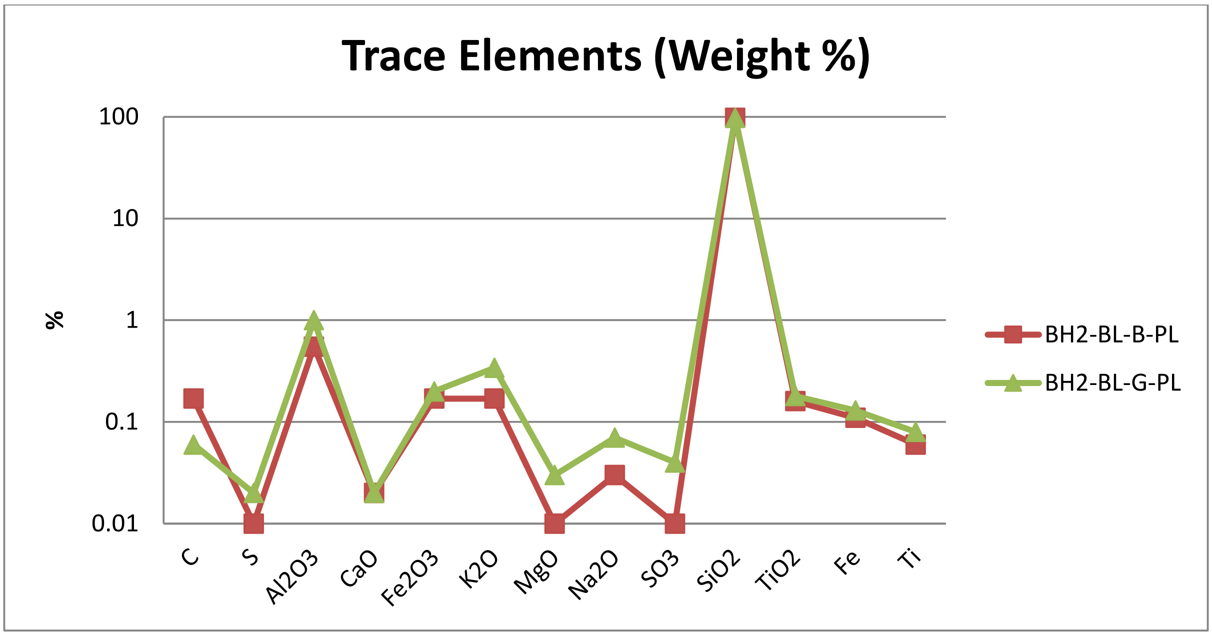

Figure 3. Note trend showing slight depletion of oxides and elements for the upper blonde sand in BH2. The exception is total carbon results which are higher in blonde sand than the lower grey beach sand (this excludes the contaminated grey sand sample in BH1). SiO2 is regarded as insoluble so does not deplete from upper to lower sand units.

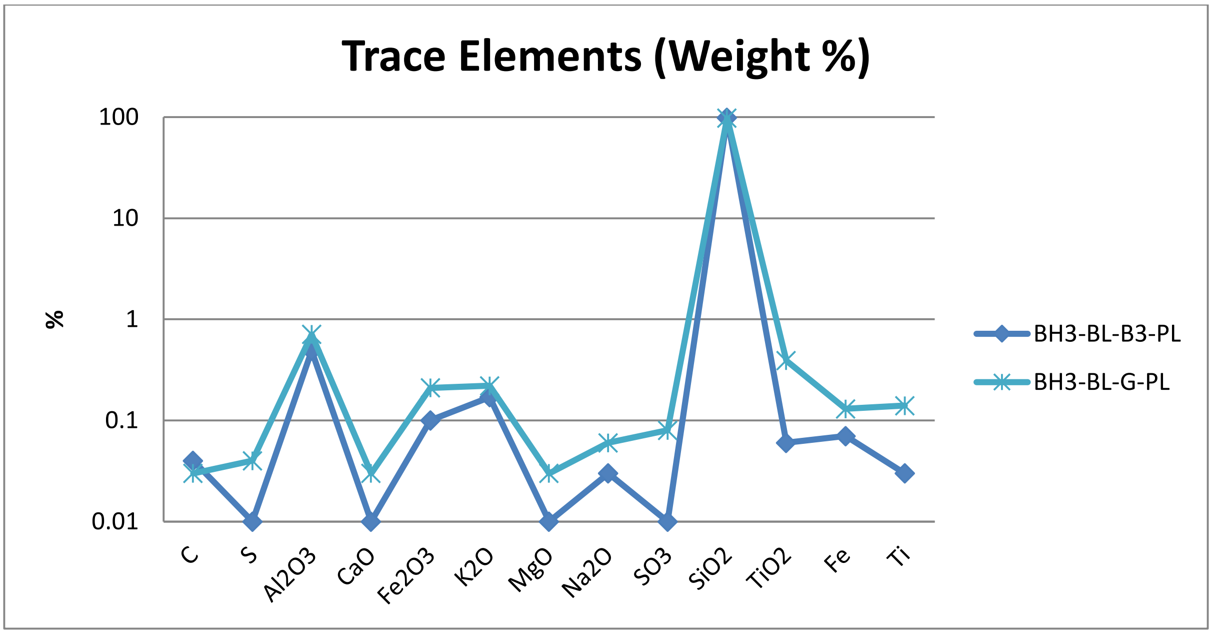

Figure 4. Note trend showing slight depletion of oxides and elements for the upper blonde sand in BH3. The exception is total carbon results which are higher in blonde sand than the lower grey beach sand (this excludes the contaminated grey sand sample in BH1). SiO2 is regarded as insoluble so does not deplete from upper to lower sand units.

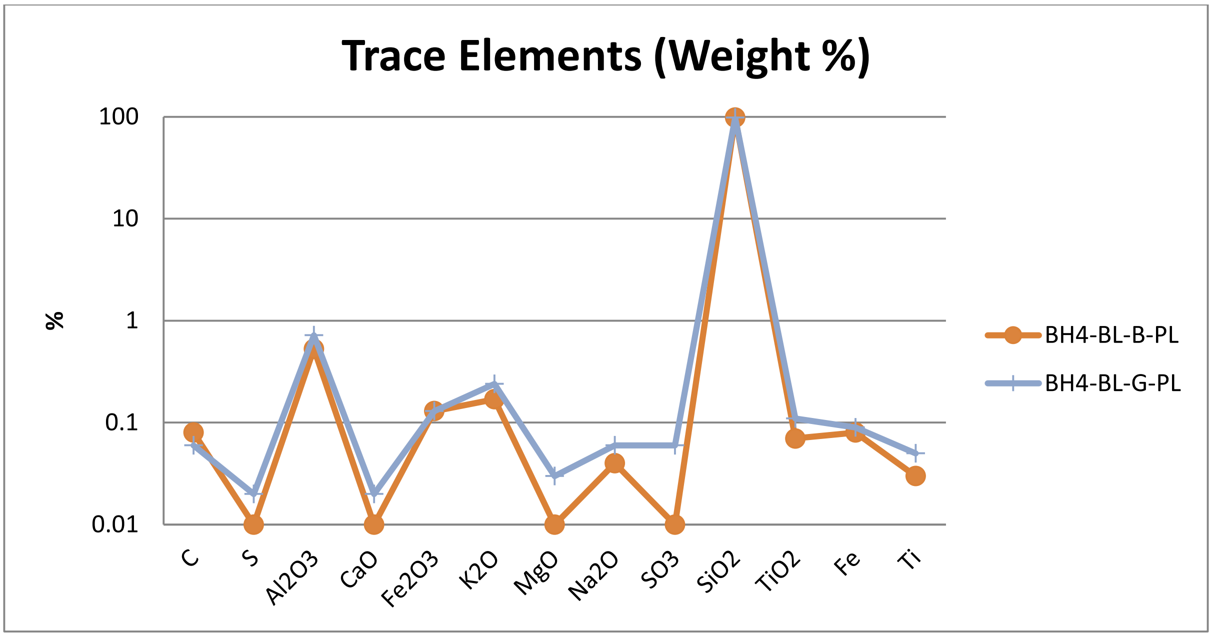

Figure 5. Note trend showing slight depletion of oxides and elements for the upper blonde sand in BH4. The exception is total carbon results which are higher in blonde sand than the lower grey beach sand (this excludes the contaminated grey sand sample in BH1). SiO2 is regarded as insoluble so does not deplete from upper to lower sand units.

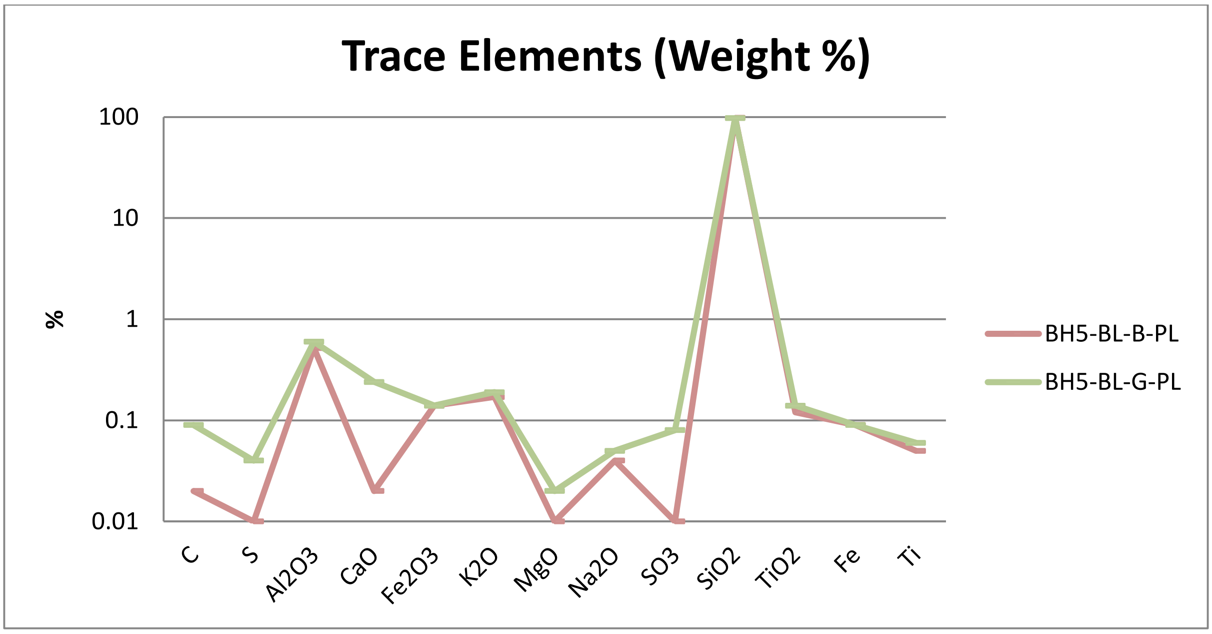

Figure 6. Note trend showing slight depletion of oxides and elements for the upper blonde sand in BH5. SiO2 is regarded as insoluble so does not deplete from upper to lower sand units.

The following figures display trends for elements in ppm.

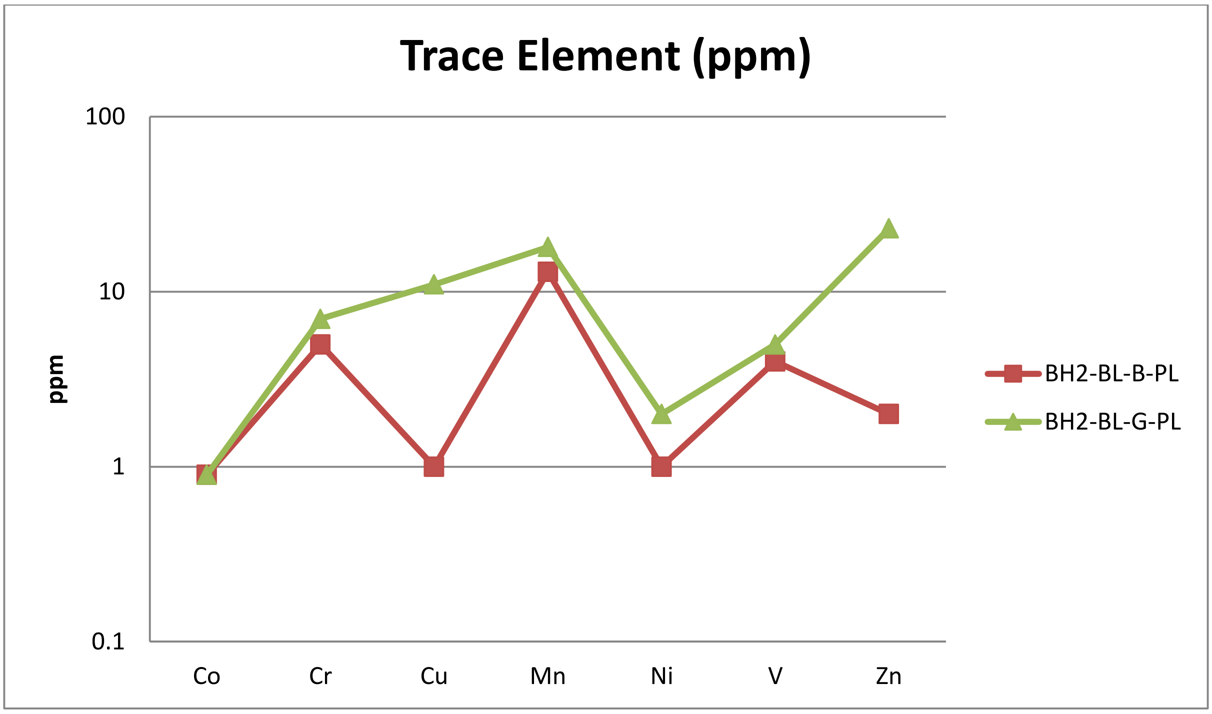

Figure 7. Note trend showing slight depletion of elements for the upper blonde sand in BH2. The Co and Ni results are quite low and relatively stable.

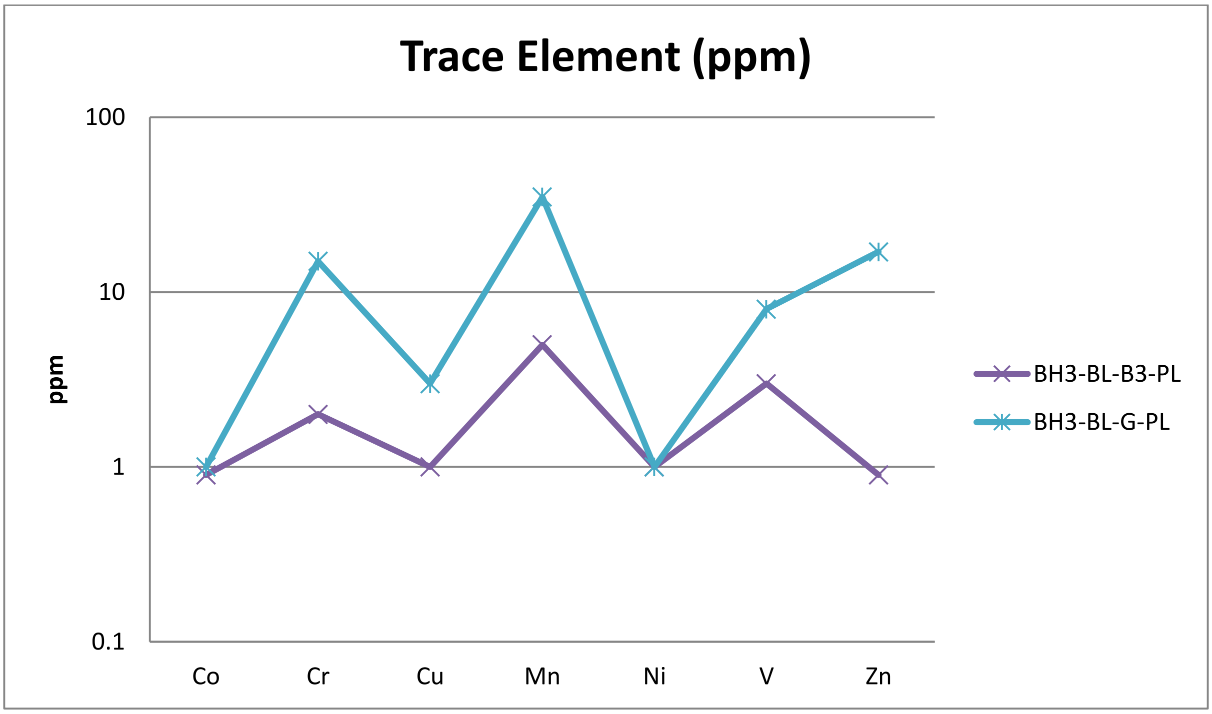

Figure 8. Note trend showing slight depletion of elements for the upper blonde sand in BH3. The Co and Ni results are quite low and relatively stable.

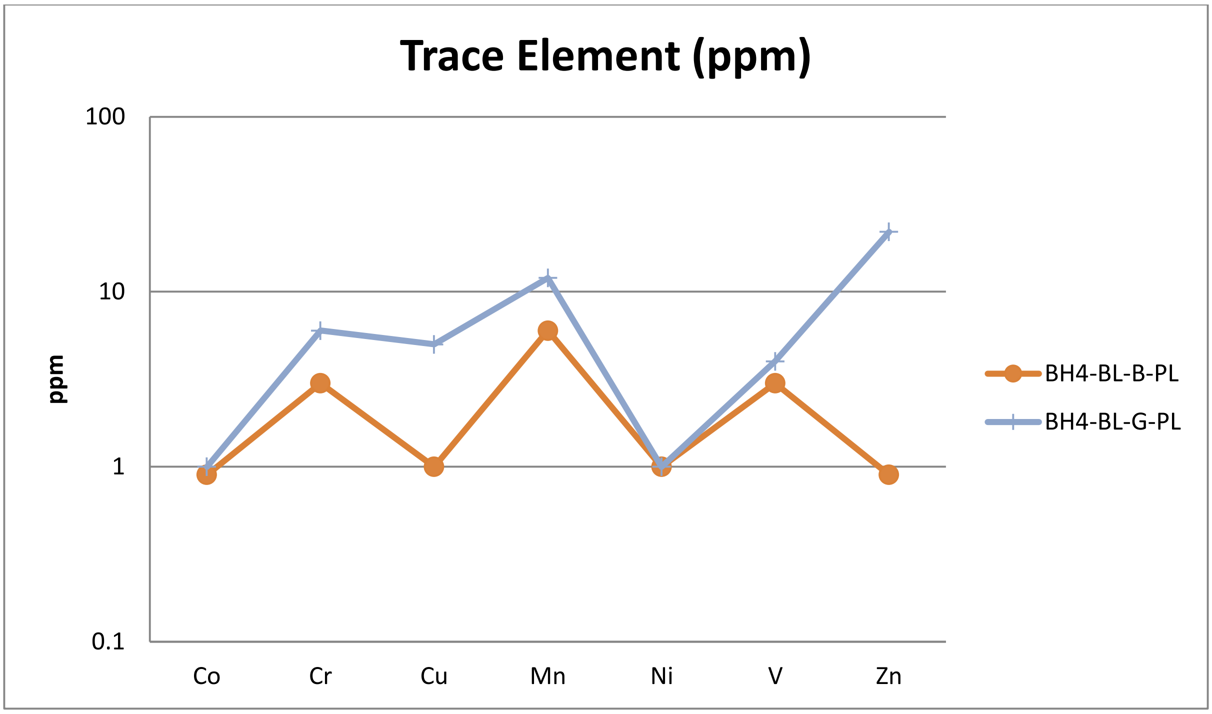

Figure 9. Note trend showing slight depletion of elements for the upper blonde sand in BH4. The Co and Ni results are quite low and relatively stable.

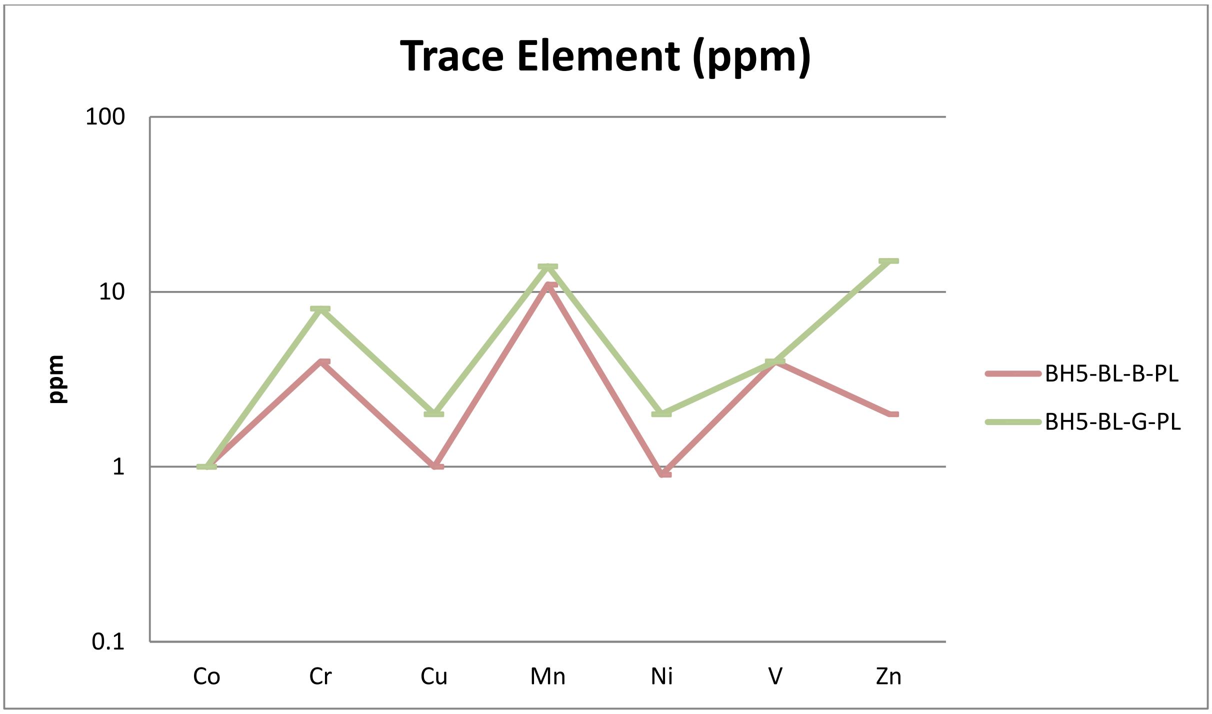

Figure 10. Note trend showing slight depletion of elements for the upper blonde sand in BH5. The Co and Ni results are quite low and relatively stable.

3.0 VALUE-ADDED SAND MATERIAL ASSESSMENT

3.1. GEOCHEMICAL REQUIREMENTS FOR FACTORY SAND USE

Following are the chemical properties of moulding sand:

Desired Constituent	Composition (%)	Average geochemical composition of 9 raw blended sand samples (%)
Silica (SiO_2)	>98.0	97.9
Combustibles	<0.2	0.4
Calcium Carbonate	<0.2	0.09 (CaO+Corganic)
Sodium Chloride	<0.1	0.05 Na_2O

The silica composition of the sand samples ranges from 97.3% to 98.3% and averages 97.9%. It seems that washing a composite sand product could push the SiO_2 level to over 98% and reduce the combustibles to <0.2% from an average of 0.4% but contamination in Sample BH1-BL-G1-PL may have elevated this result. The average of Na_2O in the nine sands is 0.05 ranging from 0.03 to 0.07 which is consistently low from flushing by rain water. Washing the sand product would also remove solubles such as NaCl, if required but the NaCl levels from soil chemistry analyses are considered to be low for the sand samples. Average of CaO plus organic carbon in the nine sand samples is 0.86% but Sample BH5-BL-G-PL (in which shell fragments are observed) has a value of 0.31% largely due to the relatively high CaO result. The shell fragments could also be removed during washing to reduce the $CaCO_3$ composition in this particular sand sample. Sample BH1-BL-G1-PL has a value of 0.26% carbon by LECO analysis which is interpreted to be mainly due to a relatively high organic carbon results (probably the result of some slight carbonaceous contamination down hole from the overlying carbonaceous layer during auger drilling).

Fire (or Furnace) Sand

Following are the chemical properties of furnace sand:

Desired Constituent	Composition (%)	Average geochemical composition of 9 raw blended sand samples (%)
Silica (SiO_2)	>95.00	97.9
(Al_2O_3)	<1.00	0.65
(Fe_2O_3)	<1.00	0.16
Other Oxides	<1.00	1.29

Overall, the supplied sand samples are regarded as having **good potential for foundry sand use (both moulding and furnace sands)** subject to further bulk testing.

3.2. GEOCHEMICAL REQUIREMENTS FOR FRAC SAND USE

Frac sand must be >99% silica. The raw blended sand samples are estimated to have an average SiO_2 content of 97.9%.

Frac sand production requires a washing process to be introduced which can be an attrition process to remove unwanted fines as well as weaker grains and impurities. The washing process may improve the silica content closer to the requirement of >99% SiO_2.

Overall, the supplied sand samples are regarded as having **some potential for frac sand use** (but occurs at the finer end of the range of acceptable grain size) subject to further bulk testing.

3.3. GEOCHEMICAL REQUIREMENTS FOR SILICA SAND IN GLASS MANUFACTURE

Chemical Characteristics

Silica sand for glass production should possess a minimum silica content of about 98 – 99% SiO_2 and around 0.2 – 1.6% Al_2O_3 with constraints on amounts of alkalis, colourants (such as Ni, Cu, Co) and refectory heavy minerals.

Generally, colourless glass specifications include:

>99wt% SiO_2
<0.03wt% Fe_2O_3
<0.1wt% TiO_2
<6 ppm Cr_2O_3

and coloured glass specifications include:

>98wt% SiO_2
<0.2wt% Fe_2O_3
<10 ppm Cr_2O_3

Silica sands from the Stockton Bight area usually supply sands for coloured (amber) glass products. Since the Bob's Farm sand deposit lies adjacent to and on the same dune ridge system as the Maccas Salt Ash Sand Quarry, it is assumed that the desired raw material specification will be similar.

Desired Constituent Composition (%)		Average geochemical composition of 9 raw blended sand samples (%)
SiO_2	> 98.6%	97.9%
Fe_2O_3	0.06 - 0.10%	0.16%
Al_2O_3	< 0.6%	0.65%
Na_2O	< 0.2%	0.05%
LOI	< 0.4%	0.4%

with colouring elements typically around:

Co	1 ppm	1 ppm
Cr	7 ppm	6.2 ppm
Cu	3 ppm	2.9 ppm
Mn	10 ppm	13.8 ppm
Ni	3 ppm	1 ppm
V	3 ppm	4.3 ppm

The raw silica sand seems to be relatively free of contaminants such as sulphides, phosphides, carbides, nitrides, organics and metallic, refractory and highly aluminous grains and particles.

The silica composition of the sand samples ranges from 97.3% to 98.3% and averages 97.9%. It seems that washing a composite sand product could push the SiO2 level to over 98% and reduce the combustibles to <0.4% from an average of 0.4% but contamination in Sample BH1-BL-G1-PL may have elevated this result. Washing the sand product would also remove solubles such as Al in clays, Fe2O3 as coatings on sand grains and Na in soluble salts.

The averaged elemental results for Co, Cu, Cr, Cu, Mn, Ni and V are within or close to the limits specified for sands for coloured glass manufacture. The dune sand should be a better product for glass production than the beach sand as it appears that elements have been leached from this upper sand layer and the analysed results are a closer fit to the specification requirements (see below).

	Average Dune Sand Composition (%)	**Average Beach Sand composition (%)**
SiO2	98.2%	97.7%
Fe2O3	0.14%	0.17%
Al2O3	0.52%	0.75%
Na2O	0.04%	0.06%
LOI	0.35%	0.43%

with colouring elements typically around:

Co	<1 ppm	1 ppm
Cr	4 ppm	8 ppm
Cu	1 ppm	4 ppm
Mn	9 ppm	18 ppm
Ni	<1 ppm	1 ppm
V	1 ppm	4 ppm

Thus, the sand deposit has **good potential to use as a product for coloured glass manufacturing** subject to further bulk testing.

4.0 CONCLUSIONS

4.1. DISCUSSION ON STAGE 2 WORK

The sand units were originally identified by colour during logging of the collected drill samples; the two sand units were labelled the blonde and grey units and were delineated by a thin carbonaceous layer between these sandy intervals. The upper blonde unit is clearly identified as a dune sand system. It is immediately underlain by carbonaceous muds and oozes. It is interpreted to have deposited in a low energy intertidal environment consisting of saline or brackish estuarine sediments with a significant organic litter component. Beneath this black carbonaceous layer is the grey unit which has been interpreted to have been deposited in a tidal beach strandline regime (evidenced by the presence of shell debris in a grey sand sample). The blonde and dune sands along with grey and beach sands are regarded as inter-changeable terminology (referring both to colour and depositional environment of the sand sequences).

The original nine composite raw sand samples from 5 boreholes were investigated by XRF analysis for elemental oxides and elements and to identify contaminant minerals by XRD analysis in selected samples with lower free silica contents. The drawback on both analytical techniques is only a small sub-sample is utilized and may not represent the whole sample. The XRD technique is limited by its detection limits which are much coarser than the XRF method. The SiO2 content (average of 97.9%) is higher than the free quartz content estimated by petrographic analysis (as expected), thus it appears that the beneficiated bulk sand samples are likely to meet the 98 - 99% SiO2 content requirement. At this stage from the evaluation of 5 boreholes, it seems that the sand is fairly consistent and washing the sand product may lift silica values to meet this desired figure by removing impurities.

If remnant bulk samples of the same nine sand samples are available, they should be washed and re-analysed to determine if sand product can be improved using this technique otherwise a bulk sample should be excavated. The washing may reduce the clay and iron coatings to some degree thus improving the final product. It seems that the upper dune sand is slightly leached and is therefore considered to be a higher purity silica product (less contaminants present) than the lower beach sand. It should also reduce the amount of organic matter and possibly float off some shell fragments and mica flakes.

The average result for Fe203 is 0.16% and Al2O3 is 0.65% which are both slight above desirable levels but average results are slightly lower in the dune sand than the beach sand and a similar trend is observed in the elemental analyses. The elemental analyses for Co, Cu, Cr, Cu, Mn, Ni and V are within or close to the limits specified for sands for coloured glass manufacture.

LECO/ICP-AES method was used to determine total sulphides (all <0.05%) and total carbon (all <0.17% except Sample BH1-BL-G1-PL with 0.37%); organic carbon (all <0.12% except

Sample BH1-BL-G1-PL with 0.24%); inorganic carbon (all <0.07% except Sample BH1-BL-G1-PL with 0.24%), sulphates (all <0.04%) and sulphides (all <0.02%). An environmental laboratory could analyse for phosphates (but P2O5 contents were all 0.01% or less) and other contaminants.

The silica sand deposit at Bob's Farm Investigation Site is considered to have potential for the production of factory sands, coloured glass silica sand and fine frac sands but should be beneficiated by at least washing the sand product to meet the strict requirements for these value-added sand products. Removal of the +0.425 and -0.075 mm fractions may also improve the sand product for some speciality uses, such as tight grading specifications which may be required for glass manufacture. After washing, the beneficiated sand product should be analysed utilizing a test for high purity silica sands (using an agate bowl to grind the samples), but the silica levels should be >99% and iron levels should be very low for this testing to be worthwhile.

In summary, the sand deposit at Bob's Farm Site appears to be fairly consistent in chemical characteristics and the sands are high silica sands with potential for value-added uses subject to washability and grain sizing issues. The upper blonde dune sand layer appears to have been slightly leached over time by water draining through the dunes, making it apparently a better high purity silica sand product. Overall, the sand deposit can be described as containing clean, free flowing fine to medium-grained quartz sands.

4.2. DISCUSSION OF STAGE 3 CONSIDERATIONS

The current investigations have been conducted of nine raw composite samples taken from 5 boreholes. Further grid spaced drilling should be conducted at a later stage to confirm the consistent chemical results obtained to date as some heterogeneity can occur in sand deposits. This evidence is required to assess if the sand at the investigation site is of sufficient quality (subject to issues of variability impacts on the quality of the sand) to satisfy intended markets. Since the Bob's Farm sand deposit lies adjacent to and on the same dune ridge system as the Maccas Salt Ash Sand Quarry, it has been assumed that that the nature and quality of the sands between these sources are similar.

It should be noted that the nature of the raw material can vary between quarry and even within a single working face so quality control of the grade of sand going to the processing plant should be maintained. A program of frequent face sampling and chemical analyses should be undertaken. Two sets of sand samples are required for grinding separate samples, the samples are processed through two different sets of grinding equipment so contamination issues are avoid. The original analysis showed high reported cobalt values which were a result of grinding the sample in a tungsten carbide mill and did not reflect values within the sand samples themselves. The cobalt analysis were run again using a steel swing mill with consistently lower results. The more expensive high purity silica analysis should be used only if silica content are >99% combined with low impurities. The process should be used to determine suitability for a range of end users and stockpiling. Large manufacturers will generally reach agreements in determining raw material contractual specifications and tolerances for supply.

Sand quality considerations are most demanding in glass production in term of physical and chemical properties. The high level of purity is usually judged by iron content and the product is generally classified as a low iron silica sand. Aluminium, magnesium, calcium and the alkalis need to occur at consistent levels as they affect melting properties of the product. Refractory mineral grains can cause flaws or defects in the glass. Tight grading specifications are used to control rate of melting.

Both the iron and aluminium levels in the sands were only slightly elevated in the investigation site. The aluminium is contained in both clay and feldspar grains and XRD results show only trace amounts of clay and between 0.9 and 1.9% K-feldspar. Washing will remove most of the clay particles (in the -75 micron fraction) but feldspar is not easily removed during processing but this may be sufficient to reduce aluminium content to required levels. The iron may be more difficult to remove during washing so a strategy may be to stockpile sand of different iron values and blend the sands together to meet specifications.

The aim of processing is to obtain a consistent product. Excavated sands will rarely have suitable grading or chemistry to be used directly for high end use. The process usually includes:

- washing to remove clays
- washed high iron sand generally classified for construction and asphalt purposes
- washed low iron sand screened to remove + 1 mm larger grains
- pumped as slurry to hydrosizers where grains are classified by size to produce a material of consistent grading
- if the iron content is still too high, further reduction of iron contamination can be achieved by passing product through a high intensity magnetic separator.

If QMS wishes to undertake any further testing programs, Geochempet Services would be happy to discuss these further with the client or suggest other organisations that would benefit the on-going investigations.

DRAFT STAGE 1 REPORT

ASSESSMENT OF POTENTIAL OF SILICA SAND DEPOSIT AT BOBS FARM, NELSON BAY ROAD, PORT STEPHENS, NSW AND RECOMMENDATIONS FOR STAGE 2 INVESTIGATION

prepared for

QUARRY MINING SERVICES PTY LTD
RED HEAD, NSW

By

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Date: 29th July, 2014

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1.0 OVERVIEW

1.1. INTRODUCTION

Geochempet Services (Geochempet) has been requested by Quarry Mining Services Pty Ltd (QMS) to conduct an assessment of current investigations and provide advice on a potential quarry site and commercial opportunities for the use of silica sand materials contained within the dune and beach sand sequences within the Bobs Farm area at 51 Nelson Bay Road; initially by re-examining data collected by a wide scope of analytical techniques. The data was supplied in a series of appendices by QMS. The intent is to broadly identify any potential beneficiation of the silica sand product to increase the commercial return on the proposed project by assessing potential add-on uses for further investigations.

QMS has contracted out test drilling, petrographic studies, particle shape analyses, geological assessments of boreholes and test pits, resource assessment, soil geochemistry, physical material testing, heavy mineral analysis on the silica sand deposit at Port Stephens, NSW.

Initial investigations indicate the presence of significant silica sand resource.

1.2. OBJECTIVES OF INVESTIGATIONS

The overall objective of this investigation is to identify additional products of value that could be potentially processed from the silica sand including but not limited to:

- Supply of silica sand for glass manufacturing
- Supply of foundry sand
- Silica sand with roughly rounded grain shapes which could be used as frac sands
- Sand for construction purposes
- Heavy-sand mineralization (rutile, zircon, etc)
- Landscaping material, such as for golf course construction
- Any other material uses that has commercial value

It also includes materials that may be suitable for use as fill in the construction of future infrastructure associated with the development of this Project.

1.3. OUTLINE OF INVESTIGATIONS

The investigation involves:

- A desktop review of the geology for the deposition of Quaternary sands of the potential resource within the Bobs Farm area. As part of this work Geochempet Services use data collected a number of existing boreholes and test pits. The assessment report includes a review of previous investigations to determine potential uses for the sand deposit.

- Analytical and geochemical testing of selected sample intervals in the boreholes and test pits. This work includes engineering petrology, particle shape analyses, soil geochemistry, physical material testing and heavy mineral analyses.

- Developing a stratigraphic sequence of borehole details from the petrographic and geochemical testing

- Identifying and verifying any anomalies from the petrographic and geochemical testing for further investigation of targets in other boreholes or locations

- Review of available drilling and petrological data for Boreholes to define target areas of potential economic value.

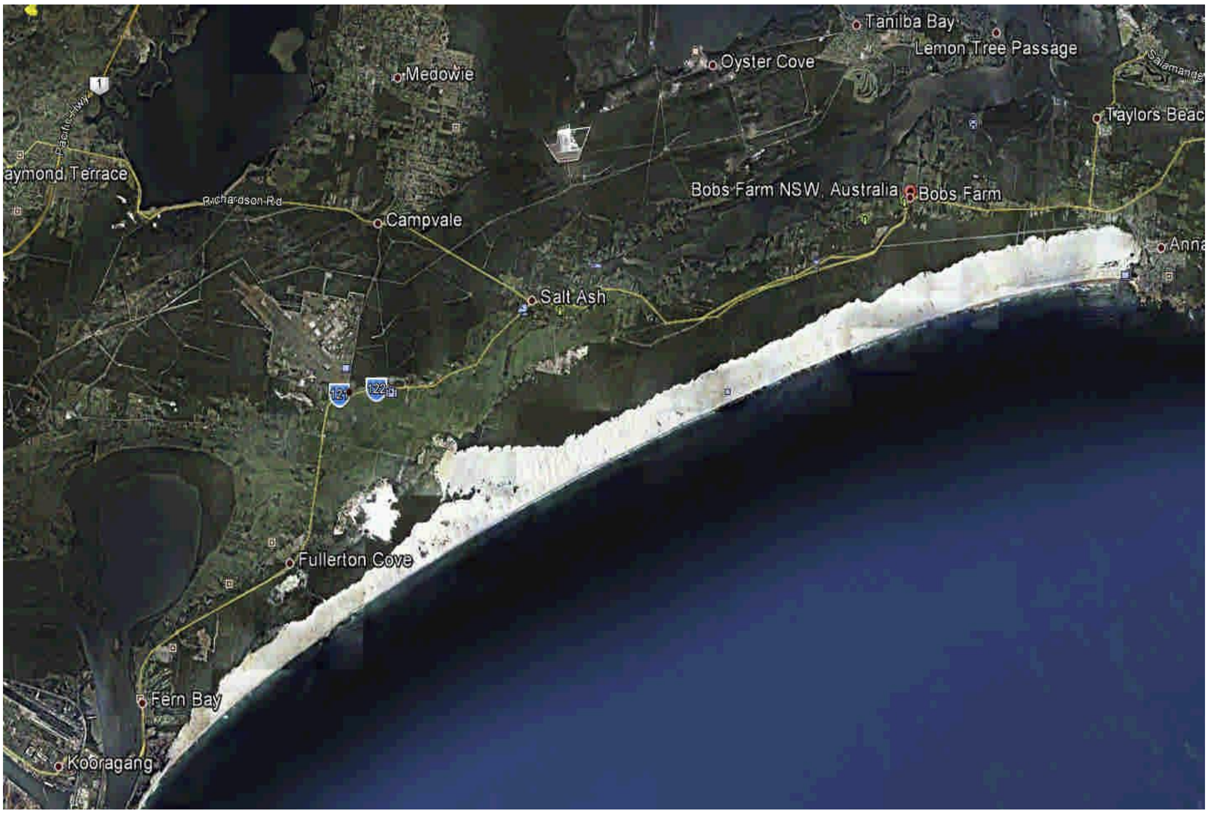
- Identification of any apparent or potential deficiencies within the current knowledge base for the project – where Geochempet believes there are deficiencies within the data these will be highlighted, and where possible, solutions to overcome these deficiencies will be recommended.

- Identify potential product characteristics – Geochempet Services will identify and document the potential product characteristics in order to match any potential market for these products. This work will include the documentation of sand sizings, material physical attributes, geotechnical and engineering properties and also identify any potential contaminate that may impact the commercial potential of these materials.

2.0 LOCATION

The Bob's Farm area is situated near the coast within the Port Stephens Council boundaries just north of the city of Newcastle, Mid-North Coast, NSW about 160 km north-east of Sydney. The investigation site is located on the Nelson Bay Road which accesses Anna Bay and Nelson Bay (Figure 1) and the area is within easy reach of the Newcastle Port. The project area has good proximity to the port for transportation of the potential quarry products. The proximity to a major port will aid logistical access to the project and facilitate the delivery of products to ports or other markets.

Figure 1. Location of Bob's Farm site.



The investigation site is located within a line of quarry sites ranging from Anna Bay Sands to the east and Boral Fullerton Cove to the west with Tilligerry Creek to the north (Figure 2). Both Sibelco and Maccas Sands Salt Ash Quarries appear to be located on the same inner sand dunes (the outer and inner Holocene dune ridges are deposited over older Holocene beach barriers) immediately inland from the current beach shoreline.

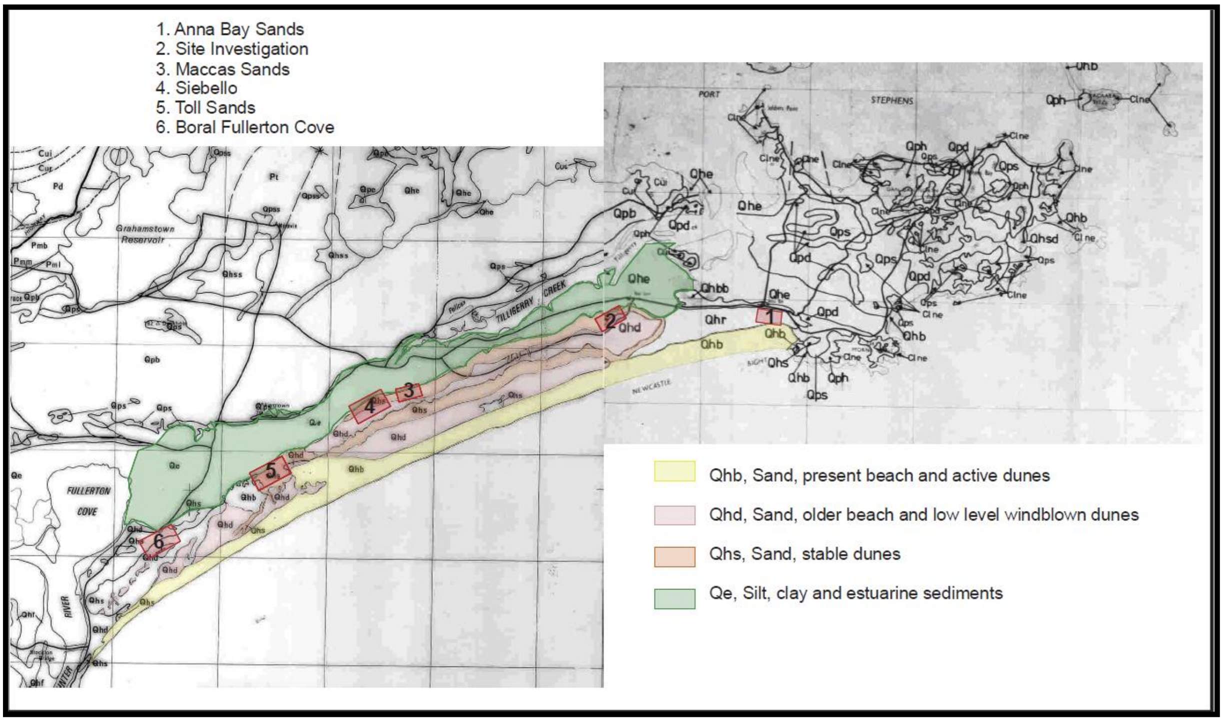


Figure 2. Map showing location of other quarries in the immediate area.

3.0 PREVIOUS INVESTIGATIONS

Two significant resource investigations have been conducted in the Stockton Bight – Port Stephens area in 1995. A Geological Survey of New South Wales – GS1995/0164 entitled Sand Resources of the Stockton Bight – Port Stephens area authored by J. Whitehouse indicated that this area is a major source of industrial and construction sand for the Sydney and Newcastle metropolitan regions. At that stage, this area supplied all the sands for colourless glass production and most of the amber or coloured glass manufacturing. It also produced small amounts of foundry sand for export. Construction sands are considered to occur in the southern parts of the sand dunes and foundry sand in the northern part. Sand deposits in the central part of the dune system are regarded as suitable for glass manufacturing but relatively high proportions of iron oxide render the sands suitable only for amber or coloured glass production.

The Stockton Bight – Port Stephens area also contained major deposits of heavy minerals mainly rutile and zircon. The project area was explored by Rutile and Zircon Mines (Newcastle) Pty Ltd (RZM) in exploration licence (EL) 3085 which extended along the shoreline of Newcastle Bight from Newcastle to Anna Bay. The results of lines of hand augering in the Bob's Farm area indicated a narrow strand line of low heavy mineral concentrations on the western edge of the dune system. The augered depths were to a maximum of 8 m and were drilled on 10 – 20 m spacings although many holes failed to reach this depth. The drilling indicated that the small tonnage and low head grade deposit was uneconomic to mine by dry mining techniques in the then prevailing conditions.

4.0 TOPOGRAPHY

The topography of the project area is an expression of a barrier sand system. The transgressive sand dunes range from less than 10 m to over 30 m in height and the highest sand dune in the investigation site is about 29 metres above sea level (Figure 3). The Tilligerry Creek area immediately to the north of Bob's Farm is considered to consist of low-lying peat and organic-rich muds and silts deposited mostly less than 5 m above sea level.

The dunes have a steep northerly to westerly face and a gentler slope showing erosion channels to the seaward side.

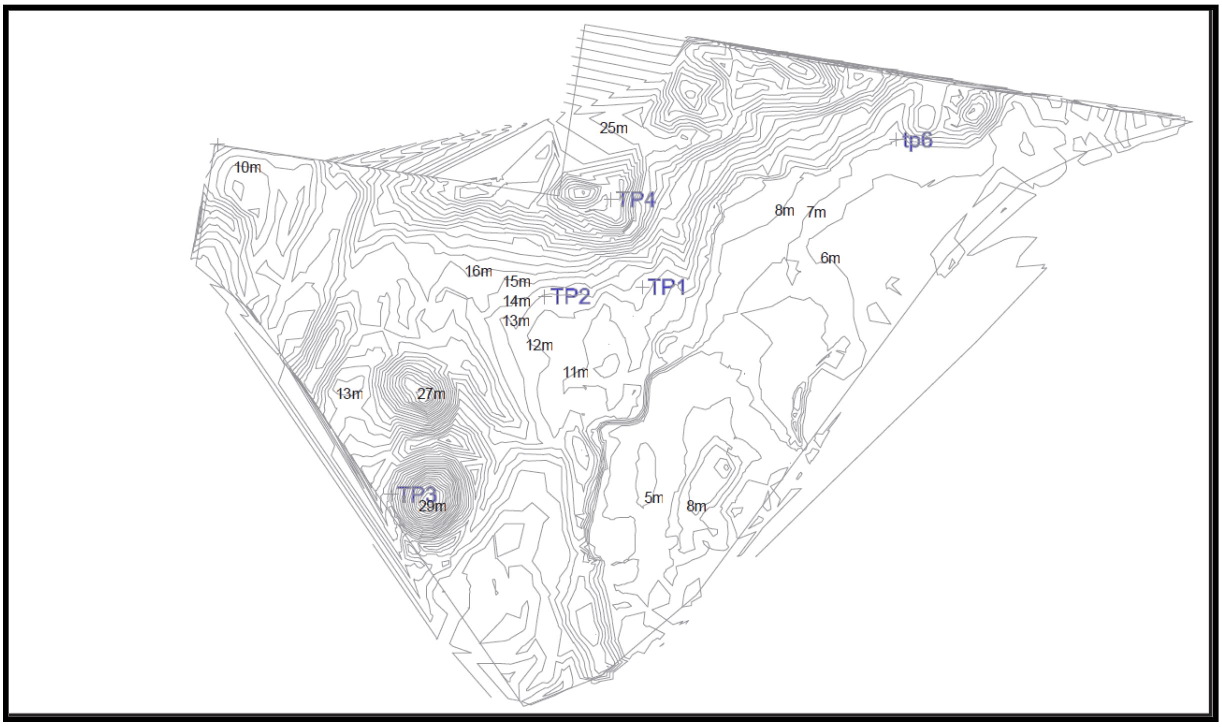


Figure 3. Contoured elevations of the Bob's Farm area.

5.0 CLIMATE, LAND USE, VEGETATION AND FAUNA

5.1. CLIMATE

The Port Stephens area has a mild maritime climate with high humidity and rainfall during warm to hot summers. Rainfall decreases during winter and spring with a change to westerly wind whereas winds are generally south-easterly in the remaining seasons.

5.2. LAND USE

The surrounding region is experiencing high rates of urban growth. Tourism is important locally and major resorts operate at Anna Bay, Nelson Bay and Salamander Bay. The beaches are used for recreational fishing, surfing, swimming and boating. There are national parks in the region. The tidal waters support fishing nurseries and historically oyster farming. Shallow groundwater resources at Anna Bay provide much of the water requirements for Newcastle and Port Stephens.

There are nearby areas of ordinance testing include impact areas and areas of shell debris from and after World War II, probably between Bob's Farm and Anna Bay (Figure 4). Unexploded ordinances may still be present in the region.

5.3. VEGETATION AND FAUNA

The Tilligerry Peninsula contains an important koala habitat but the Bob's Farm area is considered to be low, marginal koala habitat. The investigation site is covered by open eucalypt forest with a ground covering of ferns and low grasses (Plate 1). Parts of the natural vegetation have been disturbed for orchard plantings (Plate 2).

Plate 1. Open eucalypt forest with ground cover ferns under the forest canopy at Bob's farm investigation site. Photograph provided by QMS.

Plate 2. Natural vegetation partly cleared for orchard activity at Bob's farm investigation site. Photograph provided by QMS.

6.0 CONSTRAINTS ON RESOURCE EXTRACTION

The major issues affecting extractive industries are urban development, groundwater protection, national parks and conservation areas, archaeological sensitive sites and abandoned military weapons testing areas. The groundwater reserves are generally shallow and hydraulic gradients are essentially flat lying.

Extractive activity may be prohibited near the water table to prevent groundwater contamination and special conditions may apply for mining below the water table. The Holocene dunes may contain some shell middens.

7.0 GEOLOGY

The Stockton Bight – Port Stephens area is dominated by a dual barrier sand system of late Quaternary age (Figure 2). It consists of an inner barrier of Pleistocene age with marine, aeolian and estuarine sediments and an outer barrier of Holocene aeolian and marine beach sands. A narrow corridor of flat, low-lying estuarine muds and silts in an intertidal zone (of Holocene age) separate the two dune systems. The outer barrier system is considered to have begun to form about 6,500 years ago and consist of transgressive and fore dune systems. A widespread but thin deposition of estuarine mud occurred during the early stages of the formation of the outer barrier system.

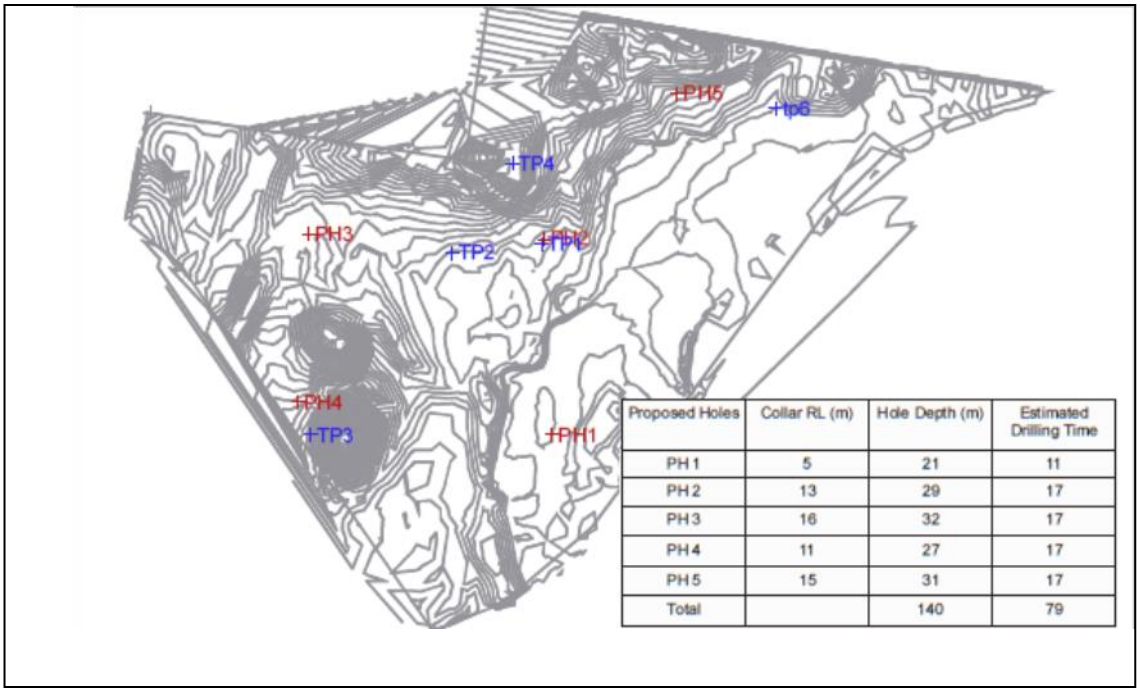
There are three phases of aeolian transgression and fore dune construction during the Holocene period. The first two phases of Aeolian dune transgression have acquired an extensive vegetation cover. The dunes in the Bob's Farm area are considered to be part of a stabilized and coast-parallel dune system developed over a 32 km long by 3 km wide dune ridge system. There is a decrease in grainsize from the south-west to north-east in the dune system. They are covered by a well-drained siliceous and sandy podsol to about 4 m deep. These vegetated dunes have an incipient B soil horizon overlain by a leached A soil horizon. The mottled brownish B horizon soils can become semi-indurated humic sands often referred to as coffee rock but it seems to be absent in the Bob's Farm area.

The dunes appear to be underlain by a marker horizon of organic-rich muds and silts which thickens and shallowly dips to the north towards Tilligerry Creek. It may have been an open water estuary which developed into an extensive, low relief area of peat and organic-rich muds and silts related to the deposition of estuarine sediments surrounding Tilligerry Creek. The lowest sequence appears to be regressive barrier beach sands which contain scattered shell fragments. These strandline beach deposits may have some potential for low grade heavy mineral concentrations that are typically composed largely of rutile and zircon in the Stockton Bight – Port Stephens area.

8.0 TEST PITS AND BORE HOLE INVESTIGATIONS

8.1. TEST PIT INVESTIGATIONS

QMS contracted VGT Pty Ltd to undertake a resource assessment on the Bob's Farm area in April, 2013. Their chosen exploration method in Stage 1 involved the digging of five test pits (PT1, PT2, PT3, PT4, PT6) using a long reach excavator (Figure 5 and Plate 3).



Proposed Holes	Collar RL (m)	Hole Depth (m)	Estimated Drilling Time
PH 1	5	21	11
PH 2	13	29	17
PH 3	16	32	17
PH 4	11	27	17
PH 5	15	31	17
Total		140	79

Figure 5. Location of test pits and boreholes.

Plate3. Excavator digging a test pit at Bob's Farm investigation site. Photograph provided by QMS.

The test pits were excavated to a maximum depth of 6.5 m due to excessive caving around the excavated areas and none of the pits reached their proposed depths and TP5 was not sunk (Table 1).

Hole Number	Easting	Northing	Ground Level (m)	Hole Depth
TP 1	406568.0	6373292.5	12.65	6.0
TP 2	406462.5	6373280.0	12.30	6.5
TP 3	406276.0	6373056.0	11.90	5.5
TP 4	406532.0	6373998.0	31.05	4.7
TP 6	406863.0	6373463.0	7.00	4.0

Table 1. Test Pit Details.

The results are interpreted to show a leached sandy soil to around an average 1.2 m depth and a mottled brown sandy soil to about 4.1 m depth on average (Table 2).

Hole Number	Unit One (base depth metres)	Unit Two (base depth metres)	Hole Depth
TP 1	1.2	5	6.0
TP 2	1.2	4.3	6.5
TP 3	1.6	3.0	5.5
TP 4	1.0	4.3	4.7
TP 6	0.9	3.8	4.0

Table 2. Test Pit Results.

The leached soil horizon contains plant matter from the vegetation cover which may require removal from the product. The colouration of mottled brown soil horizon is due to the presence of relatively abundant secondary iron oxide coatings on sand grains.

8.2. BOREHOLE INVESTIGATIONS

The second stage involved the drilling of 5 augured boreholes in the area (Figure 5) to enable definition of the resource below the water table to a maximum depth of 16 m (limits of the dredging method use to extract the material). Borehole 1 was drilled using solid flight augers and samples taken from below the water table are considered to be quite contaminated and therefore are not reliable. The remaining boreholes were sunk below the water table using hollow flight augers to ensure that the hole did not collapse and samples were collected using a bailer system although it is noted that small organic specks occur throughout the sand profiles below the water table (probably indicating limited contamination is still present).

Hole Number	Easting	Northing	Ground Level (m)	Ground Water Level (RL m)	Hole Depth (m)
BH 1	406685.6	6373153.8	5.824	2.30	19.00
BH 2	406592.8	6373286.7	11.719	2.00	26.50
BH 3	406297.2	6373318.9	15.478	2.30	26.50
BH 4	406260.7	6373082.8	9.452	2.20	24.00
BH 5	406803.7	6373515.8	18.249	2.80	26.50
Average				2.32	

Table 3. Borehole Details.

The estimated average water table level for the investigation site is 2.32 m above sea level (Table 3).

The borehole logs were examined in detail and the sand sequences intersected was divided into the five sand units as follows:

Unit 1	Leached sandy soil
Unit 2	Mottled brown sandy soil
Unit 3	Dune Sand (described as blonde sand in drilling logs)
Unit 4	Carbonaceous marker bed
Unit 5	Barrier beach sand (described as lower grey sand)

Plate4. Photograph of leached sand sample at 1.5 to 2.0 m in BH2.

Plate5. Photograph of dune sand sample at 9.5 to 10.5 m in BH5.

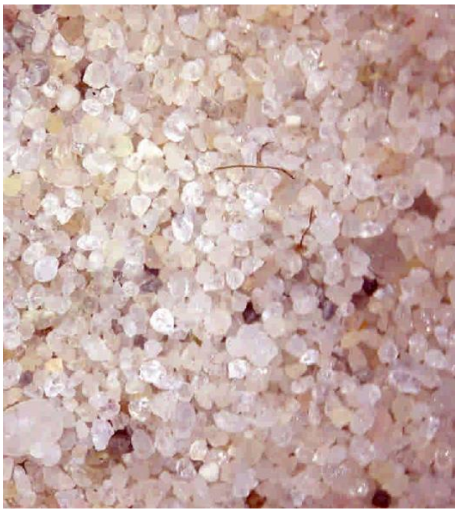


Plate6. Photograph of lower beach sand sample at 17.5 to 18.5 m in BH2.

The stratigraphic sequence for each borehole is shown in Table 4 but boundaries between units are blurred by gradational changes.

Table 4. Stratigraphic sequence in each borehole.

Hole Number	BH1	BH2	BH3	BH4	BH5
Leached Zone Thickness (m)	0-1.0	0-3.5	0-1.0	0-0.2	0-1.0
Mottled Zone Thickness (m)	-	3.5-4.2	1.0-4.0	0.2-3.0	1.0-5.5
Dune Sand Thickness (m)	1.0-4.0	4.2-10.5	4.0-14.6	3.0-5.6	5.5-20.0
Carbonaceous Thickness (m)	4.0-5.4	10.5-12.0	14.6-16.0	5.6-6.5	20.0-22.6
Beach Sand Thickness (m)	5.4-19.0	12.0-26.5	16.0-26.5	6.5-24.0	22.6-26.5
Water Table Level (m)	3.5	10.2	13.2	7.3	15.4
Carbonaceous Top of Unit	1.6mRL	1.2mRL	0.8mRL	3.9mRL	-1.8mRL
Thickness (m)	1.2	1.5	1.0	0.9	2.6

The average intersected thickness of Unit 1 is about 1.3 m.
The average intersected thickness of Unit 2 is about 2.2 m.
The average intersected thickness of Unit 3 is about 7.4 m.
The average intersected thickness of Unit 4 is about 1.6 m.
The average intersected thickness of Unit 5 is about 8.5 m.

A stratigraphic cross section running south-west to north-east (BH4- BH3-BH1-BH2-BH5) is shown in Figure 6.

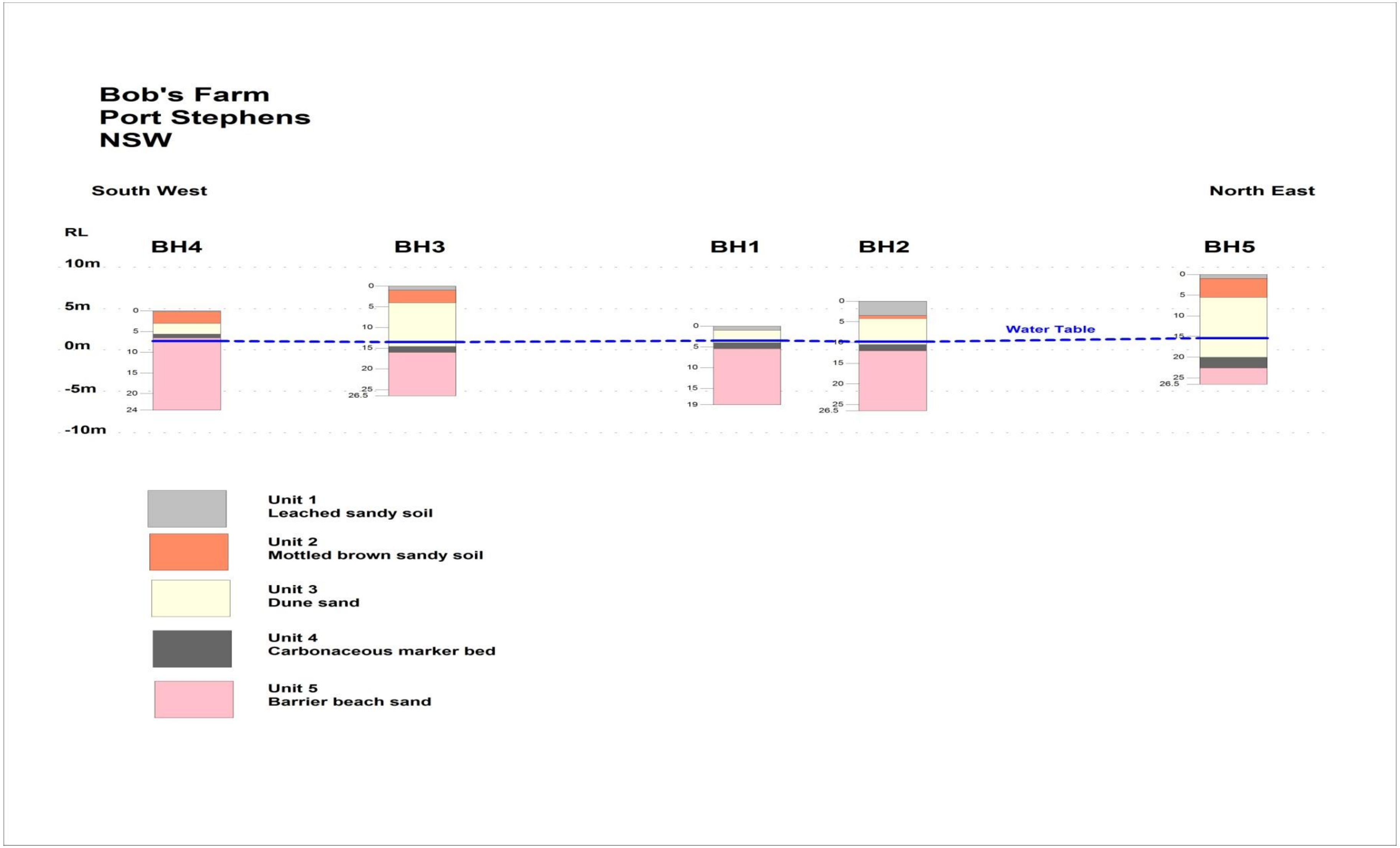


Figure 6. Stratigraphic cross section of the five boreholes showing Units 1 – 5 and water table level in Bob's Farm Area.

BH2, BH3 and BH5 show the thickest intersection of the upper dune sand deposit. BH1 is closest to the current shore line and appears to intersect the tapered seaward edge of the dune system. A drainage pattern is observed in the gentle slopes towards the shore line which flows into a back barrier swale behind the current beach foredunes. The mottled zone in BH1 is interpreted to be present but is quite thin as it is not logged in the drill samples. The sand interval from 5.4-12.0 m intersected in BH1 below the water table is quite contaminated due to the drilling technique and is regarded as unreliable. The mottled zone appears to increase in thickness with ground elevation. The carbonaceous layer occurs in the vicinity of the water table (within 5 m but usually just below the water table except in BH4 where it lies just above the water table) and appears to dip and thicken towards Tilligerry Creek to the immediate north of the Bob's Farm investigation site. The water table may slightly perch under the highest dune ridge but is generally fairly flat beneath the sand dunes.

The sulphur smell noted in the carbonaceous layer in BH1 indicate bacterial action which produces biogenic pyrite as a by-product of a reducing environment from rotting organics. This carbonaceous sediment is also observed to contain common shell debris in BH5 where sea water has intruded.

No coffee rock (or colloidal carbon) was intersected within the 5 boreholes.

8.3. PETROLOGICAL INVESTIGATIONS

Two blended test pit samples were sent to Henzel Geosciences for petrographic examination. The sand samples are designated as follows:

BL-HM-PL	blended high mottled sands from TP1-2, TP2-2, TP3-1, TP4-1, TP4-2, TP6-2
BL-C-PL	blended construction sands from TP1-4, TP2-4, TP3-2, TP3-3, TP4-3

The petrographic reports dated June, 2013 which characterise the blended sand samples from the test pits are shown below in Table 5:

Sample Number	BL-HM-PL	BL-C-PL
Composite depth (m)	1-2	2-4
Product Type	Quartz Sand	Quartz Sand
Free Silica Content	89%	93%
Grainsize	Fine to medium	Fine to medium
Grain Shape	Sub-rounded to rounded	Sub-rounded to rounded
Mineral grains	4% feldspar	2% feldspar
Lithic Clasts	9% lithic fragments	12% lithic fragments
Fe2O3 coatings	3%	<1%
Heavy mineral Content	1%	<1%

Table 5. Characteristics of blended test pit sand samples from petrographic examinations.

Sample BL-HM-PL is from the mottled sandy soil horizon from near the surface of the sand dune. The concentration of secondary iron oxide (3%) as coatings on sand grains indicates downward movement of meteoric waters leaching the top of sand dunes and concentrating dissolved secondary iron oxide into the B horizon. Sample BL-C-PL mainly represents dune sand below the B horizon which is only very lightly coated by secondary iron oxides and is regarded as a much cleaner product with a higher free silica level.

Eleven blended borehole samples were sent to Geochempet Services for petrographic examination. The sand samples are designated as follows:

BH2-BL-B-PL blended blonde dune sand from 4.2 – 9.5 m

BH3-BL-B3-PL blended blonde dune sand from 4 - 10 m

BH4-BL-B-PL blended blonde dune sand from 1.5 – 5.7 m

BH5-BL-B-PL blended blonde dune sand from 5.5 – 14.5 m

BH1-BL-G1-PL blended lower grey beach sand from 12 - 19 m

BH2-BL-G-PL blended grey beach sand from 13.5 – 26.5 m

BH3-BL-G-PL blended grey beach sand from 17 – 26.5 m

BH4-BL-G-PL blended grey beach sand from 13.5 – 24 m

BH5-BL-G-PL blended grey beach sand from 23 – 25.6 m

BH1-BL-G2-PL blended upper grey beach sand from 4.2 – 12 m
(this sample is a contaminated carbonaceous sand sample and is omitted from further discussion)

BH2-10.5-12.0-PL blended grey beach sand from 13.5 – 24 m
(this sample is logged as a black silty clay rich in organic matter and is omitted from further discussion)

The first 4 blonde sand samples are interpreted to be from the upper dune sand sequence below the mottled B horizon soil profile (Unit 3). The next 5 grey sand samples are interpreted to be from the barrier beach sand sequence (Unit 5) below the black organic-rich mud and silt sediments (Unit 4) represented by Sample BH2-10.5-12.0-PL. The contamination in Sample BH1-BL-G2-PL at 4.2 – 12 m depth renders it useless as a representation of the beach sand in Unit 5.

Nine petrographic reports dated October, 2013 which characterise the normal blended construction sand samples from the boreholes are shown below in Tables 6 and 7:

Sample Number	BH2-BL-B-P	BH3-BL-B3-PL	BH4-BL-B-PL	BH5-BL-B-PL
Composite depth (m)	**4.2-9.5**	**4-10**	**1.5-5.7**	**5.5-14.5**
Product Type	**Quartz Sand**	**Quartz Sand**	**Quartz Sand**	**Quartz Sand**
Free Silica Content	**91%**	**94%**	**99%**	**99%**
Grainsize	**Fine to medium**	**Fine to medium**	**Fine to medium**	**Fine to medium**
Grain Shape	**Sub-rounded to sub-angular**	**Sub-rounded to rounded**	**Sub-rounded to sub-angular**	**Sub-rounded to rounded**
Mineral grains	**4% feldspar**	**3% feldspar**	**<1% feldspar**	**<1% feldspar**
Lithic Clasts	**5% lithic fragments**	**7% lithic fragments**	**1% lithic fragments**	**1% lithic fragments**
Fe2O3 coatings	**3%**	**<1%**	**<1%**	**<1%**
Heavy mineral Content	**1%**	**<1%**	**<1%**	**<1%**

Table 6. Characteristics of blended borehole dune sand samples from petrographic examinations.

Sample Number	BH1-BL-G1-PL	BH2-BL-G-PL	BH3-BL-G-PL	BH4-BL-G-PL	BH5-BL-G-PL
Composite depth (m)	12-19	13.5-26.5	17-26.5	13-24	23-25.6
Product Type	Quartz Sand	Quartz Sand	Quartz Sand	Quartz Sand	Quartz Sand
Free Silica Content	97%	97%	88%	93%	90%
Grainsize	Fine to medium	Fine to medium	Fine to medium	Fine to medium	Fine to medium
Grain Shape	Sub-rounded to sub-angular	Sub-rounded to sub-angular	Sub-rounded to rounded	Sub-rounded to sub-angular	Sub-rounded to rounded
Mineral grains	<1% feldspar	1% feldspar	2% feldspar	3% feldspar	2% feldspar
Lithic Clasts	1% lithic fragments	2% lithic fragments	12% lithic fragments	3% lithic fragments	11% lithic fragments
Fe2O3 coatings	3%	<1%	<1%	<1%	<1%
Heavy mineral Content	1%	<1%	1%	1%	<1%

Table 7. Characteristics of blended borehole beach sand samples from petrographic examinations.

The petrographic reports provided by Geochempet Services where done in accordance with ASTM C295 Standard Guide for *Petrographic Assessment of Aggregates for Concrete*, the AS2758.1 – 1998 *Aggregates and rock for engineering purposes part 1; Concrete aggregates (Appendix B),* the AS1141 *Standard Guide for the Method for sampling and testing aggregate* and of the content of the 1996 joint publication of the Cement and Concrete Association of Australia and Standards Australia**,** entitled *Alkali Aggregate Reaction - Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia.*

In Sample BH5-BL-G-PL, there are an additional 1% of shell fragments in the composite sand sample.

It is also noteworthy that the larger and rounded lithic clasts are observed to be in the upper range of grain sizes in all the composite sand samples.

8.4. Particle Shape Analyses

Four blended samples were investigated by particle shape analysis in accordance with the American Petroleum Institute (19C) API Recommended Practices for Testing Sand Used in Hydraulic Fracturing Operations and ISO 13503 Measurement of Properties of a Proppants used in Hydraulic Fracturing and Gravel–Packing Operations, as follows:

BH3-BL-B3-PL	blended blonde dune sand from 4 - 10 m
BH5-BL-B-PL	blended blonde dune sand from 5.5 – 14.5 m
BH3-BL-G-PL	blended grey beach sand from 17 – 26.5 m
BH5-BL-G-PL	blended grey beach sand from 23 – 25.6 m

The average results for roundness and sphericity are shown below:

BH3-BL-B3-PL	Sub-rounded	Moderately high sphericity
BH5-BL-B-PL	Sub-rounded	Moderately high sphericity
BH3-BL-G-PL	Sub-rounded	Moderately high sphericity
BH5-BL-G-PL	Rounded	Moderately high sphericity

9.0 SIZE GRADING ANALYSIS

Particle size distributions were undertaken on seventeen sand samples from the test pit investigation. Broadly, all sand samples showed a quite narrow range of grainsizes, mostly between -0.425 mm and +0.150 mm.

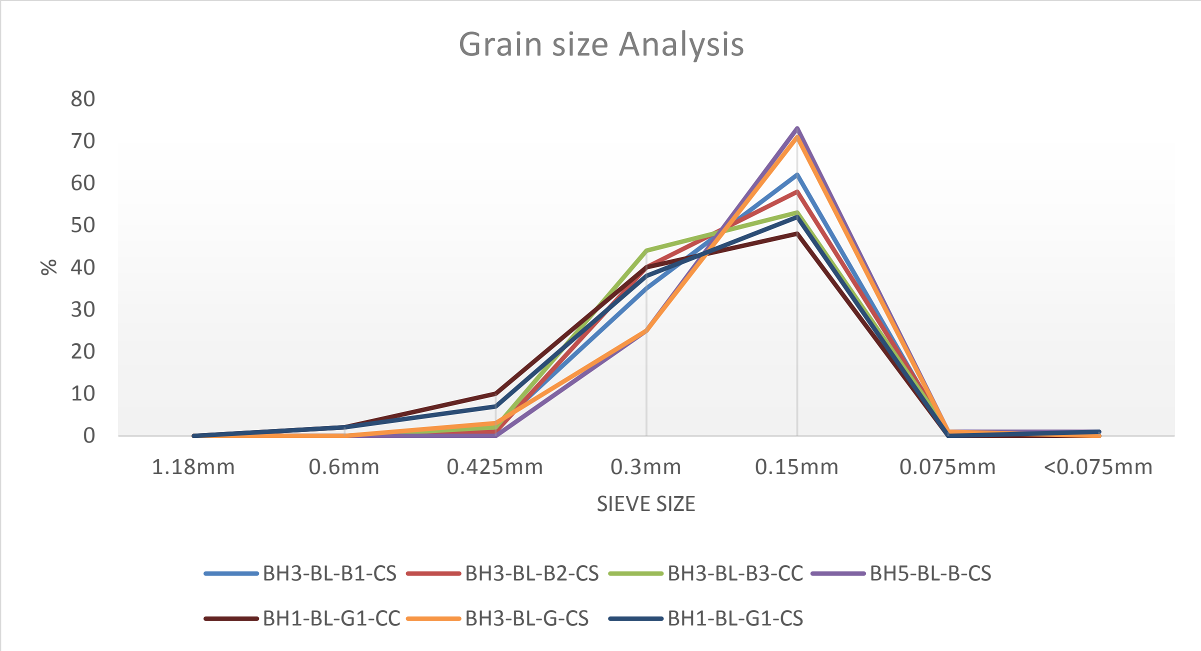
Table 8 below determines the wt% retained on each sieve for 7 borehole sand samples, details are as follows:

BH3-BL-B1-CS	Upper Dune sand	4.0 - 10.0 m
BH3-BL-B2-CS	Upper Dune sand	10.0 - 14.6 m
BH3-BL-B3-CS	Upper Dune sand	4.0 - 14.6 m
BH5-BL-B-CS	Upper Dune sand	5.5 – 14.5 m
BH1-BL-G1-CC	Lower Beach sand	12.0 – 19.0 m
BH3-BL-G-CS	Lower Beach sand	17.0 – 26.6 m
BH1-BL-G1-CS	Lower Beach sand	12.0 – 19.0 m

	Percentage retained on Sieve						
	Very Coarse	**Coarse**	**Medium**	**Medium**	**Fine**	**Very Fine**	**Silt**
Sample/Borehole ID	1.18mm	0.6mm	0.425mm	0.3mm	0.15mm	0.075mm	<0.075mm
BH3-BL-B1-CS	0	0	2	35	62	0	1
BH3-BL-B2-CS	0	0	1	40	58	1	0
BH3-BL-B3-CC	0	0	2	44	53	1	0
BH5-BL-B-CS	0	0	0	25	73	1	1
BH1-BL-G1-CC	0	2	10	40	48	0	0
BH3-BL-G-CS	0	0	3	25	71	1	0
BH1-BL-G1-CS	0	2	7	38	52	0	1

Table 8. Grain size gradings for blended borehole sand samples.

The 7 selected borehole sand samples are fairly narrowly graded, fine to medium quartz sands. The grainsizes range mainly between -0.6 and +0.15 mm but are generally concentrated in the -.425 to -0.15 mm in particle sizes (see Graph 1 below).



Graph 1. Plot of sieve sizes against wt% retain on each sieve which demonstrates the fairly narrow grainsize range.

From petrographic examination, it appears that the larger lithic clasts should be concentrated into the coarser grainsizes. A potentially easy method to improve the SiO2 content and reduce impurities may be to scalp off some of the minor coarse (between 0.6 and 0.425 mm grainsize) and silt/clay fractions (-0.15 mm grainsizes).

10.0 SOIL GEOCHEMISTRY ANALYSIS

Soil geochemistry analysis were undertaken on thirteen sand samples with eleven borehole samples and 2 test pit samples. Of the geochemical results, it was decided to look at Ph, salinity and sulphates but overall the sand samples were designated as safe for disposal or recycling.

Table 9 below displays the Ph and salinity values and Table 10 shows sulphate and other nutrient elements values while the Ph, salinity and sulphate data is displayed in Graph 2 , 3, 4; the sample details are as follows:

BL-HM (2A)	High Mottled Top Soil	Medium Acidity
BL-LM (3A)	Low Mottled Top Soil	Medium Acidity
BH1-BL-AWT-SO (1)	Above water table 0.6 – 3.5 m	Neutral
BH1-BL-G1-SO (2)	Lower Beach sand 12.0 – 19.0 m	Very Acidic
BH2-10.5-12.0-SO (3)	Carbonaceous layer 0.5 – 12.0 m	Strong Acidity
BH2-BL-B-SO (4)	Upper Dune sand 4.2 – 9.5 m	Medium Acidity
BH2-BL-G-SO (5)	Lower Beach sand 13.5 – 26.5 m	Strong Acidity
BH3-BL-B3-SO (6)	Upper Dune sand 4.0 - 14.6 m	Slight Acidity
BH3-BL-G-SO (7)	Lower Beach sand 17.0 – 26.7 m	Strong Acidity
BH4-BL-B-SO (8)	Upper Dune sand 1.5 – 5.8 m	Slight Acidity
BH4-BL-G-SO (9)	Lower Beach sand 13.0 – 24.2 m	Strong Acidity
BH5-BL-B-SO (10)	Upper Dune sand 5.5 – 14.5 m	Slight Acidity
BH5-BL-M-SO (11)	Carbonaceous layer 20.0 – 22.0 m	Neutral Highest Salinity

	pH and Electrical conductivity				
Sample Name	**pH in H2O**	**pH in CaCL2**	**Salinity dS/m**	**Na mg/kg**	**Cl mg/kg**
BL-HM	5.6	4.4	<0.02	10.3	n/a
BL_LM	5.7	4.9	<0.02	7.7	n/a
BH1-BL-AWT-SO 0.7	6.8	5.4	0.02	14.5	17
BH1-BL-G1-SO 0.5	3.9	4	0.23	18.2	15
BH2-10.5-12.0-SO 0.7	5	4.7	0.88	173	43.4
BH2-BL-B-SO- 0.9	5.8	4.6	<0.02	11.8	15.7
BH2-BL-G-SO 0.6	4.6	4.6	0.08	25.7	16.5
BH3-BL-B3-SO 1.25	6.5	6.1	0.02	14.5	13.4
BH3-BL-G-SO-0.603	4.5	4.5	0.13	28.3	21.5
BH4-BL-B-SO 0.71	6.4	5.5	<0.02	10	13.5
BH4-BL-G-SO 0.51	5	4.8	0.08	21.3	21.4
BH5-BL-B-SO 1.302	6.5	6.2	<0.02	15.8	16.3
BH5-BL-M-SO 0.633	7.5	7.3	1.34	142	55.3

Table 9. The pH and salinity values for blended borehole and test pit sand samples.

The samples in the topmost layer of the sand dunes (BL-HM, BL-LM and BH1-BL-AWT-SO) recorded very low salinity but BL-HM had elevated iron levels associated with mottling in the soil horizon. Samples BL-HM and BL-LM show moderate acidity probably associated with the precipitation of soluble iron from solution in the soil horizon but BH1-BL-AWT is regarded as fairly neutral and mottled zone is missing in this area but the relatively elevated phosphate may come from plant material.

Samples taken from the upper dune sands (BH2-BL-B-SO, BH3-BL-B3-SO, BH4-BL-B-SO and BH5-BL-B-SO) display low to moderate acidity. Salinity is considered to be very low

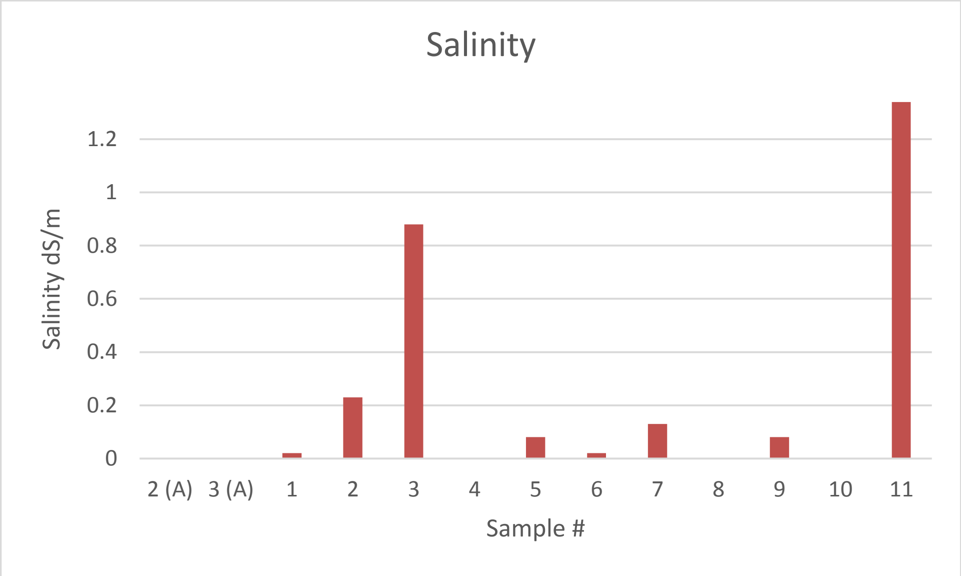
Samples taken from the lower beach sands (BH1-BL-G1-SO, BH2-BL-G-SO, BH3-BL-G-SO, and BH4-BL-G-SO) display strong to very strong acidity. Moderate salinity and high levels of sulphate and elevated iron in very acidic conditions are noted in Sample BH1-BL-G1-SO (possibly a contamination issue). The other lower beach samples recorded very low to low salinity but with moderate to high sulphate and zinc concentrations. It is possible that some contamination is occurring from the carbonaceous layer above these beach sand and acidity, zinc and sulphate levels might be elevated by the contamination.

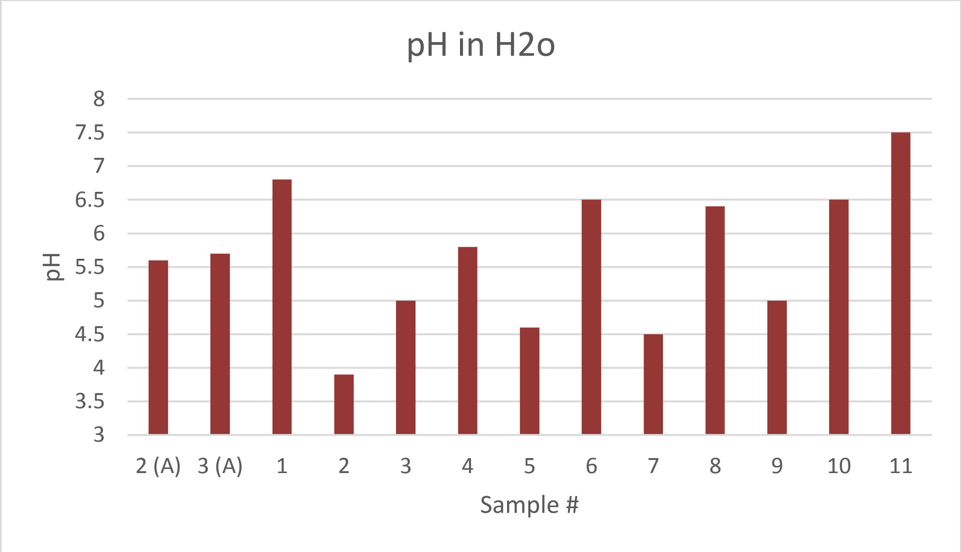
The two samples from carbonaceous layers showed quite different characteristics. Sample BH2-10.5-12.0-SO is quite strongly acidic with relatively high salinity as well as containing high sulphate, magnesium and iron and moderate levels of calcium and zinc. The high iron and sulphate are considered to indicate the presence of pyrite in this highly reducing carbonaceous layer and is regarded as an acid sulphate clayey soil. Sample BH5-BL-M-SO is considered to be neutral and is extremely saline as well as containing high potassium, sulphate, magnesium and calcium and moderate levels of sulphate, phosphate and zinc. This layer was shelly in the drill logs and is probably associated with high levels of calcium and possibly phosphate from fossiliferous matter. It may reflect the presence of marine organisms from intrusion by seawater which has neutralised the acid condition but may potentially be an acid sulphate clay-rich soil.

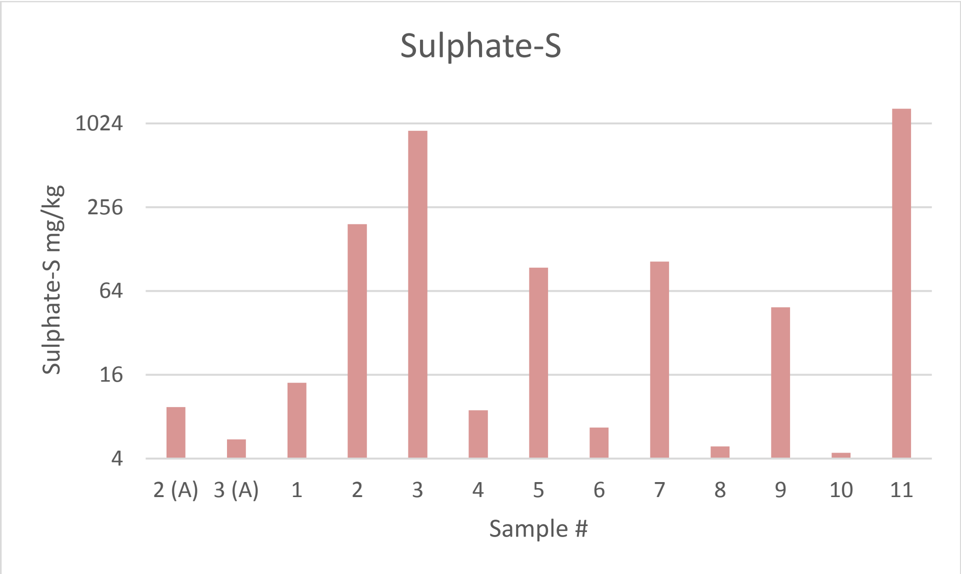
	Plant Available Nutrients (mg/kg)										
Sample Name	Nitrate-N	Phosphate-P	Potassium	Sulphate-S	Calcium	Magnesium	Iron	Manganese	Zinc	Copper	Boron
BL-HM	<0.05	2.7	23.5	9.4	15.5	8.2	162.6	<0.55	<0.65	<0.64	0.3
BL_LM	<0.05	2.8	24.4	5.5	7.5	5.2	26.5	<0.55	<0.65	<0.64	0.3
BH1-BL-AWT-SO 0.7	1	60.3	<3.90	14	47.5	8	31.3	<0.55	<0.65	<0.64	<0.1
BH1-BL-G1-SO 0.5	<0.05	13	<3.90	193	22.7	11.2	135.5	<0.55	<0.65	<0.64	<0.1
BH2-10.5-12.0-SO 0.7	0.2	16	115	906	1893	1041	561.6	10	4.7	<0.64	<0.1
BH2-BL-B-SO- 0.9	<0.05	6.2	<3.9	8.9	<4.0	<2.40	57.5	<0.55	1.6	0.8	<0.1
BH2-BL-G-SO 0.6	<0.05	4.3	<3.90	94	30	11	38.2	0.9	17	2.9	<0.1
BH3-BL-B3-SO 1.25	<0.05	5.9	<3.90	6.7	<4.0	<2.40	16.2	<0.55	<0.65	<0.64	<0.1
BH3-BL-G-SO-0.603	<0.05	3.9	<3.90	104	39.6	8.4	57.4	<0.55	18	<0.64	<0.1
BH4-BL-B-SO 0.71	<0.05	5.8	<3.90	4.9	<4.0	2.6	31.4	<0.55	<0.65	<0.64	<0.1
BH4-BL-G-SO 0.51	<0.05	3.9	<3.90	49	20.1	9.9	52.5	<0.55	9.6	0.9	<0.1
BH5-BL-B-SO 1.302	<0.05	5.4	<3.9	4.4	<4.0	3	33	<0.55	<0.65	<0.64	<0.1
BH5-BL-M-SO 0.633	<0.05	48	496	1305	4431	1772	317.7	16	3.4	<0.64	<0.1

Table 10. The sulphate and other nutrient elements values for blended borehole and test pit sand samples.

Graph 2, 3, 4 – Plot of salinity, Ph and sulphate levels against sample numbers.







11.0 SAND MATERIAL ASSESSMENT

11.1. CONSTRUCTION SAND USE

The nine composite sand samples examined petrographically were considered to be **suitable for use as fine construction sand** particularly if they are blended with a coarse natural sand or coarse manufactured sand to produce an even size grading. The composite sand samples are considered to consist of quartz sand which may be described broadly as fine to medium sand for engineering purposes. They are fairly narrowly graded.

The free silica content (or total quartz content) of the sand samples range from 88 - 99%, comprising quartz as free grains and simple crystalline composites and common quartz locked within lithic clasts. The lower the free silica content, the higher the feldspar and lithic content of the sands.

The sand is interpreted to be physically suitable for use as a fine natural sand in concrete. It consists mainly of worn grains of quartz and other minor robust lithic clasts predominately of acid volcanics. The presence of red and brown secondary iron oxides (hematite and limonite/goethite) has imparted colour to the sand, but the oxides are interpreted to be benign and stable.

Individual components in the sand which are interpreted to have some potential for alkali-silica reaction are moderately strained quartz grains and some microcrystalline quartz in acid volcanic rock fragments). The sands as a whole are predicted to have potential for mild or slow deleterious alkali-silica reactivity in concrete.

The supplied sand samples are also considered to be suitable for use as a fine component of road base and in asphalt. It may also have potential as an attractive, free flowing, fine sand used in landscaping of golf course as well as sand beach remediation and construction.

Two carbonaceous sand samples labelled BH1-BL-G2-PL and BH2-10.5-12.0-PL were not recommended for use as construction sand because the abundance of carbonaceous matter and possibly fine pyrite. Carbonaceous units are susceptible to oxidization and generally regarded as unsuitable for construction uses. It may have potential for use as sand in the plant nursery industry but it may need remediation by the addition of lime as soil spread out on an exposed flat surface to reduce the acidity in these carbonaceous materials which may be potentially acid sulphate soils.

11.2. FOUNDRY AND CERAMIC SAND USE

Large amounts of silica sand are used in iron and steel foundries to make moulds and cores for metal castings. Molten metal is poured into a shaped cavity in a block of sand where the metal cools and solidifies. The part of the cavity that forms the external surface of the castings is called the mould. Cores of moulded sand may be placed in the mould to form the internal shape and dimensions of the casting. In each application the sand particles are held together by some clayey material called a bond. The northern part of the outer barrier contains deposits of sand in the Anna Bay area suitable for foundry use (adjacent to the Bob's Farm investigation area).

General Requirements of Moulding Sands

Sand for foundry use should consist of uniform-sized rounded grains of silica (quartz), free of reactive substances. Silica sand used for steel casting must consist entirely of quartz grains to be infusible. The quality of castings produced depends largely upon the properties of the sand utilized. To ensure good castings, the sand must satisfy specifications as to (1) refractoriness, (2) bond strength, (3) permeability, (4) grain fineness and (5) moisture,

(1) **Refractoriness.** Quartz (Si02), the principal constituent of silica sand is a highly refractory mineral, the fusion point of which is 1711^{0}C, well above the pouring temperature for either iron or steel castings.

Constituent Composition (%)

Silica (SiO_2)	>98.0
Combustibles	<0.2
Calcium Carbonate	<0.2
Sodium Chloride	<0.1

(2) **Bond Strength**. Bond strength of a moulding sand depends primarily on the nature of the bonding clay.

(3) **Permeability**. The best permeability is obtained with moulding sand in which the grains are both rounded and uniform. Angular-grained sand tends to pack and makes permeability control difficult. Furthermore, if the grains are not of uniform size, small grains may pack between large ones whether they are angular or round, decreasing the porosity and thus impairing the permeability.

(4) **Grain Fineness.** Generally grain size of less than 0.425mm is desirable.

Grain size or fineness has an important bearing on the physical properties of foundry sand: the finer and more angular the sand grains, the greater the bond strength of the sand because of the interlocking of grains however increase angularity decreases permeability. Fineness also is important because of its relationship to the surface finish of castings. The finer the grains, the smoother the work produced, whereas coarse grains in the mould surface allow penetration of metal between grains, thus leaving a rough surface. The highest grade of art castings is made with the finest moulding sand. Brass and bronze require fine sands. On heavy castings a fine-grained facing sand is used to give a smooth surface.

5) **Moisture.** The ideal amount of moisture in a moulding sand is that just sufficient to yield the necessary plasticity and adhesiveness in order that moulding operations can be performed properly without excessive ramming or defective moulds. Excess moisture results in the formation of large volumes of steam, which cannot be vented adequately through the sand. Entrapped steam thus produces cavities in the casting.

Fire (or Furnace) Sand

Fire or furnace sand is used to line furnace bottoms, walls in open-hearth furnaces, cupolas and ladles. It also is used largely in forming the bottoms at copper-refining furnaces and copper-smelting furnaces.

A high Quartz content (more than 95 per cent Si02) is essential to obtain the necessary refractory properties, and a small amount of bonding material is required to hold the sand in place until the furnace lining has been fired or burned in. If the sand lacks bond, the latter is usually added in the form of plastic fireclay.

Following are the chemical properties of furnace sand:

Constituent Composition (%)

Silica (SiO2)		>95.00
Aluminium	(Al2O3)	<1.00
Iron Oxide	(Fe2O3)	<1.00
Other Oxides		<1.00

Overall, the supplied sand samples are regarded as having **good potential for foundry sand use (both moulding and fire sands) subject to further testing.** It seems the exceptions are Samples BH2-BL-B-PL, BH3-BL-G-PL and BH5-BL-G-PL where silica content is considered to be too low. A fine grainsize is preferred for this product.

11.3. FRAC SAND USE

Four shape analysis were conducted on composite sand samples to determine rounded grain shapes for frac sand potential. This determination of roundness and sphericity accords with the recommended practices of American Petroleum Institute API Recommended Practices for Testing Sand Used in Hydraulic Fracturing Operations and ISO 13503 Measurement of Properties of a Proppants used in Hydraulic Fracturing and Gravel–Packing Operations.

Frac sand specifications are the responsibility in the USA of the **American Petroleum Institute** (API) and the current standard is **API19C.**

Natural sands must be from high silica (quartz) sandstones or unconsolidated deposits. Other essential requirements are that particles are well rounded, relatively clean of other minerals and impurities and will facilitate the production of fine, medium and coarse grain sands.

Geology

Frac sand must be >99% silica.

Grain Size

The sizes recommended by the API for frac sand are:

Mesh
8/12
10/20
20/40
70/140

mm
2.38-1.68
2.00-0.84
0.84-0.42
210-105 micron

The 20/40 mesh size (0.42mm – 0.84mm) is the most widely used.

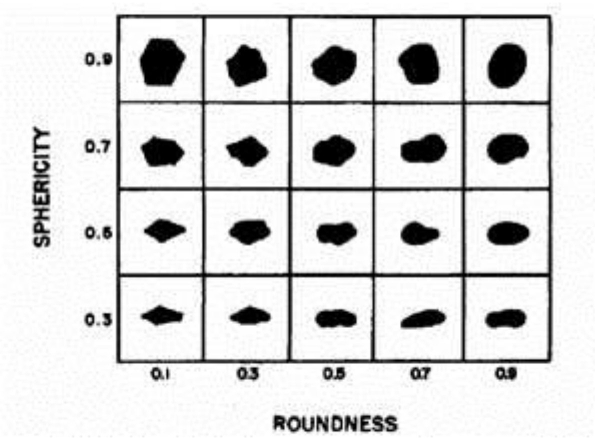
Sphericity & Roundness

The standards prepared by the API in this regard simply estimate how closely the quartz grain conforms to a spherical shape and its relative roundness.

The grain is assessed as follows:

"average radius of the corners / radius of the maximum inscribed circle"

Krumbein and Sloss devised a chart for the visual estimation of sphericity and roundness in 1955 as shown below. **API recommends sphericity and roundness of 0.6 or larger.**



Crush Resistance

API requires frac sand to be subjected to between 4000psi and 600psi pressure for two minutes in a uniaxial compression cylinder to determine its crush resistance.

The fines generated by this test are limited as shown below:

Size / Max fines by weight

6-12 mesh / 20%
16-30 mesh / 14%
20-40 mesh / 14%
30-50 mesh / 10%
40-70 mesh / 6%

Solubility

This test measures the loss in weight of a sample that has been added to a 100ml solution made up of 12 parts Hydrochloric Acid (HCI) and 3 parts Hydrofluoric Acid (HCI) and subsequently heated at approximately 65.5 degrees centigrade in a water bath for 30 minutes.

The object of this test is to determine the amount of non-quartz minerals present.

API specifications require that losses by weight as a result of this test are restricted to <2% across all mesh sizes up to 40-70 mesh where the loss permitted rises to 3%.

Turbidity

Turbidity refers to the amount of silt of clay sized particles in the sand sample. This is generally not an issue in frac sand production as production requires a washing process to be introduced which effectively removes these particles. There can also be an attrition process applied which also serves to remove unwanted fines as well as weaker grains.

Bob's Farm Samples

Geological Considerations

Sample No	% free silica
BH2-BL-B-PL	91
BH3-BL-B3-PL	94
BH4-BL-B-PL	99
BH5-BL-B-PL	99
BH1-BL-G1-PL	97
BH2-BL-G-PL	97
BH3-BL-G-PL	88
BH4-BL-G-PL	93
BH5-BL-G-PL	90

Free Silica or quartz content is determined by petrographic analysis, but results are usually given as SiO2 and a XRF analysis is recommended to accurately determine this content. It is likely that SiO_2 content is higher than the quartz content and thus increase the number of samples that meet the >99% requirement.

Grain Size

Particle sizing conducted by Coffey's based on Australia sieve sizes.

Sample No	Sieve Size %					
	1.18mm	600µm	425µm	300µm	150µm	75µm	<75µm
BH1-BL-G1-CC	0	2	10	40	48	0	0
BH1-BL-G1-CS	0	2	7	38	52	0	1
BH3-BL-B1-CS	0	0	2	35	62	0	1
BH3-BL-B2-CS	0	0	1	40	58	1	0
BH3-BL-B3-CC	0	0	2	44	53	1	0
BH3-BL-G-CS	0	0	3	25	71	1	0
BH5-BL-B-CS	0	0	2	25	73	1	1

The bulk of the sand falls between 300µm and 150µm, this meets the finest grain size within the specifications.

Sphericity & Roundness

Testing carried under Krumbein and Sloss devised a chart for the visual estimation of sphericity and roundness.

Sample No	Roundness	Sphericity
BH3-BL-G-PL	0.60	0.75
BH3-BL-B3-PL	0.60	0.74
BH5-BL-B-PL	0.61	0.72
BH5-BL-G-PL	0.65	0.74

All four composite sand samples meet API 19C specification, which recommends sphericity and roundness of 0.6 or larger

Crush Resistance

Not tested at this stage, please note specifications relate to American size mesh.

Solubility

Not tested at this stage, please note specifications relate to American size mesh

Turbidity

Not tested at this stage, however indications from visual inspection are that these samples will meet this specification.

Overall, the supplied sand samples are regarded as having **good potential for frac sand use (but occurs at the finer end of the range of acceptable grain size) subject to further testing**. At this stage, only dune sands in BH4 and BH5 meet this requirement but it is likely that sands with quartz contents around 97% will approach this limit (BH1 and BH2 beach sands).

11.4. SILICA SAND FOR GLASS MANUFACTURE

Glass producers need consistent, free flowing, correctly sized and low iron silica sand which is in short supply. Glass manufacturers usually classify silica sands by physical and chemical properties. The impurities in sand deposits differ depending on geological factors and glass manufacturers set specifications to suit each source material. Minerals such as chromite/picotite spinels, ilmenite, leucoxene-rutile, sillimanite-kyanite-staurolite and zircon have strict limits placed on the silica sand which can remain as a stone defect in glass. The heavy mineral impurities can be removed using spiral concentration if abundances are too high. Silica sands are usually mined from coastal dunes. Leached silica sands are usually preferred.

Physical Characteristics

The physical specifications relate specifically to particle sizing, a more uniform grainsize material is preferred. Typically, the grainsize ranges from 0.6 to 150 mm. The presence of oversize particles and fines can cause difficulties in glass manufacture. After removing impurities and the sand has been classified into the required size range, glass producers want the material to contain a low moisture content.

Chemical Characteristics

Silica sand for glass production should possess a minimum silica content of about 98 – 99% SiO2 and around 0.2 – 1.6% Al2O3 with constraints on amounts of alkalis, colourants (such as Ni, Cu, Co) and refectory heavy minerals.

Generally, colourless glass specifications include:

>99wt% SiO2
<0.03wt% Fe2O3
<0.1wt% TiO2
<6 ppm Cr2O3

and coloured glass specifications include:

>98wt% SiO2
<0.2wt% Fe2O3
<10 ppm Cr2O3

Silica sands from the Stockton Bight area usually supply sands for coloured (amber) glass products. Since the Bob's Farm sand deposit lies adjacent to and on the same dune ridge system as the Maccas Salt Ash Sand Quarry, it is assumed that the raw material specification will be similar. The desired specification requirements are:

SiO2	minimum of 98.6wt%
Fe2O3	between 0.06 and 0.10wt%

Al_2O_3	maximum of 0.6wt%
Na_2O	maximum of 0.2wt%
LOI	maximum of 0.4wt%

with colouring elements typically around:

Co	1 ppm
Cr	7 ppm
Cu	3 ppm
Mn	10 ppm
Ni	3 ppm
V	3 ppm

The raw silica sand should be relatively free of contaminants such as sulphides, phosphides, carbides, nitrides, organics and metallic, refractory and highly aluminous grains and particles.

The sand deposit has **some potential to use as a product for coloured glass manufacturing** (as per adjacent Maccas Salt Ash Quarry). At this stage of testing, only dune sands in BH4 and BH5 meet this requirement but it is likely that sands with quartz contents above 95% will approach this limit (BH1 and BH2 beach sands). A fine to medium grainsize is preferred.

11.5. PURE SILICA SAND FOR ADVANCED HIGH-TECH APPLICATIONS

Quartz of very high purity for advanced high-tech applications is sourced from a very few locations world-wide. The expected growth in demand for these purer quartz products will widen the search for suitable deposits. The main restriction to supply of high purity quartz products is the beneficiating methods required. The applications include semi-conductors, high temperature lamp tubing, telecommunications, optic fibres, micro-electronics and solar silicon panels.

Quartz for high-tech applications require beneficiation of raw quartz material using modified processing techniques and specifically designed equipment. The end-use product should have a total impurity level of 20 – 30 ppm. Quality assurance regulations are applied globally and are difficult to meet as well as expensive as several cycles of testing is required on progressively larger quantities of materials. The specifications vary from industry to industry.

The main source for these high purity quartz products are lump quartz deposits which are then granulated. Fluid and mineral inclusions need to be removed from the raw quartz material to process into a high value refined product.

12.0 CONCLUSIONS

The full assessment of the potential of the silica sand deposit at Bob's Farm at Port Stephens, NSW should be conducted as a staged project. The first stage involved interpretation of the compiled data from the initial investigations in the project area by Geochempet Services in the current report. The following conclusions are reached:

- The upper dune sands are potentially the easiest to develop as an excavated sand pit to about 2 m above the water table with good potential for fine construction sand (broadly) and foundry sand, ceramic sand, frac sand and silica sand for glass manufacturing (localized areas).
- The carbonaceous marker horizon in the vicinity of the water table (usually with 5 m) is potentially an acid sulphate soil layer and has little potential for construction or landscaping use.
- The lower beach sands are potentially difficult to develop as consent need to be sought from Government authorities. Extraction to 16 m below water table level by dredging is proposed. It is considered to have **good potential for fine construction sand (broadly) and foundry sand, ceramic sand, frac sand and silica sand for glass manufacturing (localized areas)** but suspected contamination issues make interpretation more difficult.

The next suggested stage of work (Stage 2) is outlined and discussed below.

12.1. DISCUSSION ON STAGE 2 PROPOSAL

The work undertaken during Stage 2 or in later stages should focus on the upper dune sand deposit and should include the following:

1. Examination of the original nine composite raw sand samples by XRF analysis for elemental oxides and elements and to identify contaminant minerals by XRD analysis in selected samples with lower free silica contents. The drawback on both analytical techniques is only a small sub-sample is utilized and may not represent the whole sample. The XRD technique is limited by its detection limits which are much coarser than the XRF method. The SiO_2 content is higher than the quartz content estimated by petrographic analysis and thus increases the number of samples that meet the 98 - 99% SiO_2 content requirement. At this stage, only dune sands in BH4 and BH5 meet this requirement but it is likely that sands with quartz contents above 95% will approach this limit (BH1 and BH2 beach sands).
2. A grid of boreholes for further sampling of the upper dune sand deposit is recommended to better define the resource to indicate areas of localized high-value product. The use of hollow stem augers with core barrels for extracting the samples is suggested as the cheapest and easiest method. Split spoon samplers should be inserted through the centre of the auger and driven into the soil in the bottom of the auger, then the samples extracted. The top of the sample must be discarded because it contains

material from the earlier layers and may be contaminated by material falling into the hole from above. Either a hollow reverse circulation air-core or vibra-coring (sonic) methods would probably produce less contaminated samples but would be more expensive.

3. The drill samples should be sampled at 0.5 – 1 m intervals, each sample should be photographed and both a geological and drillers log should be kept for each borehole.
4. If enough samples are collected (or if raw sample splits were kept from the particle size analysis done by Coffey), graded samples should be collected and analysed as in Item 1. This should reduce lithic clast content (and raise SiO2 content) and reduce the fines content (thereby reducing impurities).
5. The same sand samples in Item 2 should be washed and re-analysed as in Item 1. The washing may reduce the iron coatings to some degree thus improving the final product

The XRF analysis should cover at least SiO2, Na2O, K2O, CaO, MgO, Al2O3, TiO2, Fe2O3, Cr2O3 and LOI. The elemental analysis should cover at least Cu, Co, Cr, Cu, Fe, Mn, Ni, Ti, V and Zn. The XRD analysis may identify some refractory heavy minerals and highly aluminous minerals if in high enough concentrations. LECO method may be used to determine total sulphides and total carbon and organic carbon while inorganic carbon would be the difference between the two results. An environmental laboratory could analyse for phosphates and other contaminants.

Geochempet Services would be prepared to undertake the geochemical analysis and could undertake sieve sizing on the raw sand samples to produce samples for further geochemical testing, if required. Geochempet Services will issue a second stage report for all work completed during this period, if required as per original quote. The final report for the Stage 2 work will include a detailed Scope of Work for Stage 3 and costs for the proposed work.

If QMS have identified any further testing programs, Geochempet Services would be happy to discuss these further with the client or client suggestions on any other organisations that would benefit the on-going investigations.

Silica Sand Review
Focus on
Australian Demand
& Asian Export Potential

SEPTEMBER 2014

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Silica sand review

1 Executive Summary

This report examines the market for fine aggregate sand quarry products in the Sydney / Newcastle region as well as exports over the next 20-25 years, with an emphasis on value added industrial sand markets & construction sand markets.

Ammos Resource Management (AMR) is seeking an opinion on supply and demand of silica sand for industrial and construction use. AMR seeks to better understand the market dynamics and prices along with international trade issues.

This review, in conjunction with the appendices, considers local and global silica supply and demand but focuses largely on Asia Pacific as we believe that is the region with the best growth prospects for the foreseeable future.

2 Disclaimer

While every effort has been made, to ensure accuracy of this report, including its appendices, Quarry Mining Systems and any contributing sub-contractors accept no liability for any error or omission. I particular in this reports opinions have been given and estimates made on the basis of incomplete data and, while these are our professional best estimates, no guarantees can be given of validity of these. Quarry Mining Systems and contributing sub-contractors can take no responsibility if the conclusions of this report are based on incomplete or missing data.

Quarry Mining Systems and contributing sub-contractors are independent of Ammos Resource Management and have no financial interests.

Estimates of resources at individual quarries are based on limited publically available data and have not been classified in accordance with the JORC code nor in accordance with NI43-101, nor do they constitute 'resources' as described in these codes.

3 FINE AGGREGATE (SAND)

Fine Aggregate is defined as having a nominal size of less than 5 mm (AS 2758). Fine aggregate includes both natural and manufactured sand. In the Sydney and surrounding regions four main types of fine aggregate are produced:

- Fine to medium sand of a dune beach origin. It is currently mined from sand dunes in coastal areas and may potentially be dredged from offshore deposits.
- Medium to coarse sand that is usually sourced from fluvial (alluvial) deposits and friable sandstone. This type of sand can contain varying amounts of clay.
- Fine to coarse clayey sand that is usually sourced from friable sandstone.
- Manufactured sand, which is crushed rock that is usually used in combination with fine natural sand.

Sand from different sources has different characteristics, including grain size and shape, and the presence and absence of materials such as clay and shell grit. The types of natural fine aggregate deposit are summarised in Table 1.

Pienmunne & Whitehouse (2001) estimated that around 7Mt of natural fine aggregate is consumed in the Sydney region each year of which around 1Mt was imported from surrounding areas (imports of sand have been increasing since 2001). Almost half of Sydney's fine aggregate consumption is fine to medium grained sand, one third medium to coarse grain and the remainder clayey sand. Future requirements for fine aggregate were estimated by Pienmunne & Whitehouse (2001) at around 8 million tones per year around 2031.

It is anticipated that the Sydney & Hunter region markets will require up to 3.0 million tonnes of extra sand per year by 2015 if additional resources are not made available. (refer to Umwelt, 2009a for further detail). It is also anticipated that this demand will grow by 1% per annum (Department of Mineral Resources, 1992).

In the medium term (2010 to 2020) the predicted demand for all types of construction sand in the Sydney market is 83.8 million tonnes, medium to coarse sand 30.6 million, fine to medium sand 40.4 million and clayey/mortar sand 12.8 million tonnes. Within the Sydney region known resources are capable of supplying an estimated total of 65 million tonnes over time.

However not all of this can be produced in the medium term and the total estimated shortfall for the period 2010 to 2020 is in the range of 40 to 45 million tonnes. Unless new deposits within the region are made available for extraction this tonnage (40 to 45 million tonnes) will have to be imported from outside the Sydney region (Department of Mineral Resources, 2001). There is clearly a need for additional sources of fine to medium grained sand within the Sydney region, both in the short and long term. It is therefore into a market of rising demand and diminishing local supply that sand will be sold.

Table 1: Fine aggregate deposit types

	Deposit Type	Examples	Grainsize/Characteristics
Marine	Coastal barriers & dunes	Kurnell, Stockton Bight	Fine to medium, well sorted
	Beach & estuarine sands	No longer available	Fine to medium, well sorted, may contain shells or silt
	Marine Sand	Offshore resources, not currently available	Fine to medium, well sorted, clean
Fluvial	Alluvial sediments	Penrith lakes, closing	Medium to coarse, gravel
	Alluvial sediments	Agnes Banks, Maroota	Fine to medium, clayey, mainly mortar sand
Friable sandstone	Deeply weathered sandstone	Newnes Plateau, Maroota, Southern Highlands	Fine to coarse, clayey

Source: Whitehouse (2006)

Table 2: Major construction and industrial sand quarries Stockton Bight

Company	Location	Production Capacity (tonnes per annum)	Main Applications
Toll Bulk Sands	Williamtown	300,000 - 400,000	Concrete, rendering, tiling, fill
Boral Resources P/L	Fullerton Cove	300,000	Concrete sand (70%); blended with manufactured sand from Seaham Quarry
Unimin Australia Limited	Anna Bay, Salt Ash, Tilligerry Peninsula	~ 200,000	Industrial (glass/foundry), minor construction applications
Mackas Sand P/L	Salt Ash	2,000,000	Industrial and construction applications
Metromix P/L	Anna Bay	10,000 – 50,000	Foundry Sand and construction applications
Robinsons Anna Bay Sands	Anna Bay	30,000 – 90,000	Fill, industrial (adhesives), foundries
Rocla – Raymond Terrace	Raymond Terrace	50,000 – 100,000	Construction purposes

Source: Whitehouse (2202), Ray & Whitehouse (2004)

Pienmunne & Whitehouse (2001) summarised the applications of fine to medium sands as follows:

Concrete manufacture is the main use for fine to medium grained sand. A total of 63.8% is used, with 59.2% for readymix concrete (59.2%) and 4.6% for concrete products (4.6%). In concrete mixes fine sand would be approx 50 to 70% of the sand component which would equate to approx 500 to 700kg/m3. A moderate proportion (18.3%) of this type of sand is used for rendering, which is reported as 'mortar' category.

4 LOCAL MARKET DYNAMICS FINE AGGREGATE

Sydney is facing a shortage of aggregates, especially of high quality fine aggregates, with the impending closure of the Penrith Lakes Scheme, expected in the next year. This operation was a joint venture between the three main market players, Australian listed company Boral, Hanson (owned by Heidelberg cement) and Swiss giant Holcim. The Penrith Lakes Scheme had provided up to 6 Mtpa of aggregate, around half the Sydney market demand in recent years, supplying both sand and river gravel. Supplies of natural sand for fine aggregate are even more restricted than supplies of coarse aggregate.

Apart from the Penrith Lakes Scheme, sand supplies are currently sourced from dunes at Kurnell (about to exhaust supply) in Sydney's south, minor deposits of clay rich alluvial sands in Sydney's northwest, coastal dune sands from the Newcastle district and sand made from friable sandstones north and west of Sydney. As the Penrith Lakes Scheme comes to a close, more pressure will be exerted on existing sand deposits to make up the shortfall. Friable sandstones are relatively abundant but require significant washing to remove clays, so high water demand and large quantities of clay tailings increase their costs and environmental impact and this is expected to limit any larger scale development of these resources. .

The use of well designed manufactured sands as a sand component in concrete and asphalt: is well established by the larger suppliers however there is an ongoing issue with consistency of manufactured sand properties causing operational difficulties for many. Suppliers are still relying on the fine dune sands from Kurnell and Newcastle areas to provide the mix quality and performance that the market demands. Increased attention to the design of manufactured sand can create products which can substitute for all or most fine natural sand in a mix, and this is likely to reduce future demand pressure on natural sand supplies.

The projected shortfall for natural fine sand will place pressure on imports of sand from the Hunter Region. In the absence of other supplies, typical prices in the Sydney region for natural fine sand are expected to rise to over $40 in the near future.

Table 3: Overall use of fine aggregate in Australia

Use	%
Readymixed concrete	59.2
Mortar	15.5
General Construction	10.7
Fill	5.2
Concrete Products	4.9
Asphalt	3.7
Industrial	1.2
Other	1.3

Source: Pienmunne & Whitehouse (2001)

5 ALTERNATIVE OPTIONS FOR LOCAL FINE AGGREGATES

Alternative materials such as slag, quarry sand (crusher fines), manufactured sand, recycled building and demolition materials, excavated rock and fly ash are potential alternatives for natural sand. The current use of these alternatives however are negligible, due to constraints such as cost of production, increased transport, limited availability, erratic quality and technical difficulties in obtaining suitable ranges of particle sizes and particles or acceptable shape and roundness (Department of Mineral Resources, 2001). None of the alternative materials considered, therefore, have the ability to replace natural construction sand in high quality applications such as concrete to any significant degree.

6 OPPORTUNITIES FOR LOCAL FINE AGGREGATES

- The critical shortage of natural sand creates an opportunity to import natural sand into the Sydney Region from deposits elsewhere. However this opportunity may only exist until government policy is amended to permit dredging of marine sands.
- The closure of Penrith Lakes and Kurnell is likely to increase the price of fine sand thus providing opportunities of greater imports of fine sand from deposits elsewhere that were not economically viable due to transport costs prior to price increases.

7 CONCLUSIONS FOR LOCAL FINE AGGREGATES

While significant hurdles and risks exist the, the inescapable conclusion is that the Sydney Region has a large and growing demand for fine sand and options for supply are extremely limited.

Supplies from existing sources will be insufficient to meet current and projected demand for sand (2015) with market intelligence indicating that supplies are already in short supply.

Industrial use of sand has been diminishing in NSW with the contraction of both the foundry industries and the glass manufacturing industries however some demand still exists for these value added sands.

Table 4 below shows our best estimate of markets for 750,000 tonnes of sand extracted from the AMR deposit dependant on price point.

Table 4: Estimated demand of AMR deposit with production capacity 750,000 tpa

Fine Aggregate Use	**Ktpa**
Fill Sand - Local	50
Construction Sand - Local	200
Landscape Sand - Local	25
Foundry Sand - Local	5
Foundry Sand - Export	170
Glass Sand - Local	5
Glass Sand – Export	270
Other Industrial Sands - Local	5
Other Industrial Sands - Export	20

Source: Industry Estimates

8 MARKET DYNAMICS INDUSTRIAL SILICA SANDS

8.1 GLOBAL SILICA SAND

Silica sand is a strong growth mineral due to the construction sector which impacts flat glass for window, continuing movement of capacity away from Western Europe and USA to Asia particularly China. An example of this is the massive closure of Pilkington/NSG in UK and expansion in China.

8.2 VOLUMES

Global silica sand demand has recently been forecast to grow at approximately 4.5% to reach 280 million tonnes by 2016 from a base of 225 million tonnes in 2011. Silica sand demand by region is shown in Table 1 below.

Table 5: Estimated demand of silica sand by region 2012

Region	% of Global Demand
Asia Pacific	47%
North America	20%
Western Europe	16%
Eastern Europe	8%
Africa/Middle East	5%
Central & South America	4%

Source: Industry estimates 2012.

9 PROCESSING TECHNOLOGIES FOR INDUSTRIAL SILICA SAND

Silica deposits are normally exploited by quarrying and the material extracted may undergo considerable processing before sale. The objectives of processing are to clean the quartz grains and increase the percentage of silica present, to produce the optimum size distribution of product depending upon end use and to reduce the amount of impurities, especially iron and chromium, which colour glass.

Cleaning the quartz grains and increasing silica content is achieved by washing to remove clay minerals and scrubbing by attrition between particles. Production of the optimum size distribution is achieved by screening to remove unwanted coarse particles and classification in an upward current of water to remove unwanted fine material. Quartz grains are often iron stained and the staining may be removed or reduced by chemical reaction involving sulphuric acid at different temperatures. Impurities present as separate mineral particles may be removed by various processes including gravity separation, froth flotation and magnetic separation. For the highest purity, for electronics applications, extra cleaning with aggressive acids such as hydrofluoric acid combined with thermal shock may be necessary. After processing, the sand may be dried and some applications require it to be ground in ball mills to produce a very fine material, called silica flour. Also, quartz may be converted to cristobalite in a rotary kiln at high temperature, with the assistance of a catalyst. Some specialist applications require the quartz to be melted in electric arc furnaces followed by cooling and grinding to produce fused silica.

Industrial sand is a term normally applied to high purity silica sand products with closely controlled sizing. It is a more precise product than common concrete and asphalt gravels. Silica is the name given to a group of minerals composed solely of silicon and oxygen, the two most abundant elements in the earth’s crust. In spite of its simple chemical formula, SiO_2, silica exists in many different shapes and crystalline structures. Found most commonly in the crystalline state, it also occurs in an amorphous form resulting from weathering or plankton fossilisation.

Extracted ore undergoes considerable processing to increase the silica content by reducing impurities. It is then dried and sized to produce the optimum particle size distribution for the intended application. For industrial and manufacturing applications, deposits of silica yielding products of at least 95% SiO_2 are preferred. Silica is hard, chemically inert and has a high melting point, attributable to the strength of the bonds between the atoms. These are prized qualities in applications like foundries and filtration systems. Quartz may be transparent to translucent and has a vitreous lustre, hence its use in glassmaking and ceramics. Industrial sand’s strength, silicon dioxide contribution and non-reactive properties make it an indispensable ingredient in the production of thousands of everyday products.

Glassmaking: Silica sand is the primary component of all types of standard and specialty glass. It provides the essential SiO_2 component of glass formulation and its chemical purity is the primary determinant of colour, clarity and strength. Industrial sand is used to produce flat glass for building and automotive use, container glass for foods and beverages, and tableware. In its pulverized form, ground silica is required for production of fibreglass insulation and reinforcing glass fibres. Specialty glass applications include test tubes and other scientific tools, incandescent and fluorescent lamps, television and computer CRT monitors.

Metal Casting/Foundry: Industrial sand is an essential part of the ferrous and non-ferrous foundry industry. Metal parts ranging from engine blocks to sink faucets are cast in a sand and clay mould to produce the external shape, and a resin bonded core that creates the desired internal shape. Silica’s high fusion point (1,760°C) and low rate of thermal expansion produce stable cores and moulds compatible with all pouring temperatures and alloy systems. Its chemical purity also helps prevent interaction with catalysts or curing rate of chemical binders. Following the casting process, core sand can be thermally or mechanically recycled to produce new cores or moulds. Chromite, zircon and olivine sand all compete with silica but usually in small quantities and mainly as a thin covering on top of the silica for actual molten metal contact.

Metallurgical: Industrial sand plays a critical role in the production of a wide variety of ferrous and non-ferrous metals. In metal production, silica sand operates as a flux to lower the melting point and viscosity of slag to make them more reactive and efficient. Lump silica is used either alone or in conjunction with lime to achieve the desired base/acid ratio required for purification. These base metals can be further refined and modified with other ingredients to achieve specific properties such as high strength, corrosion resistance or electrical conductivity. Ferroalloys are essential to specialty steel production, and industrial sand is used by the steel and foundry industries for de-oxidation and grain refinement.

Chemical Production: Silicon-based chemicals are the foundation of thousands of everyday applications ranging from food processing to soap and dye production. In this case, SiO_2 is reduced to silicon metal by coke in an arc furnace, to produce the Si precursor of other chemical processes. Industrial sand is the main component in chemicals such as sodium silicate, silicon tetrachloride and silicon gels. These chemicals are used in products like household and industrial cleaners, to manufacture fibre optics and to remove impurities from cooking oil and brewed beverages.

Building Products: Industrial sand is the primary structural component in a wide variety of building and construction products. Whole grain silica is put to use in flooring compounds, mortars, specialty cements, stucco, roofing shingles, skid resistant surfaces and asphalt mixtures to provide packing density and flexural strength without adversely affecting the chemical properties of the binding system. Ground silica performs as a functional extender to add durability and anti-corrosion and weathering properties in epoxy based compounds, sealants and caulks.

Paint and Coatings: Paint formulators select micron-sized industrial sands to improve the appearance and durability of architectural and industrial paint and coatings. High purity silica contributes critical performance properties such as brightness and reflectance, colour consistency, and oil absorption. In architectural paints, silica fillers improve tint retention, durability, and resistance to dirt, mildew, cracking and weathering. Low oil absorption allows increased pigment loading for improved finish colour. In marine and maintenance coatings, the durability of silica imparts excellent abrasion and corrosion resistance.

Ceramics & Refractories: Ground silica is an essential component of the glaze and body formulations of all types of ceramic products, including tableware, sanitary ware and floor and wall tile. In the ceramic body, silica is the skeletal structure upon which clays and flux components attach. The SiO_2 contribution is used to modify thermal expansion, regulate drying and shrinkage, and improve structural integrity and appearance. Silica products are also used as the primary aggregate in both shape and monolithic type refractories to provide high temperature resistance to acidic attack in industrial furnaces.

Filtration and Water Production: Industrial sand is used in the filtration of drinking water, the processing of wastewater and the production of water from wells. Uniform grain shapes and grain size distributions produce efficient filtration bed operation in removal of contaminants in both potable water and wastewater. Chemically inert, silica will not degrade or react when it comes in contact with acids, contaminants, volatile organics or solvents. Silica gravel is used as packing material in deep-water wells to increase yield from the aquifer by expanding the permeable zone around the well screen and preventing the infiltration of fine particles from the formation.

Oil and Gas Recovery: Known commonly as proppant, or “frac sand”, industrial sand is pumped down holes in deep well applications to prop open rock fissures and increase the flow rate of natural gas or oil. In this specialised application round, whole grain deposits are used to maximise permeability and prevent formation cuttings from entering the well bore. Silica’s hardness and its overall structural integrity combine to deliver the required crush resistance of the high pressures present in wells up to 2,450 m (8,000 ft) deep. Its chemical purity is required to resist chemical attack in corrosive environments.

Recreational: Industrial sand even finds its way into sports and recreation. Silica sand is used for golf course bunkers and greens as well as the construction of natural or synthetic athletic fields. In golf and sports turf applications silica sand is the structural component of an inert, uncontaminated, growing media. Silica sand is also used to repair greens and to facilitate everyday maintenance like root aeration and fertilisation. The natural grain shape and controlled particle size distribution of silica provides the required permeability and compaction properties for drainage, healthy plant growth and stability.

10 SILICA SAND SITUATION BY COUNTRY

10.1 AUSTRALIA

Australia is currently the largest exporter of silica sand in the region. Last year the tonnage exported exceeded 2 million tonnes, and several years ago exported 3.2 million tonnes. Its market share has been impacted upon by 3 Vietnamese sand exporters which enjoy a closer proximity to the key NE Asian markets of Japan, South Korea and Taiwan.

Currently, Australian silica sand exports are largely controlled by Japanese companies.

10.2 CHINA

The actual largest producer of both glass grade sand and foundry sand but this is achieved through more than 200 small to medium sized producers rather than a small number of large producers. This is undergoing change and both Sibelco and US Silica are making attempts to "buy into" Chinese supply chain but to date with limited success and mainly as miners of quartzite rather than alluvial sand deposits. A Hong Kong based company, Fineton Ltd, has several sand operations in China also but these supply only local customers rather than export. Also when the leases expire there is a tendency for these producers to lose control back to local ownership, making life difficult for them.

Table 6: China Domestic Demand Forecast of Major Non-metallic Minerals in 2015

Product	Unit	2005	2010	2015	Annual Growth Rate (%)
Silica sand for glass	Millions of tonnes	12	26	30	2.9

Silica Sand

Application:

glass making, mould and casting making, water filtration, sand blasting, concrete producing, etc

Feature:

dry, clean (wash-free, can be used directly), bad-smell-free, even-granular.
Please refer to the following charts for details.

	Standard	Degree of Grain
Standard and Degree of Grain	425μm - 250μm	95.00%
	250μm - 180μm	90.00%
	180μm - 125μm	90.00%
	125μm - 85μm	85.00%

Item	Chemical Index	
	High Quality Products	Quality Products
SiO_2(%)	>=99.50	>=98.99
Al(*10-6)	<=10	<=15
Fe(*10-6)	<=1	<=1
K(*10-6)	<=1.5	<=3
Na(*10-6)	<=1.5	<=3

Figure 1: A typical Chinese silica sand specification

The Chinese government mention in a recent report (available if requested) that "at present, the non-metallic minerals industry is still faced with the following problems":

(i) The development and protection of mineral resources fail to meet requirements; wasting and destruction of resources remains serious; and some key minerals are exposed to excessive exploitation in a disorderly manner;

(ii) Enterprises have a small scale and are distributed sparsely, indicating low degree of industrial concentration and unsatisfactory scale effects;

(iii) The engineering level of the whole industry is low and the deep-processing and application technique is less sophisticated; and

(iv) The industrial management system is unsound and the operational monitoring is to be improved urgently.

These matters relate not only to silica sand but to a range of other non-metallic minerals.

10.3 INDONESIA

Indonesia is made up of 14,000 islands and three of these produce the bulk of the silica sand. These are Belitung, Bangka and Borneo (Kalimantan). Apart from these big three sand resources, a number of uninhabited islands in the seas between Sumatra and Borneo are also mined on a campaign basis. About two years ago the Indonesian Government clamped down on illegal export of much of these operations as the sand was being barged to Singapore which needs to import huge quantities for construction as well as landfill. When these shipments were stopped then Cambodia became the new source for much of this sand requirement, and this has caused considerable damage there.

10.4 MALAYSIA

Malaysia is well positioned and has many good silica sand reserves. The main ones are at Bintulu, in Sarawak. The Government took the steps several years ago to try to reduce the raw sand exports, mainly to Japan at that time. It was decided better to produce added value products instead and this has been somewhat successful with sodium silicate (waterglass) and also sending to the glassworks on Peninsula Malaysia, near Klang Valley and Jahor Baru in barges. Small amounts are still exported though, and some good deposits in northern tip of Sabah (known as Dog's Face)have been investigated as new silica mines, but lack of infrastructure especially powerlines have held up development of these resources.

Silica is obtained from natural silica sand deposits, processed tailings sand and crushed quartz rock (silica powder). It is mainly used in the manufacture of glass, filter sand in the water treatment, foundry sand and in the chemical and ceramic industries.

Figure 2: Sarawak map showing location of Bintulu the silica sand resource in Malaysia & Brunei

High-grade natural silica sand deposits are found in Telaga Papan, Merang and Tembila in Terengganu; Kuala Jemaluang, Teluk Tenggaruh and Pasir Seruang in Johor; Bintulu in Sarawak and Pulau Balambangan in Sabah. Smaller deposits are also found in Kelantan and Perak. There are currently more than 20 companies producing a variety of glass products, which include laminated and tempered glass, household glass products, TV panels and optical lenses. Perhaps the best purest sand is available at Bintulu, in central coastal Sarawak.

With new dams being planned for Sarawak, industry including silicon metal and other value added products such as high purity silica/quartz for electronics and photovoltaic cells, etc., are being considered. Malaysia has a good record of adding value to its mineral resources.

10.5 THAILAND

Thailand has thriving glass and foundry industries and therefore uses considerable tonnages of silica sand each year. The main sources of their best (low iron) sand are in the east around Rayong industrial area and close to the Cambodia border. Much of the future sand reserves has been “sterilised” by building of resorts and industrial parks so in the longer term, Thailand could become an important importer of silica sand. More than one million tonnes of silica sand is quarried in Thailand each year. This is consumed in the large glass, ceramic and construction industries. The glass manufactures here have stated they will need to import much more silica sand in the years ahead. Thailand and Cambodia are the two most obvious sources but both are problematic in regards to both government policy and environmental concerns.

10.6 BRUNEI

The Brunei Government has just recently (May 2012) called for tenders for companies to consider setting up silica mines one in the SW and the other in NE part of this tiny country. In recent months Russian companies have begun investigations to evaluate these two sand areas. It is likely that at least one and possibly both areas will be brought into production, for local consumption but also for export. They, like Malaysia are keen to set up value-adding industries such as specialty glass and maybe frac-sand plant as their huge oil and gas sector would benefit from this development. It will possible that in late 2013-14 these plans will become clearer. The silica sands at Tutong in the NE part of Brunei occur as a flat terrace remnant some 11 kms long and up to 1.6 km wide. The deposit is bisected by the main Seria-Tutong Road between Sungai Telamba in the west and Sungai Tutong in the east. The sand forms terraces rising to about 15 m above MSL over relatively low, flat Recent/Quaternary clay with an average thickness of 3 m. Local development of podzol soil occurs but in general the sand has very poor nutrient content and hence the terraces are largely devoid of vegetation except for shrubs and thin primary forests. Two types of sand are present: 1) an upper, fine white sand of excellent glass making quality, with varying in thickness between 0.6 to 4.6 m, 2) an underlying, humus stained fine sand. Sieve analyses on the sands indicate that more than 90% consist of the ‘ideal’ grains (36 + 100 mesh sieve sizes). The white sands are rather pure. Sample analysis indicated that they consist of 99% silica (SiO_2) and less than 0.05% of iron (Fe_2O_3). Analysis in the Netherlands in 1987 confirmed the pure quality (Fe_2O_3 0.015 weight %). The sand is suitable for manufacturing good quality glass, but the Fe_2O_3 level is too high for optical glass manufacturing. The silica sand deposits cover a total area of about 7.8 km^2. With an average thickness of 1.8 m the reserves are roughly 15 million m^3 for the upper good quality sand, and approximately the same amount for the poorer quality sands.

10.7 TAIWAN

Taiwan, being volcanic/upthrust in geology lacks low iron alluvial sand. Much of the construction sand/aggregates used here are crushed rock (such as granite) from near Taichung area and the large glass and fiberglass industry here buy bulk sand from Mitsubishi's Cape Flattery deposit and some from Vietnam. Sibelco have a facility near Taichung where they upgrade the imported Queensland sand and bring it up to LED/TFT grade and then some is exported to Japan and Korea.

10.8 KOREA

South Korea is a major importer of silica sand from Australia and Vietnam. South Korea is second only to Japan in imports now. Glass and foundry are the two key end uses.

10.9 JAPAN

Japan, being largely volcanic in geology, has little alluvial sand and therefore needs to import most of its requirements. Many Japanese companies have set up subsidiaries and JVs in China and one of the driving factors is source of consumables more available there at lower cost. One of these is silica sand.

■The granulometry and the chemical composition table of the main silica sand

Malaysian sand

Australian sands

		Sand.Granulometry (wt.%)											Chemical composition (%)											
	MESH	18.5	26	36	50	70	100	140	200	280	PAN	AFS.FN	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	TiO_2	Li_2O	K_2O	ZrO_2	Cr_2O_3	Ig-loss
	Name / Size µm	850	600	425	300	212	150	106	75	53														
Domestic sand	Yunotsu Silica Sand	0.1	4.1	22.9	36.3	23.1	7.9	3.8	1.4	0.3	0.1	45.96	95.0	2.50	0.19	0.01	<0.01		<0.01					0.31
	Utsumi Silica Sand #6	0.2	5.7	13.7	20.2	24.8	25.8	8.3	1.9	0.2	0.1	55.47	89.6	4.01	1.83	0.82	0.29							0.47
	Enshu Silica Sand #6		0.1	1.0	27.6	47.1	22.4	1.5	0.2	0.1		52.57	75.8	11.2	2.45	1.93	1.09		0.23					0.84
	Mikawa Silica Sand #6					15.8	39.6	32.2	10.8	1.4	0.2	86.30	97.6	0.80	0.29	0.01	0.08	0.03	0.01		0.16			0.39
Imported sand	Sarawak Silica Sand		0.1	2.6	12.1	33.6	31.8	14.5	4.4	0.6	0.3	67.46	99.8	0.06	0.01	<0.01	<0.01	<0.01	0.03		<0.01			0.10
	Peal Silica Sand	1.4	18.3	40.6	27.3	8.4	2.7	1.0	0.2	0.1		34.47	99.8	0.02	0.01				0.03					0.12
	Hooker Silica Sand			0.2	3.2	61.7	33.9	0.9	0.1			59.99	95.9	1.07	0.17	0.55	0.03		0.06					0.54
	Albany Silica Sand #27	3.9	23.2	49.1	18.6	3.3	1.2	0.4	0.3			30.51	99.8	0.01	<0.01	<0.01	<0.01		0.03					0.10
	Albany Silica Sand #35	0.4	18.4	42.4	24.5	9.6	4.3	0.3	0.1			34.49	99.8	0.01	<0.01	<0.01	<0.01		0.02					0.10
	Albany Silica Sand #48		0.4	14.2	37.8	31.8	13.8	1.9	0.1			47.06	99.8	0.01	<0.01	<0.01	<0.01		0.02					0.10
	Albany Silica Sand #90			0.3	2.0	16.6	39.0	24.8	13.4	3.5	0.4	88.25	99.8	0.01	0.01	<0.01	<0.01		0.03					0.11
	Albany Silica Sand #90 Magnetic separation			0.2	0.2	7.5	42.0	33.6	13.7	2.6	0.2	91.87	99.8	0.01	<0.01	<0.01	<0.01		0.07					0.10
	Kemerton Silica Sand · for Glass Bottle			0.7	20.4	43.2	28.8	6.4	0.4	0.1		57.29	95.4	2.41	0.024				0.02		1.80			0.25
	Kemerton Silica Sand · for Sheet Glass		0.5	6.5	32.2	37.9	18.6	3.6	0.7			51.48	96.8	1.70	0.021			0.12	0.02		1.30			
	ACI Silica Sand			0.5	8.2	39.4	45.9	5.2	0.6	0.2		61.70	99.8	0.04	0.01				0.02					0.10
Special sand	Spojyumen (GGS)		2.0	19.3	32.1	28.4	14.5	3.5	0.2			47.16	75.4	18.5	0.10	0.05	<0.01	0.24	0.01	5.10	0.19			0.11
	Jirukon				0.2	8.0	36.3	50.5	4.8	0.1	0.1	87.21	31.6		0.06	0.02	0.02		0.31			65.71		0.14
	Arusand#500	0.1	0.1	3.9	41.4	36.6	41.4	2.5	0.6	0.2	0.2	50.48	18.4	75.1	2.1				3.2					
	Arusand#650			0.1	6.1	39.0	39.5	14.5	0.7	0.1		65.30	15.0	78.0	2.0				3.0					
Recycled sand	Recycled sand #6		0.5	4.6	15.5	33.4	35.6	9.6	0.7	0.1		60.08	93.9	3.09	0.65	0.27	0.32							0.11
	Recycled sand #7		0.1	0.1	0.6	5.2	31.2	47.3	14.0	1.4	0.1	94.73	95.0	2.41	0.94	0.21	0.70							0.28

Figure 3: Various Silica Sands Available in Japan from Various Sources, including Australia, Vietnam and also recycled glass after use in Japanese foundries.

10.10 VIETNAM

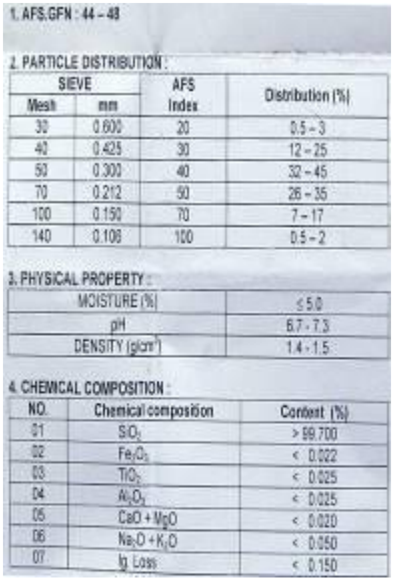
During the past decade Vietnam silica sand, which is available in large almost inexhaustible quantities along the whole 2,000 km plus coastline, has been through cycles of exporting raw sand, exporting of semi-processed (spirals to remove heavy minerals and trommels to wash and remove organic trash), to actual bans placed on sand by the Government which has a tendency to bring in such legislation very quickly. The current situation is only washed and upgraded sand is allowed to be exported and tariffs have been added to ensure more value stays in Vietnam.

Figure 4 Typical silica sand mining 60 km south of Danang Vietnam. Bulldoze then load truck Sand depth ~ 2 metres.

Process: scrape off vegetation and stockpile soil for rehab later. Us bulldozer as shown to push sand into mounds, then use tracked digger to load trucks. These trucks travel along this sand strip to the factory where simple trommell and spirals are used to wash and remove organic matter and heavy minerals- mainly black specs of ilmenite. The sand is used locally and remainder exported especially to Korea for foundry and glass use. Visited Minco/Vitis operations shown above.

KIND OF PRODUCT	CHEMICAL COMPOSITION (%) THÀNH PHẦN HOÁ HỌC (%)					
LOẠI SẢN PHẨM	SiO_2	Fe_2O_3	TiO_2	Al_2O_3	Ig.Loss	Moisture
PROCESSED S. SAND						
TTB(42- 47)	> 99.7	< 0.018	< 0.02	< 0.03	< 0.03	< 4
TTB(60-64)	> 99.7	< 0.018	< 0.02	< 0.03	< 0.03	< 4

Silica Sand Export from this Section of Vietnam – green strip.



1. AFS.GFN : 44 – 48

2. PARTICLE DISTRIBUTION :

SIEVE		AFS Index	Distribution (%)
Mesh	mm		
30	0.600	20	0.5 – 3
40	0.425	30	12 – 25
50	0.300	40	32 – 45
70	0.212	50	26 – 35
100	0.150	70	7 – 17
140	0.106	100	0.5 – 2

3. PHYSICAL PROPERTY :

MOISTURE (%)	$\leq$ 5.0
pH	6.7 - 7.3
DENSITY (g/cm^3)	1.4 - 1.5

4. CHEMICAL COMPOSITION :

NO.	Chemical composition	Content (%)
01	SiO_2	> 99.700
02	Fe_2O_3	< 0.022
03	TiO_2	< 0.025
04	Al_2O_3	< 0.025
05	CaO + MgO	< 0.020
06	Na_2O + K_2O	< 0.050
07	Ig Loss	< 0.150

Nam Trung Bộ "South Central Coast" has Vietnam's best silica sand resources

10.11 PHILIPPINES

Philippines has some excellent sand especially on Palawan Island. However about 10 or 12 years ago it was decided that the sand should be left to ensure am ongoing tourism sector had good beaches. After this then almost all sand has been imported from Australia, mainly Mitsubishi. Some loads of sand have be imported from Vietnam, but the low value compared to rice, which the same ships carry between the two countries has meant this trade usually stops eventually. As the Australian sand is more pure (mainly iron and Ti content) this is preferred as it can be used for both flint and coloured glass, whereas Vietnam sand is only suitable for coloured/amber glass.

10.12 INDIA

India has some good sand reserves across the country. The relatively poor infrastructure (roads, etc.) mean that freight often costs more than the sand ex pit. The road to good JVs in India is not easy, and often the Indian party uses the evaluation as a cheap way to find out more and then don't proceed. Indian glass companies are assessing sand imports from Saudi and other Gulf states at present, and the frac/proppant sands are now mainly coming from Saudi Arabia.

10.13 NEW ZEALAND

NZ industry is relatively small, and most of the glass sand has been imported from North Stradbroke Island (formerly ACI now Sibelco).

10.14 NORTH AMERICA

This is a massive silica sand market, with glass, foundry and now frac sand being very important. The biggest silica sand producers are Sibelco/Unimin, US Silica and Fairmount Minerals. All three are multinational, multiplant producers. See profiles later in this report.

10.15 ECUADOR

In Loja, Southern Ecuador there exists a concession for a large mountain made of reasonably pure fine white silica sand of the quite high quality. Silica Sand analysis result: Al_2O_3 = 0.151%, Fe_2O_3 = 0.014%, SiO_2 = 98.32%. Stratum was approached by this company and a small sample received by courier. It may be useful for electronics and glass manufacture, and there is definitely a lack of glass production in this part of South America. This sand mountain has not been exploited due to lack of access to transportation, but it is quite near the projected route of a heavy railroad line. Orders for this sand have come to from Korea, China, and other countries, as much as we can produce, for prices of $25 to $45/t. This sand is available by simply loading it with a power shovel. There is an estimated of 50 million metric tonnes. It is excellent-quality gray sandstone, medium to fine grain, good for the multiple uses already indicated. The existence of an access road to the mine is a plus for the realisation of such a project. The ease for exploitation will reduce the operational cost to a maximum. The only negative factor is the considerable distance from the market. Transportation cost will increase the final price.

UNIVERSIDAD TECNICA PARTICULAR DE LOJA
UNIDAD DE SERVICIOS GEOLOGICO MINEROS
LABORATORIO DE BENEFICIO DE MINERALES

MUESTRA: [illegible]
PROCEDENCIA: [illegible]
ANALISIS: [illegible]
SOLICITA: [illegible]
FECHA: [illegible]
ANALISTA: [illegible]

ANALISIS GRANULOMETRICO

MALLA Nº	Abertura um	Peso (gr)	Peso %	Retenido Acumulado %
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SUMA				[illegible]

UNIVERSIDAD TÉCNICA PARTICULAR DE LOJA
LABORATORIO DE ANÁLISIS INSTRUMENTAL

RESULTADO DE LOS ANÁLISIS

Arenas Silíceas

% Al_2O_3 0.151
% Fe_2O_3 0.014
% SiO_2 98.32

Análisis certificado por:

JEFE LABORATORIO DEL ANÁLISIS INSTRUMENTAL U.T.P.L.

10.16 Belgium

Sibelco home base is here, but they have plants worldwide, including Australia, and are growing by mergers and acquisition each year. Sibelco Group is a worldwide supplier of quality industrial minerals to industrial and specialty applications. SCR-Sibelco NV was founded in 1872 in Belgium as a family owned silica sand operation. Sibelco has grown rapidly with over 277 sites in 38 countries and now supplies diverse industrial minerals especially including silica, clays, kaolins, feldspars, olivine and nepheline syenite. Sibelco minerals are essential components for diverse applications including glass, ceramics, foundry, electronics, functional fillers, paints, and plastics. Other specialty applications include flame retardant, proppant sands for natural gas production, technical sand for sport fields and high temperature fillers. Sibelco works in highly populated European countries where the environment is already under permanent pressure so this is a strong motivation for Sibelco’s considerable efforts to respect and sustain the environment. Sibelco’s silica business delivers silica sand and flour in the form of quartz and cristobalite, micronised quartz and surface treated silica, processed in dedicated plants to comply with the strict quality specifications of the customer. Sibelco Europe’s silica businesses include Sibelco NV, Sibelco UK Ltd, Sibelco France SA, Sigrano Nederlands BV, Lieben Minerals BV, Sibelco Italia SpA, Askania A/S, Sibelco Hispania SA and Sibelco Portuguesa Ltd.

10.17 Germany

Quarzwerke Corp is the largest silica sand producer here. They are part owned (~13%) by Sibelco so together they dominate industrial sands. They have expanded into Russia and Eastern Europe in a big way and also are undertaking acquisitions in Vietnam and India (yet to finalise). They are a very professional firm and also part ownership of AKW which is a leader in building sand washing plants worldwide. They have built several new plants in Saudi Arabia recently for glass and frac sands, etc.

Figure 5: Sand mining at Hirschau Germany by Quarzwerke

Figure 6: Washing kaolin from silica sand in trommel drums at Quarzwerke Hirschau plant

Note: Quarzwerke are a part owner of AKW, a leader in sand processing in Europe, Middle East and increasingly in Asia including China where several facilities have been commissioned.

11 SILICA SAND USAGE BY MAIN SECTORS

Market sector	% Global Market in Tonnes	Comments
Glass-includes flat/float/containers & specialty (LED/TFT)	~37%	Growing fast in Asia and diminishing in Western Europe & North America
Foundry	~32%	Automotive foundries in Asia, especially in China driving growth
Frac/proppant sand including resin-coated grades	~15%	Fastest growth sector in USA, and Australia as non-conventional gas expands in importance globally especially in USA, Australia, China (coal-bed methane & shale gas)
Other – sodium silicate soda ash, etc.	~16%	

Source: Industry & Stratum estimates.

12 GLASS MANUFACTURING BASICS

This is the single largest industrial use of industrial silica sands (excluding construction/concrete sands). The key is to have the correct particle size, to ensure no large "stones" get into the glass products and cause fractures/explosions. Also not too much "fines" as these tend to float up into the exhaust stack or fill up the heat retention regenerators with dust.

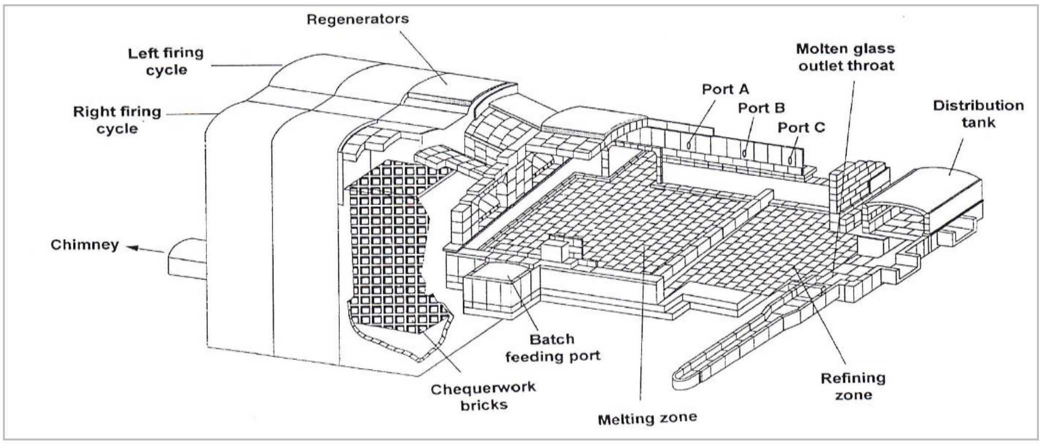


Figure 7: Schematic view of glass furnace

PARTICLE SIZE ANALYSIS							
SAND GRADE	A Optical glass	B Tableware and lead crystal	C Borosilicate glass	D Colourless container glass	E Float glass	F Coloured container glass	G Fibreglass
	%ge	%ge	%ge	%ge	%ge	%ge	%ge
+1 mm		Nil	Nil	Nil	Nil	Nil	
+710µm		0.25 max	0.25 max	0.25 max	0.25 max	0.25 max	
+500µm		5.0 max	5.0 max	5.0 max	5.0 max	5.0 max	Nil
+355µm	Nil						
+250µm	15.0 max						20.0 max
-125µm	5.0 max	5.0 max	13.0 max	5.0 max	5.0 max	5.0 max	
-90µm		Nil	Nil	Nil	Nil	Nil	

Figure 8: Indicative silica sand particle size for various products

12.1 Processing to Remove Impurities

Refractory heavy minerals (RHM) represent the raw material impurity most avoided in most glass compositions. RHM include kyanite–sillimanite–andalusite, zircon, corundum, chrome and other spinels, rutile–leucoxene, and staurolite. These minerals do not melt in most glass compositions at normal glass making temperatures and end up, unmelted, in the finished product as a solid inclusion or stone defect. Specifications for RHM usually relate to particle size and quantity. Particles larger than 0.25 mm are the greatest concern and the quantity may be specified either as a weight percent or on a particle count basis.

12.2 Sizing

Size segregation represents a major processing function. Each glass maker may have slightly different requirements for their gradation, but generally they want raw materials to range from 0.59 to 0.149 mm. After processing to remove impurities and classifying the product to its proper size range, the final step is drying. Glass producers generally want the raw materials to contain less than 0.1% moisture.

CHEMICAL COMPOSITION OF SILICA SAND FOR VARIOUS GLASS QUALITIES							
SAND GRADE	A	B	C	D	E	F	G
	%ge	%ge	%ge	%ge	%ge	%ge	%ge
SiO_2	99.7	99.6	99.8	99.8	99.0	97.0	94.5
Permissible variation		±0.1	±0.1				
Al_2O_2	0.2	0.2	0.2	Nom	0.5	Nom	3.0
Permissible variation		±0.1	±0.1		±0.15	±0.1	±0.5
Fe_2O_3	0.013	0.010	0.010	0.030	0.100	0.250	0.300
Permissible variation		±0.001	±0.001	±0.003	±0.005	±0.03	±0.03
Cr_2O_3	0.00015	0.0002	0.0002	0.0005			
L.O.I.	0.2	0.1	0.1	0.2	0.2	0.5	0.5
Permissible variation				±0.02		±0.1	
Total Alkalis							2.5
Permissible variation							±0.3
Cu max	0.0001						
Ni max	0.0001						

Figure 9: Typical Chemical Composition for different glass types

Property	Colourless (Flint) glass containers	Flat glass (Float, sheet & rolled plate)	Coloured (Amber & green) glass containers
Silica (SiO_2) content	98.5 to 99%		
Iron (Fe_2O_3) content	<0.035%	0.04 - 0.1%	0.25 - 0.3%
Alumina (Al_2O_3) content	0.5% max.	0.03% max.	0.2 – 1.6%.
Limits on:	Alkalis (Na_2O & K_2O), colourants (Ni, Cu, Co) & refractory minerals (chromite, ilmenite, zircon, rutile, corundum etc…)		
Particle-size	0.1 to 0.6mm (100 to 600 microns)		
Particle-shape	Angular quartz grains may aid melting?		

Figure 10: Glass Sand typical Properties.

Compound	Flat Glass	Container Glass
SiO_2	≥99.5%	≥99.5%
Fe_2O_3	≤0.04%	≤0.03%
Al_2O_3	≤0.3%	±0.01%
TiO_2	≤0.1%	≤0.03%
Cr_2O_3	≤2 ppm	≤10 ppm
CO_3O_4	≤2 ppm	
MnO_2	≤20 ppm	
CaO-MgO		±0.1%
ZrO_2		≤0.01%
Na_2O-K_2O		±0.1%
Moisture		≤0.1%

Figure 11: Glass Silica content Typical Grade Chemical

12.3 PHYSICAL CHARACTERISTICS OF SILICA SAND FOR GLASS

The physical specifications deal exclusively with particle size. The grain size of batch materials strongly affects the amount of energy required for melting. Glass makers prefer a near uniform size to the batch ingredients to insure efficient melting; they typically use material whose grains range from 0.59 to 0.149 mm. However, in textile and reinforcing fibre glass more than 90% of the raw material grains are smaller than 0.045 mm (45 µm). There is consideration to tighten these limits from 0.3 to 0.1 mm, especially for sand since it is the most difficult component to melt. Grain shape of the sand also affects melting. Angular grains offer more surface area and faster melting than rounded grains. Likewise, frosted or pitted grains offer an increase in surface area that can enhance melting. Uniform size among all of the ingredients also speeds melting, minimises segregation during the batch handling, and homogenises the melt. If very much of the batch is coarser than the specified range, incomplete melting often occurs, which results in a poor quality product. If very much of the batch is finer, dusting occurs which creates housekeeping problems outside the furnace. Inside the furnace fines can harm the furnace refractories and heat exchangers.

Note- Some high alumina sands such as from Kemerton Silica sands in Western Australia have inherent Al_2O_3 content of say 1-3%. This is useful for some glasses which benefit from requiring smaller amounts of calcined alumina (expensive) added during the batching process. It is important however to ensure the alumina content is consistent in load to load basis. Glassmaking is a major sector which needs consistent, correctly sized and low iron silica sand. Silica sand is the major raw material used in glassmaking, comprising some 70 by volume of raw material but far less than that in value. Glass manufacturers usually classify silica sand into separate groups on the basis of chemical and physical properties. Since the impurities of silica sand in different deposits around the region are dependent on numerous geological factors, glass producers have set specifications to each source of approved material and in general, manufacturers are concerned mostly about the consistency of the approved material on a day-today basis. Minerals such as chromite, picotite, ilmenite, leucoxene, kyanite and zircon are minerals on which strict limits are placed for glass raw material. Because of their refractory nature, such minerals either do not melt or only partially melt which results in stones or feathers in finished glass. These create stress concentration points which lead to potential fracture.

12.4 FLOATING PROCESS

This is an innovative flat glass production process invented by Pilkington of the United Kingdom. Utilising the specific gravity difference between glass and molten tin. As glass is lighter than molten tin, it flows over the molten tin and glass itself is molten in a furnace and the finished glass is pulled out by crimp rollers without any strain after the annealing process. This type of glass can even be used for mirrors as is. These days, this process is used throughout the world. Asia is continuing strong annual gains, due largely to sustained expansion in China. Long-term prospects remain favourable, based on the region's pressing need for adequate new housing, industrial expansion, and rising motor vehicle production. Over the long-term, glass demand is growing at 4% to 5% p.a., significantly above global economic growth rates. Capacity utilisation is expected to remain above 85% over the coming years. Demand growth for glass is driven not only by economic growth, but also by legislation and regulations in response to the growing need for energy conservation. Demand for value-added products is growing more quickly than for basic glass, enriching the product mix and boosting the sales line of the building products industry. Value-added products are also becoming increasingly important in the automotive market, delivering greater functionality to a vehicle's glazing and adding a further growth dimension to automotive glazing sales. A proportion of the high quality float glass, and indeed some of the rolled, is further processed by laminating, toughening, coating and silvering and some of this ends up in the form of insulating glass units or automotive windscreens and sidelights. Glass manufactured in flat sheets (float, sheet and rolled) which may be further processed. On average 1 tonne is approximately 125 m^2. The global market for float/sheet glass (excluding rolled glass) is approximately 30 million tonnes p.a. This is dominated by Europe, China and North America, which together account for over 70% of demand. China is increasing in its global importance as with many other products including steel and cement, all driven by strong economic growth.

12.5 CONTAINER GLASS MANUFACTURING PROCESS

Apart from the flat glass motioned above, the other dominant user of silica sand is glass containers, many of which are bottles. Huge changes in this sector have been occurring during the past decade including the "light-weighting" of bottles, lead by Japan, and the increased use of cullet brought about by new colour sorting equipment, again lead by Japan. A brief summary of the main processes involved in making container glass follows.

12.5.1 Batching Plant

Commercial glass is made by melting predominantly silica sand, soda ash and limestone.

Secondary ingredients (carbon, red iron oxide, chromite, etc., are added to control colour, provide ultra-violet protection and enhance the working properties of the molten glass. As much as possible cullet is included in the batch. Many glass container plants in the region now include the latest computerised control technology. Raw materials are stored in silos from which they are automatically weighed out from computerised control rooms and transported to batch mixers according to pre-programmed recipes. The mixed material (or batch) is then transported to the holding bin at the furnace.

12.5.2 Melting

From the holding bin, the batch is continuously fed to the furnace where it is converted to molten glass and maintained at temperatures up to 1500ºC. Molten glass is continuously withdrawn through a submerged throat where it proceeds to the refiner area of the furnace and cooled to approximately 1200ºC, before being delivered to the individual bottle-making machines via the forehearths. The furnaces are fully computerised and critical parameters are controlled to very close tolerances. Most glass plants in the region are now some of the most modern in the world with a productive life span (known as a campaign) of +10 years whilst, at the same time, allowing finer temperature control resulting in improved productivity and quality, with a productive life span (known as a campaign) of +10 years whilst, at the same time, allowing finer temperature control resulting in improved productivity and quality.

12.5.3 Forming

The molten glass enters the feeder to the bottle-making machine where the streams of glass are cut into pieces of a pre-determined weight, called gobs, each required to make a single bottle. The gobs of molten glass are then individually fed into the moulds of the bottle-making machine. The bottle is formed in two stages. Firstly, the gob of glass falls into a blank mould to produce a parison. Here the finish (neck) of the bottle is formed and a long narrow cavity is blown within the centre of the parison. All blowing is done by means of compressed air. The parison is transferred to the main mould where the bottle is given its final shape. Air is forced under pressure into the hollow cavity to expand the glass to its final shape inside the mould. The newly formed bottle is coated with a thin layer of tin oxide to strengthen it before entering the annealing lehr. In the lehr, the bottle is cooled from 560°C to 100°C in a controlled manner to remove the stresses caused by uneven cooling and to ensure the bottle is stable and safe to handle.

Modern treatments to the formed containers include:

- **Hot end coating -** Tin oxide added for scuff resistance and prepares the glass surface for coldend coating.
- **Freon application -** For bloom prevention.
- **Lehr furnace -** An annealing process reducing temperature in a controlled manner from 560°C to 120°C. This gradual cooling down remove stresses and makes a strong product.
- **Cold end spray -** Involves a polyethylene wax between the rows providing lubricity for ware handling of container.
- **Palletising -** Automatic packaging of glass at high speeds Automatic empty pallet and full pallet delivery via shuttle car. Plastic shrouding of pallets for storage and transportation of glass to the customers.

13 FLOAT GLASS PRODUCTION PROCESSES

13.1 COLBURN PROCESS

Nihon Sheet Glass Co. used to produce sheet glasses by means of Colburn process since sheet glass can be pulled out horizontally which allows having a longer gradual cooling span for producing soft and sticky glass sheets.

13.2 FOURCOURT PROCESS

Asahi Glass Co. used to produce sheet glasses by this process. Since it pulls out the sheet glass vertically in a tall building, but the cooling process span is short and sheet glass becomes very solid and fragile. Its advantage over the other processes is to be capable of providing a plural number of glass pulling-out gates from a melting chamber. Although these two processes enabled to produce flat surface sheet glasses in certain extent, buffing processes were necessary for mirrors. Still some of foreign manufacturers are using these processes.

13.3 FLOATING PROCESS

It is an innovative flat glass production process invented by Pilkington of the U.K. Utilising the specific gravity difference between glass and molten tin as glass is lighter than molten tin, glass flows over the molten tin and glass itself is molten by a burner and the finished glass can be pulled out without any strain which can be used for mirror as is. In these days, this process is used throughout the world.

13.4 OTHER MANUFACTURING PROCESSES OF SPECIAL TYPE GLASSES

13.4.1 The Fusion Process

The fusion, if translated into Japanese, is to indicate something molten, but this process enables to produce sheet glass by not touching impurities contained in the material of a melting chamber. Therefore the products are maintained at very high physical reliability. Its major usage is for liquid crystal displays. Especially, it is most suitable for colour liquid crystal displays (Colour LCD). In 1991, Corning Glass Works of the United States began to sell its products in Japan and is covering majority of market demands. The Nippon Sheet Glass Co. has been in development with Hoya Glass Co. and are supplying prototypes named Corning 7059NH.

13.4.2 Down Draw Process

This process is good for volume production of thin glasses. Asahi Glass Co. is well known as a supplier of a 0.05 mm thick glass used for the cover of solar battery. We are supplying a 0.2 mm thick cover glass for touch panel which is also produced by this process. Manufacturers who can supply this type of glasses are Corning Glass Works of the United States, DESAG, a division of Shott of Germany and Asahi Glass Co. of Japan. This type of glass is used for medical inspection, cover glass of microscope and touch panel for the displays.

13.4.3 Re-draw Process

This process is a secondary processing rather than a production process. The Down Load process referred to in the above requires highly advanced techniques as well as sophisticated facilities; therefore, this process features to pull out horizontally thicker glasses of 1.0 mm to 2.0 mm by giving heat. Nippon Electric Glass Company's continuous re-draw process is one of the most sophisticated production facilities in Japan. It is capable of producing 0.1, 0.2, 03 mm thick glass sheets, etc. Use of such thin glass sheets are for Liquid Crystal Displays and Touch Panels. Engineers in the field of electronics components are really interested in these glasses for more use Silica is the most important oxide and constitutes the most tonnage of all the glass making raw materials. Glassmakers depend on a relatively small number of sources. Silica is abundant but glass grade material is relatively scarce. Optical and specialty glasses require even more pure materials that are scarcer. Quartz sand supplies most of the silica to the glass batch. Glass grade sand deposits occur throughout Asia-Pacific with Australia, Vietnam, Malaysia and Indonesia perhaps the largest producing countries. Thailand has good glass sand reserves but the location is adjacent to tourist areas in Rayong and new resources will be needed in the foreseeable future. Cambodia and Vietnam have the closest resources but Australia is another likely source.

13.4.4 TFT-LCD Glass

All of the world's top-four glass-substrate makers have set up production plants in Taiwan to cash in on the booming thin film transistor-liquid crystal display (TFT-LCD) panel manufacturing business.

Foundry Sand Basics

Property	Range
Silica (SiO_2) content	98% minimum
Limits on:	CaO and MgO (to reduce the acid demand value & minimise binder demand)
Particle-size	Range from 0.1 to 0.5mm (100 to 500 microns).
Particle-size distribution	Narrow size distribution (improves permeability)
Grain Fineness	AFS (American Foundrymen's Society) index indicates average grain size. Ranges from 45 to 90 AFS (higher = finer) e.g. 50-60 AFS = 250-220 microns
Particle-shape	Rounded to sub-angular grains with reasonable sphericity are preferred (reduces binder demand, and improves compaction and mould strength)

Figure 12: Typical foundry sand properties

Foundry sand is essential and economical as it can be recycled many times. It is used with several different binder technologies. The traditional binder in bentonite (active is montmorillonite) a natural clay. Also, hot-box resins (thermosetting phenol formaldehyde resin), are also widely used. Both have specific properties but the key is to have clean silica sand with minimal fines so as the resin-demand is not excessive keeping costs to a minimum. Automotive industry uses both of these technologies and drives the larger volume buyers.

Figure 13: Range of Products made from Silica sand & Quartz

14 Silica Sand Pricing Guide

Most silica sand of standard glass grade and foundry grades are surprisingly similar. Like all commodities there is an envelope of pricing and the following chart addresses this matter.

Table 7: Pricing guidelines

Application	Delivery	Indication ex Works per Tonne in Bulk
Container glass (<4% moisture)	Bulk truck or rail	$US 24-29
Float (window) glass (<4% moisture)	Bulk truck or rail	$US 24-29
Foundry sand coarse (AFS 45) dried	Bulk truck	$US 48-52
Foundry sand medium (AFS 50) dried	Bulk truck	$US 50-56
Foundry sand fine (AFS 65) dried	Bulk truck	$US 65-68
Note 1: Fine sand for foundry is getting more difficult to find sources. Increasing in price. Note 2: Foundry sand is always more expensive than glass sand as it needs to be dried.		

Source: Melbourne & Sydney industry suppliers.

15 Profiles of Selected Major Silica Sand Producers

15.1 Mitsubishi – Owns and operates Cape Flattery Sand, Queensland

Cape Flattery Silica Mines, a wholly owned subsidiary of Mitsubishi Corporation, is the leading producer of world class silica sand for the glass, foundry and chemical industries. Founded in 1967, the mine was purchased by Mitsubishi in 1977 and in 1987 a deep water jetty was brought into operation. Cape Flattery Silica Mines employs over 100 people. It should be noted that Sibelco Corp has attempted on two occasions to purchase this operation from Mitsubishi but were repelled both times.

The Cape Flattery Mine Site on Cape York covers a lease of around 6500 hectares and has an estimated resource of over 500 million tonnes of silica sand. Cape Flattery Silica Mines is the largest global exporter of silica sand and has the highest production of silica sand for any mine in the world. It is useful to use Cape Flattery of world benchmark example of how silica mines in Australia could be established such as Mourilyan sand resource although the deposit there contains around 10 million tonnes rather than hundreds of millions of tonnes and also it is not actually next to a purpose-made wharf but some 15 km from one, provided a bridge is constructed to handle haul trucks.

Table 8: Cape Flattery Silica Sand Standard Quality

1. Chemical Analysis	Standard Quality	Comment
SiO_2	99.90%	Important factor
Fe_2O_3	0.020%	Lower is better for glass
Al_2O_3	0.07%	Less critical
TiO_2	0.02%	Somewhat critical
CaO	0.003%`	Remains of shells

2. Size	Distribution	Standard Quality
Mesh	**µm**	**Weight (%)**
(10 + 14)	(-1,700/1,180)	0.00
(14 + 20)	(-1,180/+850)	0.00
(20 + 28)	(-850/+600)	0.07
(28 + 35)	(-600/+425)	2.29
(35 + 48)	(-425/+300)	17.52
(48 + 65)	(-300/+212)	32.49
(65 + 100)	(-212/+150)	38.73
(100 + 150)	(-150/+106)	8.52
(150 + 200)	(-106/+75)	0.30
(200 + 270)	(-75/+53)	0.05
(-270)	(-53)	0.03
		AFS 60.20

Source: Company literature.

15.2 Cape Flattery Mining Operations

Mining cannot commence until surveys are done involving drilling of dunes, flora and fauna surveys completed, approval from the traditional owners and an environmental license obtained from the government. The vegetation and a 300 mm layer of topsoil is taken first for seed removal to assist in regeneration. Silica sand is then removed by front end loader and transported for washing by either conveyor belt or slurry line. Impurities, rocks and vegetation are removed by an extensive washing and filtering process before the graded sand can then be sent to the wharf for loading and export.

Mountains of silica sand stretch out like snow-covered peaks across Cape Flattery, lying approximately 250 km north of Cairns, in Northern Australia. Operated by Mitsubishi Corp. Silica sand is the primary raw material used in making glass products.

Figure 14: Cape Flattery port storage for bulk ship loading

Japan-bound silica sand exports from the Site through MC began in 1968. Cape Flattery Silica Mines Pty., Ltd., established in 1977 as a wholly-owned subsidiary of MC, stably supplies superior quality silica sand under an integrated system that includes mining operations such as extraction and refining, shipping and distribution.

In the late 1980s, Mitsubishi constructed on the shoreline a large-scale dock, accommodating a large-scale refinery plant and ships of up to 70,000 tonnes and loading some 20,000 tonnes of silica sand per day. Currently, about 2 million tonnes of silica sand annually is shipped from the Site to Japan as well as South Korea, Taiwan, the Philippines and other countries in Asia.

The wharf is situated on the southern point of the Cape Flattery headland and runs out to sea for some 500 m in a SSE direction, 250 m of trestle approach and 250 m of operation deck. The wharf is laid at 12.5 degrees into the prevailing SE wind. The normal set of the drift is below half a knot towards the NE. Hence the prevailing wind will push a vessel positioned parallel with the structure against the wharf while the drift tries to hold it off. The operation deck is 220 m long and has a minimum depth of 15 m of water. The minimum air draft of the traversing ship is 14 m. There are 5 breasting dolphins and 3 mooring dolphins. There are a total of 17 quick release hooks. Port pilots are used for all berthing. The anchorage and pilot boarding station is in the bay at the North of Cape Flattery headland.

15.3 TOCHU CORPORATION

TOCHU owns and operates two high quality silica sand mines in Australia. These mines are producing high quality sand by the advanced process plants. ALBANY SILICA SAND is produced by AUSTSAND MINING in Western Australia. This sand has round shape and wide range of size distribution. This sand is the best sand not only for foundry casting industry but also for high quality glass products because of its high silica content and extremely low impurities contents such as iron content.

Kemerton Silica Sand Pty Ltd in Western Australia. This sand contains both Al_2O_3 and K_2O and is the best sand especially for Sheet glass.

16 SILICA SAND PRODUCTS

The silica sand produced by Kemerton Silica Sand is used predominately by manufacturers of glass containers, computer monitors and TV screens.

Silica Sand is also used for the following:

- Glass containers i.e. jars, wine bottles, beer bottles, etc.
- Plasma display
- Computer screens
- Cathode ray tubes
- Sheet glass i.e. windows
- Unique flat glass i.e. coloured sheet glass
- Foundry sand
- Synthetic turf, top dressing sports ground, top dressing playing surfaces
- Chemical manufacture
- An abrasive in the manufacture of silicon carbide
- Ceramics and ceramic glazes
- Fused silica in optical laboratory instrument glassware
- Cement manufacture
- Water filtration medium
- As a proponent to increase the permeability or oil and gas bearing rock formations.

To meet wide range of customers' requirements, TOCHU is now supplying such high quality sands from Southern hemisphere. There is still abundant undeveloped sand resources left in Australia and South East Asian countries. TOCHU established subsidiary companies in Australia. Through those subsidiaries, TOCHU has developed silica sand mines in Australia and is importing various types of high quality sand from both own mines and contracted mines to Japan. These imported sands are processed further at our plants and are supplied to end users in accordance with their requirements and needs.

Domestic sand supplied by TOCHU is mainly mined at Yunotsu mine in Shimane Prefecture. Both quality and production volume of this sand are the top class level in Japan. This sand is suitable sand for Glass industry requiring high quality products as well as Cast industry.

Table 9: Summary of possible silica sand/flour markets

Industrial Sector	Estimated tonnes per year	Typical Pricing US$ per tonne, packing	Comments
Fibreglass	100,000	$110 delivery by tanker or bulker bags	Largest markets are in Taiwan & China, much for PC components such as motherboards. Possibly insulation fibreglass manufacturers such as at Ingleburn, Sydney, but some can use sand and grind in-house rather than buying in silica flour. The reinforcing fibre-glass plant in Dandenong two years ago. They used ~5,000 TPA.
Ceramics Frit & Glaze	2,000	$90-140	Buyers could include Caroma, Ferro, Austral Brick, etc.
Paint	< 500	$150-200	Larger paint companies include Dulux, Ameron Coatings, Taubmans and Wattyl. Switching to silica-free products such as Minex 5 & 7, which is micronised nepheline syenite. Needs to be white.
Oil & Gas Drilling	24,000	$75-118	Used as component for cementing in deeper “hotter” drill holes. Mixed with cement and other additives.

Table 10: Selected Australian Producers of Silica Sand

Indicative Chemical analyses of selected, important silica deposits throughout Australia (Interim)									
		%							
Deposit Location	**Type**	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**Na_2O**	**Cr_2O_3**	**TiO_2**
Cape Flattery	Sand	99.70	0.02	0.25	0.012	<0.002	0.002	0.024	n/a
		99.60	0.002	0.35	0.018	<0.002	0.002	0.02	n/a
Nth. Stradbroke Island	Sand	99.94	0.024	0.008	<0.01	<0.01	<0.01	0.0001	0.031
Port Stephens Central NSW	Sand	96.51	1.27	0.81	n/a	n/a	n/a	0.05	0.10
	Sand	96.77	1.22	0.75	n/a	n/a	n/a	0.02	0.08
Botany Bay Sydney NSW	Sand	97.22	1.75	0.40	0.30	0.18	n/a	n/a	n/a
Lang Lang, Victoria	Sand	96.91	0.66	1.36	0.12	0.27	n/a	n/a	n/a
Cranbourne, Victoria	Sand	96.09	2.15	0.49	0.10	0.38	n/a	n/a	n/a
Kemerton, Bunbury, W.A.	Sand	97.37	1.34	0.48	0.12	0.11	n/a	n/a	n/a
Perth, W.A.	Sand	99.65	0.01	0.02	0.10	0.20	n/a	n/a	0.03
Tasmania	Sand	98.80	0.17	0.20	0.04	0.03	n/a	n/a	0.37
	Natural silica flour	98.76	0.17	0.20	0.04	0.03	n/a	n/a	0.37
Mount Compass, Sth Australia	Sand	96.1	1.83	0.78	n/a	n/a	n/a	n/a	n/a

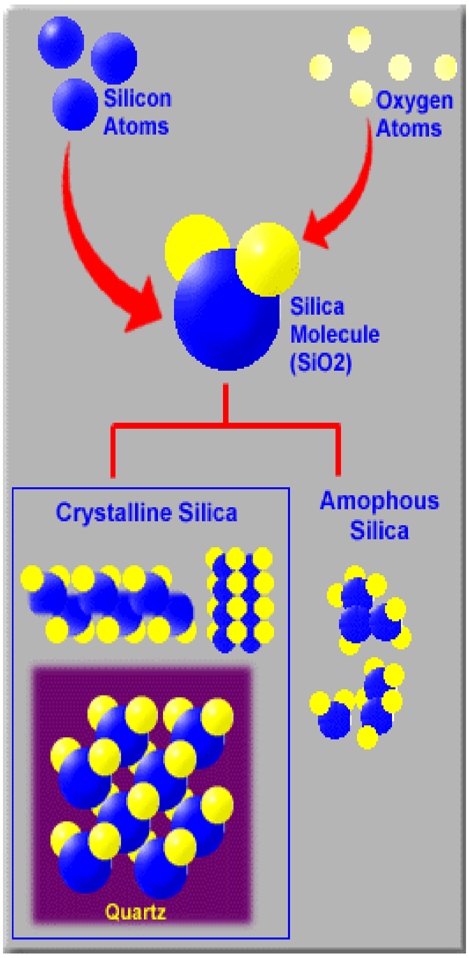
The Basics on Silica

Silica is a mineral compound made up of one silicon atom and two oxygen atoms.

Oxygen is the most abundant element in the earth's crust. Silicon is the second most abundant. Due to such abundance, the formation of the compound silica in nature is very common.

There are other compounds that contain silicon whose names are quite similar, such as silicate and silicone. Do not mistake these for silica. They are not the same thing.

If the individual silica molecules are lined up in order and create a repeatable pattern then the silica is in crystal form. This is "crystalline" silica. There can be more than one repeatable pattern in silica. The various crystal patterns are given their own name. There are quartz, cristobalite, tridymite, and other rare forms of crystalline silica. Quartz is so common that the term quartz is often used to refer to crystalline silica. And sand is often used to refer to quartz.

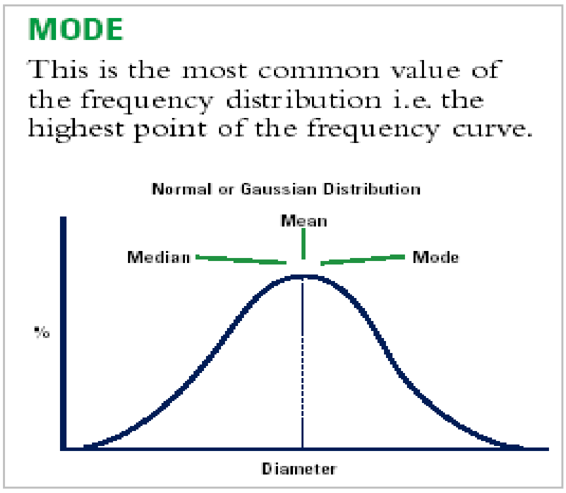


Crystalline silica is the name of a group of minerals composed of silicon and oxygen. The term crystalline refers to the fact that the silicon and oxygen atoms are arranged in a three-dimensional repeating pattern. The main minerals included in this group are: quartz, cristobalite and tridymite. Quartz is the most common of them and, after feldspar, is the second most abundant mineral on the Earth's surface. Crystalline silica, basically in the form of quartz, has been mined for thousands of years. It is really one of the building blocks of ancient and current civilisations, being also vital for modern technologies. Main applications include glass production, foundry, ceramics, building materials, etc. Crystalline silica has also acquired a fundamental place in the emerging information society, as the source of silicon.

16.1 INTRODUCTION

Silica is the name given to a group of minerals composed of silicon and oxygen, the two most abundant elements in the earth's crust. Silica is found commonly in the crystalline state and rarely in an amorphous state. It is composed of one atom of silicon and two atoms of oxygen resulting in the chemical formula SiO_2.

The first industrial uses of crystalline silica were probably related to metallurgical and glass making activities in three to five thousand years BC. It has continued to support human progress throughout history, being a key raw material in the industrial development of the world especially in the glass, foundry and ceramics industries. Silica contributes to today's information technology revolution being used in the plastics of computer mouses and providing the raw material for silicon chips.



16.2 Geology and Occurrence of Industrial Silica

Silica exists in nine different crystalline forms or polymorphs with the three main forms being quartz, which is by far the most common, tridymite and cristobalite. It also occurs in a number of cryptocrystalline forms. Fibrous forms have the general name chalcedony and include semi-precious stone versions such as agate, onyx and carnelian. Granular varieties include jasper and flint. There are also anhydrous forms - diatomite and opal.

Quartz is the second most common mineral in the earth's crust. It is found in all three of the earth's rock types - igneous, metamorphic and sedimentary. It is particularly prevalent in sedimentary rocks since it is extremely resistant to physical and chemical breakdown by the weathering process. Since it is so abundant, quartz is present in nearly all mining operations. It is present in the host rock, in the ore being mined, as well as in the soil and surface materials above the bedrock, which are called the overburden.

Most of the products sold for industrial use are termed silica sand. The word "sand" denotes a material whose grain size distribution falls within the range 0.06-2.00 mm. The silica in the sand will normally be in the crystalline form of quartz. For industrial use, pure deposits of silica capable of yielding products of at least 95% SiO_2 are required. Often much higher purity values are needed. Silica sand may be produced from sandstones, quartzite and loosely cemented or unconsolidated sand deposits. High-grade silica is normally found in unconsolidated deposits below thin layers of overburden. It is also found as "veins" of quartz within other rocks and these veins can be many metres thick. On occasions, extremely high purity quartz in lump form is required and this is produced from quartzite rock. Silica is usually exploited by quarrying and it is rare for it to be extracted by underground mining.

16.3 Physical and Chemical Properties

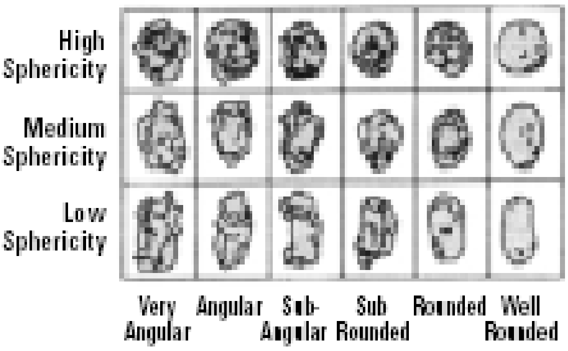
The three major forms of crystalline silica - quartz, tridymite and cristobalite - are stable at different temperatures and have subdivisions. For instance, geologists distinguish between alpha and beta quartz. When low temperature alpha quartz is heated at atmospheric pressure it changes to beta quartz at 573°C. At 870°C tridymite is formed and cristobalite is formed at 1470^{o}C. The melting point of silica is 1610^{o}C, which is higher than iron, copper and aluminium, and is one reason why it is used to produce moulds and cores for the production of metal castings.

Quartz is usually colourless or white but is frequently coloured by impurities, such as iron, and may then be any colour. Quartz may be transparent to translucent, hence its use in glassmaking, and have a vitreous lustre.

Quartz is a hard mineral owing to the strength of the bonds between the atoms and it will scratch glass. It is also relatively inert and does not react with dilute acid. These are prized qualities in various industrial uses.

Depending on how the silica deposit was formed, quartz grains may be sharp and angular, sub-angular, sub-rounded or rounded. Foundry and filtration applications require sub-rounded or rounded grains for best performance. Various roundness of grains is indicated below.

16.4 VARIOUS PARTICLE SHAPES OF SILICA PARTICLES



Index Minerals Ltd, in Tasmania, produces a wide range of high quality Silica Flours for:

- Optical Glass
- Fibreglass
- Cleansers
- Tableware Glass
- Quality Crystal & Decorative Glass
- Ceramic Glazing
- Abrasives
- Grouts & Tiles
- Refractories
- Computer Components
- Monitor Screens.

Index Mineral Processors provide a wide range of high quality Silica Flours and Sands suitable for: Index was a JV between local Brisbane company (machinery suppliers) and Sumitomo.

Tasmanian Advanced Minerals Sumitomo Corp. have recently (2 years) opened a sole-owned facility next door at Corinna, Tasmania

16.5 NATURALLY OCCURRING FINE SILICA

Figure 18: Silica stockpile at Corinna

Silica is mined and exported for use in the manufacture of liquid crystal glass substrate.

The silica is produced by Tasmanian Advanced Minerals, a company owned by Sumitomo Corporation, Sumitomo Australia, KCM Corporation and local company Cominex. TAM's product is a high purity silica that is required for making high tech glass applications such as high-end LCD displays.

• Optical Glass • Fiberglass • Cleansers and Abrasives • Quality Crystal & Decorative Glass • Ceramic Glazing • Dental Industry • Grouts & Tiles • Refractories • Computer Components • LCD/TFT Monitors • High Definition T.V. Screens.

Silica sand is an industrial term used for sand or easily disaggregated sandstone with a very high percentage of quartz (silica) grains. Natural silica (silicon dioxide-SiO_2) stone, quartz (lumps) is a simple compound of the elements silicon and oxygen. It is the most abundant mineral on the earth and is also one of the most important minerals on the earth. Industrial uses of silica depend on purity and physical characteristics. Some of the applications are: electronics, glass, paint fillers, asphaltic concrete and general construction, water filtration, sand blasting, fillers for plastic and tire industries, refractory for glass and steel industries, epoxy grouting and foundry moulding sand, etc.

Table 11: Corinna, Tasmania product range typical analysis is listed below

Index	U.S.	Percentage							
Grade	**Mesh**	**SiO_2**	**Fe_2O_3**	**TiO_2**	**Al_2O_3**	**CaO**	**MgO**	**Na_2O**	**Cr**
Coarse	60	99.9	0.0020	0.004	0.010	0.0400	0.0200	0.0005	0.0002
Fines	200	99.8	0.0035	0.004	0.010	0.0400	0.0200	0.0005	0.0003

Silica sand is an industrial term used for sand or easily disaggregated sandstone with a very high percentage of quartz (silica) grains. Natural silica (silicon dioxide-SiO_2) stone, quartz (lumps) is a simple compound of the elements silicon and oxygen. It is the most abundant mineral on the earth and is also one of the most important minerals on the earth. Industrial uses of silica depend on purity and physical characteristics. Some of the applications are:

electronics, glass, paint fillers, asphaltic concrete and general construction, water filtration, sand blasting, fillers for plastic and tire industries, refractory for glass and steel industries, epoxy grouting and foundry moulding sand, etc.

All IMP Silica products are available in bulk or in one tonne bulk bags. Alternative packaging in smaller multi-ply paper sacks is also available on request.

Large high-grade silica reserves in Tasmania had already produced some of the best silica flour in the world. Pro-active quality assurance procedures were introduced to guarantee the consistency of material produced. Perhaps the most effective of these was the introduction of more thorough assaying of raw material before its delivery to the plant. This allowed production staff to blend raw materials to ensure the plant never produced product of lesser quality than dictated by our tight specifications.

16.6 PROCESSING TECHNOLOGIES

Silica deposits are normally exploited by quarrying and the material extracted may undergo considerable processing before sale. The objectives of processing are to clean the quartz grains and increase the percentage of silica present, to produce the optimum size distribution of product depending upon end use and to reduce the amount of impurities, especially iron and chromium, which colour glass.

Cleaning the quartz grains and increasing silica content is achieved by washing to remove clay minerals and scrubbing by attrition between particles. Production of the optimum size distribution is achieved by screening to remove unwanted coarse particles and classification in an upward current of water to remove unwanted fine material. Quartz grains are often iron stained and the staining may be removed or reduced by chemical reaction involving sulphuric acid at different temperatures. Impurities present as separate mineral particles may be removed by various processes including gravity separation, froth flotation and magnetic separation. For the highest purity, for electronics applications, extra cleaning with aggressive acids such as hydrofluoric acid combined with thermal shock may be necessary.

After processing, the sand may be dried and some applications require it to be ground in ball mills to produce a very fine material, called silica flour. Also, quartz may be converted to cristobalite in a rotary kiln at high temperature, with the assistance of a catalyst. Some specialist applications require the quartz to be melted in electric arc furnaces followed by cooling and grinding to produce fused silica.

Silica has played a continuous part in man’s development and been one of the basic raw materials supporting the industrial revolution (as refractory, flux, and moulding sand) and today’s information technology revolution (providing the raw material for silicon chips).

Industrial silica is used in a vast array of industries, the main ones being the glass, foundries, construction, ceramics, and the chemical industry.

Silica in its finest form is also used as functional filler for paints, plastics, rubber, and silica sand is used in water filtration and agriculture.

Other examples of everyday uses include the construction and maintenance of an extensive range of sports and leisure facilities.

Crystalline silica is also irreplaceable in a series of high-tech applications, for example in optical data transmission fibres and precision casting. It is also used in the metallurgical industry as the raw material for silicon metal and ferrosilicon production. Another specialised application is in the oil production.

Altogether there are several hundreds of applications of industrial silica in our daily life. Silica products have become so obvious to us that we don’t even know they are being applied. Reading this page, you will be surprised to find out how many times per day you see, touch and use products containing crystalline silica.

17 Queensland Silica sand Project derailed by Native title and Environmental issues

Pacific Silica Pty Ltd Australia is expected to generate a steady stream of earnings and expand in scope of businesses in distributing technical products. Using the latest cost effective mining techniques, Pacific Silica completed a major plant expansion project in November 1998 which increased its mining capacity by three-fold to 600,000 tonnes of silica sand per annum.

17.1 Prime Location and Large Reserves

Situated north of Brisbane, Australia and spreading over 2,437 acres of freehold land, the Pacific Silica’s mining operation contains the largest approved reserve of fine to medium silica sand in southeast Queensland. An independent geological survey certified that the sites contain substantial reserves of multi-grade high quality silica sand suitable for a wide range of industrial applications. Recoverable reserves totalling 25 million tonnes have been identified so far. The location of the site is ideal. It is north of Brisbane and in one of the fastest growing regions in Australia.

17.2 Product Diversity and Strong Demand

Pacific Silica produces high quality, processed sands; both wet and dry, for commercial and industrial uses. Markets for the silica products are both domestic and regional. The well-graded sand is suitable for a number of applications including technical, manufacturing, metalwork, foundry, glass, horticulture, construction, filtration, golf courses and oil frac industries. Value adding can also be done to the sand by downstream processing into products such as resin coated sand and silicon carbide.

17.3 Beachmere or Ningi Sands (silica sand) - Southern Pacific Sands Pty Ltd

The Ningi silica sand-mine operation, located about 50 km north of Brisbane, produces a range of quality silica sands for the construction, foundry, filtration, glass manufacture, golf course, sports ovals and specialty sands industries. The company’s website reports that reserves are still in excess of 15 m. The silica-sand deposits are a mixture of fine bay sands and coarse river sands, allowing the company to provide a wide range of silica-sand particle sizes for specific clients.

17.4 HIGH TECH APPLICATIONS

The silica sand is also suitable for such specialty uses as silica flour. The silica flours are of a very high quality, with an estimated 99.8% silicon dioxide content. Silica flour is one of the essential materials for a wide scope of manufacturing and technological applications, in particular, the production of high quality optical lenses, solar panels and calcium silicate boards. Fused silica is used in electronic and refractory industries due to its high purity, high resistance to thermal shock and low thermal conductivity. The market for fused silica is increasing particularly with the continued growth in the electronics industry where it is used as inert, low expansion filler for epoxy resins. Chips and micro-circuits are packaged in a blend of fused silica and epoxy for protection. Silica sand is sold domestically and overseas.

Table 12: Summary of possible silica sand/flour markets in Australia

Industrial Sector	Estimated tonnes per year	Typical pricing $ per tonne, packing
Fibreglass	3,000	$110 delivery by tanker or bulker bags
Ceramics	2,000	$90-140
Paint	< 500	$150-200
Construction products, flooring systems etc	20,000	$80-120
Oil & gas Drilling	2,000	~$80-120 FIS
Brickie sand	10,000-15,000	~$30 usually picked up by buyers
Filter Sand	20,000	$160-200 in bulker bags or 25 kg paper sacks
Sand blasting media	2,000	$60-70 in 25 kg paper sacks or woven PP bags. Maybe some bulk customers.

Table 13: Identified Silica Flour Markets in Asia

Producers / Sand Source	Location	Estimated sales into Asia	Main product sizings	Comments
Baolin Taiwan Sibelco/Sani Mining (JV) Cape Flattery, Queensland (Mitsubishi)	Taichung Port, Taiwan	150,000	200 #, 325#	Sand cost ~ $US26 to port, unloading & local delivery extra $20. Selling price is ~$US 124/t FIS tanker delivery.
Sibelco/Lautan Laus JV Belitung Island	Jakarta, Indonesia	18-25,000	200#, 325#	Commissioned in 2000

Producers / Sand Source	Location	Estimated sales into Asia	Main product sizings	Comments
Sibelco Asia Malaysia Bintulu East Malaysia	Jahore Bahru (opposite Singapore)	3,500 only adjunct to feldspar to fill the mill.	100#, 200#, 325#	Buying dried sand in bulk bags with 1,000 barge freight at around $US 75 plus milling charge of $35 then freight (plus profit) makes it unattractive to most potential users. Plan to install drier to enable purchase of wet sand.
Syarikat Sebangun Sendirrian Bhd.	Bintulu (Sarawak) East Malaysia	10,000-20,000 (uncertain) Sand capacity 400 kt/yr.	200#, 300# (probable)	Awkward location far from most industry. Large supplier to Japanese &Taiwanese glass industry. Competitor to Cape Flattery (Mitsubishi) sand from Queensland.
L & T Minerals From old tin mine tailings	Malaysia	4,000	200#, 325#	Smaller player but strong diversified company with a “tin mining” background.
SIMPCOR (Division of Saniwares) Siruma, Camarines Sur, near Naga City	Philippines	6,000	100#, 200#, 300#	Naturally very fine and white firing silica flour, dug by hand, bagged and shipped in 40 tonne lots
Sibelco Stradbroke Island (Queensland) & , Lang Lang (Victoria)	Australia	2-3,000+/-	200#, 300#	Problem with competing on price against local producers.
Sibelco Lang Lang pit & mill, Victoria	Australia	1,000 Another 6,000 in Aust.	200#, 300# (75 microns, 53 microns)	Costs make export of this difficult, but lower $A may help, however customers currently in slow-down.

Source: Industry estimates

Sibelco Asia also has two quartzite/sand ventures underway in China and is likely to become the main supplier to the region in time with modern mills being the key factor. Also can supply cristobalite and special silicas from Europe.

17.5 S.C.R. - SIBELCO

Website: http://www.sibelco.be

S.C.R.-SIBELCO was founded in 1872 as a local Belgian silica sand operating company. It has been growing constantly into the present industrial minerals group, still producing basically silica sand and flour but also a series of other advanced minerals such as clays, kaolin, bentonite, feldspar, nepheline syenite, olivine, etc., at over 225 production sites worldwide.

The Belgian operation employs 300 people at 3 industrial sites producing 4 million tonnes of silica products.

Working in a country with a dense population and nature under permanent pressure is an extra motivation for Sibelco's considerable efforts to operate in a spirit of respect for the environment.

Main markets: glass, fibreglass, electronics, foundries, ceramics, coatings, plastics, fillers, polymers, silicon, decorative plasters, abrasives, etc.

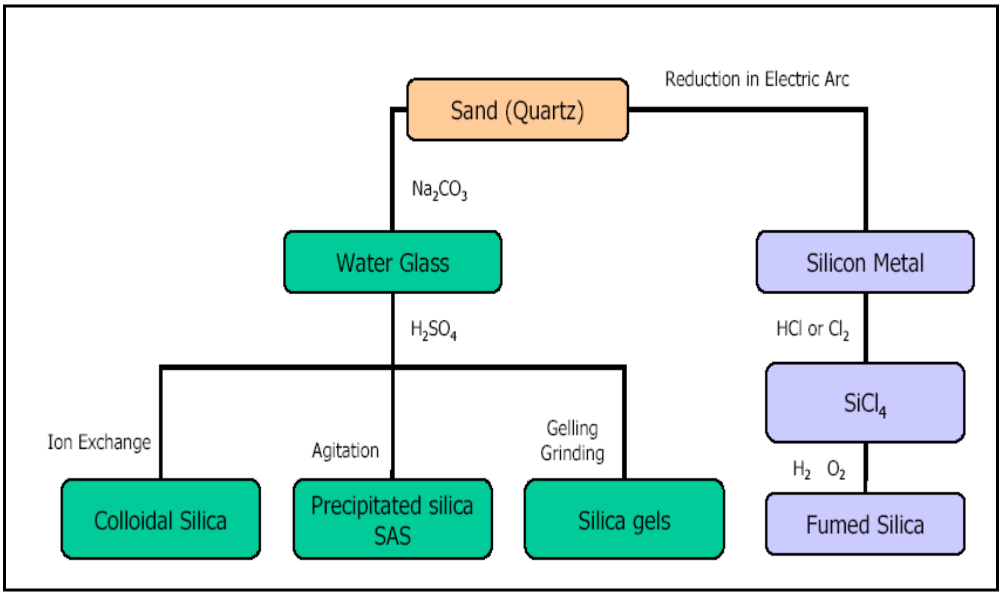


Figure 19: Simplified flowsheet of adding value to Silica and Quartz materials

End-use industry	Application	Major function
Rubber	**Footwear** **Tires** **Industrial rubber**	**Reinforcement** **Abrasion and cut resistance** **Low rolling resistance** **Enhanced resin and textile adhesion**
Paper	Printing/Writing paper Ink-jet papers Thermal papers	Improved strike-through resistance Rapid ink retention
Food and healthcare	Dentifrice Dried foodstuffs Cosmetics	Abrasive and thickener Free-flow and anti-caking Fragrance carrier
Plastics	Film Battery separators	Anti-blocking Microporous additive
Paint and coatings	Range of inks and paints	Matting agent Suspension and viscosity control Titanium dioxide extender

Figure 21: Precipitated Silicas Major Applications

Table 14: Summary of Specialty Silica Production by Type and Region in tonnes

Region	Precipitated Silica	Silica Gel	Fumed Silica	Colloidal Silica	Total
Asia-Pacific-a	550,000	120,000	65,000	100,000	835,000
North America	204,620	44,040	35,085	29,535	313,280
Western Europe	223,430	15,190	38,675	14,565	291,860
Latin America-b	27,840	11,030	2,090	265	41,225
Eastern Europe	10,505	1,685	1,050	215	13,455
Nth Africa/ Mid East	12,680	-	-	-	12,680
Total	1,029,075	191,945	141,900	144,580	1,507,500

Source: Industry Estimates

17.6 Form of Specialty Silicas

17.7 Selected Buyers of Fine Silica Products by Asian Country

Rubber is the most important sector using precipitated silica, which consumed an estimated 550,000 tonnes of precipitated silica in 2010 in Asia (mainly China). The silica is primarily used as a reinforcing agent for rubber used to manufacture footwear, tires, belting, rice de-husking rollers, and other industrial goods. Footwear is the major application in the region and represents around 63% of the total tonnes of precipitated silica used in rubber goods production. Green tyres is a fast rising sector with partial replacement of carbon black using precipitated silica. China has numerous companies manufacturing this material and growth is around 5% / year.

Its effectiveness results from its fine particle size and relatively large surface area. Additional benefits include its high tear strength, tensile strength, dimensional stability, and abrasion resistance. In hose compounds, precipitated silica provides hot–tear resistance and controls elongation. In seal and gasket materials, it is used to modify the aging and relaxation properties of the rubber resins used under conditions of high temperature and pressure. Precipitated silicas also increase adhesion between rubber resins and textile reinforcements, and provide cut resistance in off-road tyre treads compounds. Tyres produced for trucks and buses utilise the majority of silica used in Tyres although partial replacement of the traditional filler, carbon black, in passenger vehicle tyres is a growing trend. Aircraft tyres, which are made entirely from natural rubber, due to the need to tolerate the rapid temperature change upon descent and remain yielding, are not filled with precipitated silica.

Most types of rubber, including natural, SBR, neoprene, nitrile, and butyl can be reinforced with precipitated silica. Its major competitor is carbon black, which generally gives better reinforcement. However, precipitated silica is preferred in non black applications, particularly those which require translucency or colouring which is very popular in sports shoes and this is the main reason for the growth in the demand for precipitated silica in the region during the 1990s. Because of the cut resistance and stiffness that precipitated silica provides it is used in such black-rubber products as tyre treads and sidewall compounds. The most widely used grades include PPG's Hi-Sil 233 series, United Silica's (Degussa) Ultrasil VN 2 and VN 3 series, Oriental Silica's Perkasil and Ketjensil range and Rhodia's Zeosil series. Blue Star Chemicals has increased participation in this sector by acquisition of Elkem and parts of Rhodia.

Precipitated silica is used as a carrier of rubber compounding chemicals, which are used for curing purposes, accelerators, cross-linking peroxides, coupling agents and insoluble sulphur.

17.8 GLASS

Silica is the main ingredient of this unique material: whether in crystal; flat glass (windows and mirrors); container glass (bottles, tableware); fibreglass; glass wool; technical glass (screens); foam glass (cellular glass) or optical glass (spectacles and binoculars). The more stringent the specifications for crystal and glass, the more uniform and pure the silica particles must be.

Sibelco Group products set the standards around the world. High purity silica flours with consistent particle size distribution, low levels of iron and good refractive elements offer more uniform batch chemistry for greater control over critical quality parameters like viscosity, colour and clarity.

Bao-Lin has been supplying high quality materials to support glass industries particularly for alkali-free TFT-LCD mother glass substrate, glass fibre (fibreglass), container/jar glass, heat-resistant glass, and refractory applications that require the utmost in quality and consistency; hence Bao-Lin has a good reputation in Asian high-class fibre glass industry.

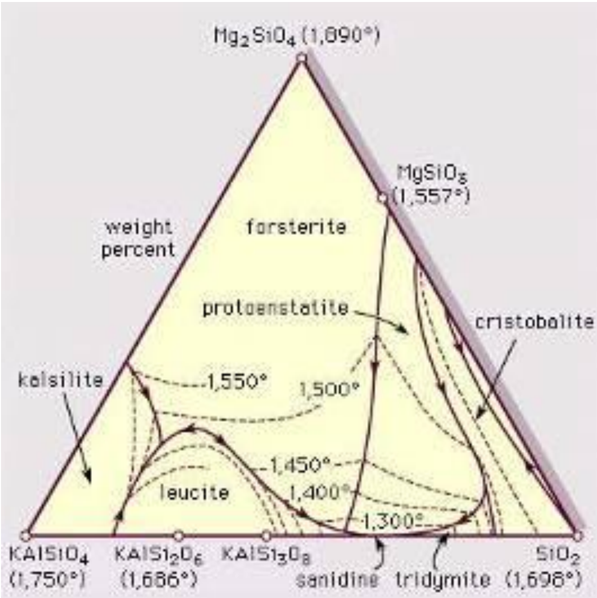
17.9 CERAMICS

Pure quartz sand, ground silica and cristobalite flour are essential ingredients for body and glaze applications in the ceramics industry: ranging from refractory bricks to wall bricks, and from sanitaryware to tableware and tiles. Ceramic grade ground silica produced from high purity crystalline silica feedstock is ideal for the formulation and manufacture of ceramic whitewares, enamels, glazes and frits.

Silica products in ceramics is used because it:

- Helps in controlling shrinkage
- Helps regulate the co-efficient of thermal expansion in bodies and glazes
- Strengthens the body

- Regulates the melting point and controls viscosity in glazes and enamels.



17.10 Construction

Silica as functional filler in fibre-reinforced cement products.

Fibre-reinforced cement products are made from binders, fibres, fillers and additives.

Generally a combination of following products is found:

- Cement (Portland P40)
- Mineral fibres: wollastonite (Casiflux from Ankerpoort)
- Cellulose fibres
- PP-fibres (hollow polypropylene fibres with diameter of +- 10 µm)
- Chemical additives: cellulose-ethers, etc.
- Silica sand (GA38 ex Sifraco, average grain size 100 µm)
- Silica flour (MILLISIL® M6 ex SIBELCO, average grain size 30 µm)
- Ultra-fine silica (SIKRON® M500 ex SIBELCO, average grain size 3 µm).

Asbestos has long provided the required processing and rheological conditions during production. A cocktail of sophisticated components is the only option available to replace asbestos, and long-term stability of the end products can only be achieved through the use of the highest specifications for these components.

Using recovered materials brings a major risk: contamination in paper-scrap (cellulose) and agglomerates in fumed silica (dust-recovered) can lead to the formation of cracks and instability in fibre-cement end products. Even with a high-speed dissolver or a compulsive mixer, the agglomerates in recovered fumed silica are not sufficiently reduced. The grain size of the agglomerates after mixing often exceeds 10 µm, although some claims are made for sub-micron grain sizes. Conglomerates of fumed silica, with a very large specific surface, absorb large quantities of water and induce high levels of internal tension in variable climatic conditions such as rain to frost and rain to sunshine.

Therefore, there are strong arguments for the use of SIKRON® M500 as an ultra-fine silica-filler. It contains a significant level of reactive amorphous silica; it's easy to wet; it does not exhibit a tendency to agglomerate, and it has a low specific surface area.

17.11 CHEMICAL INDUSTRIES

The chemical applications of quartz products are wide-ranging. Quartz derivatives are used in many areas, such as pesticides, fertilisers and pharmaceutical preparations.

Another derivative from quartz sand is water glass. This versatile substance has many uses, such as: a binding agent in paints and adhesives; in cosmetics; as an environmentally friendly bleaching agent in the paper industry; and also as an ingredient in detergents and washing powders.

Silicon carbide is created by the fusion of quartz and carbon: It is the raw material for abrasives, anti-slip and polishing products.

17.12 FILLERS

Silica is used as filler in Rubber, adhesives, plastic and paint (RAPP). Our range of ultra fine, chemically pure and stable silica flours is available for a wide variety of filler applications. Completely inert and pH neutral, this range of silica flours will not alter or initiate when incorporated in catalysed or multi-component chemical systems nor degrade when employed in extreme temperature or harsh environments. The hardness and low surface area of the silica flours offer minimal oil absorption for high loading and stiffening of elastomerics, high performance epoxies and cementitious systems. Chemically pure, silica flour serves as an excellent non-conductor in electrical assembly potting compounds and a non-combustible filler in thermal insulating or fire retardant applications.

Sibelco's functional fillers reduce production costs and offer specific advantages in many applications. The use of SIBELITE® as an ultra white and inert pigment extender in decorative plaster works and self-cleaning outdoor wall paint is widespread.

17.12.1 Silica as a functional filler in Heavy Duty Paint

Silica flour has been available in a micron-fine ground form with an average grain size of 3 µm since the 60s. Subsequently cristobalite has become available in the same range of fineness.

To prevent coarse silica particles wearing out machinery or spray-nozzles, the use of fine micron grades are recommended:

SIKRON® M600, SIBELITE® M4000, SIBELITE® M6000

$A \sim D^3$

A = Abrasion

D = particle-diameter

A 40 µm particle is 2370 times more abrasive than a 3 µm particle.

A ~ Moh's scale hardness

Hardness for dry products:

See: Calcite = 3 Quartz = 7 Cristobalite = 6.5

A ~ Rosiwal abrasion resistance

Hardness in water:

SiC 1 000, Quartz 120, Cristobalite +-60, Feldspar 37, Calcite 5

The inner frictional forces caused by the use of Silica in the dissolver give excellent pigment extender capacity

Low level of oil absorption

20 - 30 gr./100 gr.

Ground silica is often confused with precipitated or fumed silica.

17.12.2 Other Aspects

Silica is chemically inert.

SIKRON® has very little influence on gloss and ha . It improves the mechanical properties including resistance against abrasion and scratch-resistance.

SIBELITE® , apart from the benefits offered by quartz, cristobalite is less abrasive. It brings improved optical properties and a matting effect which is an advantage for primers.

Conclusion: Micron-fine quartz & cristobalite are used worldwide for anti-corrosion paints (offshore, marine & heavy duty) due to the resistant & inert properties of silica.

17.12.3 Silica as a Filler in Floor Coatings and Epoxy Floorings

Good mechanical properties can only be achieved in a floor coating if an appropriate choice of filler is used.

In floor coatings with a thickness of up to 300 µm, generally hard but micron fine fillers are used: ground Silica flour (SIKRON® M300 or SIKRON® M500) and Cristobalite flour (SIBELITE® M3000 or SIBELITE® M4000).

Nepheline Syenite, such as MINEX® 4, is one of the few alternatives without crystalline free silica. For spray painting, the 3 µm - fine fillers avoid high wear on nozzles and airless pumps. For brush applications the 10 µm types are adequate.

In epoxy flooring, particles up to half the layer-thickness may be used. The Fuller-theory is often used to reach a maximum filler-content. With the square root of the grain size on the X-axis, and the sieve residue on Y-axis, the ideal Fuller-curve is a straight line.

Washed, dried and calibrated sands are produced by:

FILCOM BV (the Netherlands tel. Int. +31 78 615 81 22).

For ultra high resistance, aluminium oxide fillers can be used such as PORTALUM produced by: ANKERPOORT B.V.

17.12.4 Silica Filler: Transparency in Paints and Polymers

When a filler is mixed into a polymer it often gives a misty or milky aspect, called HAZE.

An important parameter is THE OPTICAL REFRACTIVE INDEX: nD

The smaller the difference between the nD of the polymer (or binder) and the nD of the filler, the higher the transparency, and vice versa: A mixture of two products reaches a high hiding power when the difference in refractive indices (nD) is significant.

Example:

- nD(PMMA) = 1.49 (1)
- nD(SIBELITE®) = 1.48 (2)
- nD(TiO_2) = 2.76 (3)

A mixture of SIBELITE® in PMMA (polymethyl methacrylate):

(1) - (2): 1.49 - 1.48 = 0.01 transparency

Conclusion: SIBELITE® is an ideal transparent filler in PMMA.

A mixture of TiO_2 (titanium dioxide) in PMMA:

(2) - (1): 2.76 - 1.49 = 1.27 high opacity

Conclusion: TiO_2 is an ideal pigment in PMMA.

Silica and other silicates are often used in the paint and plastics industry for their transparency, for example: antiblock additive in transparent PE (Polyethylene). Not only are they used in transparent applications for flooring (PVC + MINEX® or EPOXY + MILLISIL®) but also in deep-tone colour applications - transparent fillers do not hide the pigments.

For example: Typically SIBELITE® M3000 (Cristobalite) is used in deep-tone red powder coatings. If Dolomite is used instead of SIBELITE®, the red colour becomes pink.

17.12.5 Silica Flour in Australia

Excludes the very large tonnage produced by companies in-house for fibro-cement products & ceramic tile body (e.g. National Tiles, Rutherford) and sanitary ware body (Caroma). Usually this silica is wet ground and delivered straight into the process, however at times they run short, due to equipment repairs etc. and at these times need large amounts of silica flour at very little notice, but it costs them considerably more than wet milling themselves.

Table 15: Summary of Australian milled silica (estimated tonnes per year)

Company	Location	Estimated capacity	Estimated production	Comments
Sibelco Australia (Formerly Commercial Minerals + ACI Resources)	Lang Lang (Victoria)	18,000	6-7,000 note dropped considerable when ACI started producing at Dandenong	Mainly for ceramics, paint, epoxy, etc. 1 Silex lined mill & flint pebbles. Occasional use in fibro-cement (James Hardie) when customer's mill down. Shipped to Adelaide also. Small tonnage for oil drilling (cementing) at times. Previously exported to Taiwan, but too expensive now.
	Granville (NSW)	20,000	4,000	Mainly for ceramics, paint, etc. One Alumina-lined ball mill.
	Dandenong (Decommissioned)	50,000	12,000	Approx. 9,000 for fibreglass. Balance for ceramics & export. 2 Alumina mills. Balance is to exports, etc. but difficult with the weaker currencies in region now.
Cook Industrial Minerals	Jandakot (WA)	~60,000 (stated in WA Mines booklet but likely to be less.)	6-8,000 Note this mill is also used to mill zircon, spodumene & alumina	Mainly for road-marking paint, ceramics, limited export, 2 Alumina-lined mills. Use Rocla or other local sands.
Index	Burnie (Tas)	20,000	12,000?	Virtually all exported to Japan for electronics use & crystal glass. 1 Autogenous-grinding unit with pebbles added. Iwatani source from India & Sri Lanka but this is cobbled quartz rather than flour.
Estimated packaging of total silica flour as delivered: Road-tankers 45%, 1t bulker bags 15%, 25kg paper bags 40%; Exports mainly in bulkers and small packs. Note 40 kg bags were banned by unions so 25kg is normal.				

1. Nth. Stradbroke Island

Nth. Stradbroke Island is only sand for glass containers and some bulk export no flour is produced here.

The main 400-tonne of molten glass at any one time, a continuous process tank in Melbourne, but cullet content is around 40% these days is glass for beer & wine bottles.

Sibelco Australia has the main silica flour facilities in Australia at Lang Lang and Granville since it closed Allendale a few years ago.

2. China

Two locations, annual capacities, grades produced/markets served by Sibelco's two joint ventures. Also, name – not known yet, location both believed to be in the eastern part near coast, one near Shanghai and one in Fujian province, capacity of both is estimated at around 40-50,000 tonnes per year

Shaanxi grades / markets for company producing 80 to 1,000 mesh ultrapure Details are as yet are not known.

3. India

Details of India not known at present but silica flour imports into Indonesia for use in ceramic tiles from feldspar producers occurred prior to Sibelco mill commissioning.

4. Indonesia

Sibelco-Lautan Laus in Jakarta are producing 18,000 to 25,000 tpy. Any info on installed capacity and/or grades? Believed to have 2 alumina mills with an estimated capacity of around 20-25,000 each.

5. Japan

Kyoritsu Ceramic Materials Co. Ltd. at Hishino, Aichi reportedly is producing 2,000 tpy.

Inagaki Clay Mining Co. Ltd. at Tajimi City - The silica is a by-product of the clay washing process. It is poor colour and is sold for mixing into roof tile blends at companies set up to supply prepared bodies to tile producers. The Taiwanese have used this process for many years also.

6. Malaysia

Syarikat Sebangun at Bintulu - annual capacity and grades produced/markets served – believed to be supplier of silica flour widely used in cementing of deeper holes where the temperature gives problems without this technique, to the oil drilling industry in the region especially in Brunei and Indonesia. Mainly for sand for glass production, and is the secondary supplier to Japan.

L & T Mineral - location of plants, believed to be near Ipoh, in Perak State and another in Johor state in the south. Capacity, is estimated at around 5,000 tonnes per year grades 100 mesh, 200 mesh & 325 mesh. Markets are mainly for ceramic glazes, paints and epoxy resins.

Note: the mills used are also used to grind other minerals such as zircon, etc. The silica is actually the waste by - product of tin mining over many years and hence has a very low value due to large supplies in many parts of Malaysia.

Kaolin (Malaysia) S/B - at Tapah, Batang; reportedly produces 2,400 tpy, but this is quartz washed from kaolin operations not silica flour. There are several uses for this by-product but due to colour variability normally do not command a high value.

7. Pakistan

Swat Mining Corp. - at Mingora, Swat, NWFP - 10 tpd capacity (for silica grinding?).

Pak Mineral Dressing & Processing Ltd. - reportedly produces 4,000 tpy; where and of what grades?

8. Philippines

SIMPCOR - produced 6,000-8,000 tpy at Siruma, Camarines Sur—capacity is estimated at 12,000 tonnes per year but is dependent upon how many manual workers digging the material from the silica horizons under less than a metre of top soil. Normally about 20 men dig, bag and load onto the 10 tonne truck 3 to 4 times per day 6 days per week. Boat carries 40 tonnes in bags each day to Naga city about 5 hour sailing. However, due to poor roads, frequent cyclones etc., and very casual labourers output can vary considerably.

Two Grades –First grade or super-white which is used in glaze in sanitary ware and tiles.

Second grade -slightly iron stained for sanitary ware.

This site may have closed with the demise of Saniwares bathroom supplies, however the naturally fine silica is of good quality and should be re-evaluated.

Vulcan Industrial Mining Corp. - on Palawan; may be a producer of ground silica. Understood to be completely closed several years ago as sand mining was deemed environmentally damaging to one of the foremost overseas tourist resorts. The President’s wife was Environment Minister.

9. Taiwan

Sibelco - Sani Mining joint venture at Taichung - Estimated capacity is around 50,000 tonnes per year. 20,000 tpy is minimum production and likely to be growing in an effort to supply part of the requirements at Chai-yi fibreglass facilities close by. Main grades are 100#, 200# and 325#.

10. Thailand

Clays & Minerals (Thailand) Ltd. Believed to produce around 7-8,000 tonnes per year. Produced in same mills as the feldspar. This is the A.M.A./WBB joint venture mainly producing feldspar used by their joint venture party which produces sanitary ware. Same mill used to produce silica flour for glazes on as needed basis.

F&S International Inc. (New York) used to market high-purity silica (60 to 200 mesh) for Tasmanian company Index Mineral Processors. This plant is located in Burnie on northern coast of Tasmania, shipped from nearby wharf. It was sold at auction then started again under new management. Ground silica capacity is estimated at around 20,000 tonnes, but problems occur with very wet weather here and washing of organic material into the deposits, which are numerous small pits in the forest. This is the same operation as the M. K. Silica joint venture, which in 1987. It was had an initial flour capacity of 20,000 tpy and has been supplying material to Japanese producers of optical glasses, lead crystal, quartz crucibles, and advanced ceramics?

17.13 SILICA FLOUR FOR CERAMIC APPLICATIONS

Silica sand and quartz are added to ceramic bodies to control plasticity and firing shrinkage. Silica is a relatively inexpensive ingredient, typically less than one third the price of clays. In some circles the word flint is used when discussing silica for ceramic applications, but the chemical analysis is the same. This means that it is used as a filler material to lower the overall material costs.

Health and safety issues are now appearing in the industry, particularly for the micronised grades used in enamels or glazes. In many deposits, such as those in Sarawak, Malaysia, the sand is naturally fine grained and no dry milling is necessary. However, where dry milling is required, it can produce the fine crystalline dust, which is claimed to be a carcinogen and precautions have to be in place that add to the cost of the product used in a wide range of applications, each requiring distinct mineral characteristics.

Ceramic grade silica sand should possess a minimum silica content of 98.5-99% SiO_2, and <1% Al_2O_3, with constraints on alkalis, colourants (Ni, Cu, Co) and refractory minerals such as chromite and zircon and rutile. Fe_2O_3 content should be as low as possible as it is this, along with TiO_2, which has an impact on the fired colour of the whiteware. Ground silica is used in most ceramic bodies and glaze products, and typical specifications require <0.10% Fe_2O_3. Silica flour has an average particle size of 60 µm, while both flour and ground silica requires a brightness of ~ 90%.

The region is well placed with regard to silica supply. Silica occurs as dunal silica sand and also as massive quartzite, which can be crushed and milled, to a suitable size. Some whiteware manufacturers choose to source silica sand from a local mineral supplier/quarry especially for body component when the material will be milled along with feldspar, etc., in normal body preparation. Some of these same ceramic producers, however, choose to buy in the smaller quantities of silica flour for addition to glaze formulations, to save the trouble of grinding small batches of such a hard material. Some sanitaryware producers in fact buy in silica flour for the body formulation as well, seeing their role as a ceramic producer, not a mineral processing company. The higher cost of buying the flour is partly offset by the reduced energy costs.

In ceramic bodies, silica flour is the constituent, which reduces drying and burning shrinkage and assists promotion of refractoriness. Silica has an important bearing on the resistance of bodies to thermal and mechanical shock, because of the volume changes, which accompany crystal transformation. In the unburned body, it lowers plasticity and workability, lowers shrinkage and hastens drying. A coarse crystalline form of quartz, called macro-crystalline quartz, is sometimes used for ceramic silica rather than the cryptocrystalline form. The maturing temperature of a body is lowered materially by the use of cryptocrystalline silica but over-firing will take place more rapidly than in bodies where silica is used.

Cryptocrystalline flint will show more crystobalite development under heat treatment than will quartz flint. This property has an important bearing on thermal shock resistance of whiteware bodies, allowing more resistant bodies to be made using silica flour. Impurities in the silica and the fineness to which it is ground have a decided effect on the behaviour of the body; this effect is probably of more commercial importance than that caused by the type of silica used. In any clay/feldspar ceramic mix, clay slightly increases rather than decreases the coefficient of expansion. Up to 45% flint added to any constant clay-to-feldspar ratio slightly decreases the coefficient of expansion and tends to reduce crazing.

The largest producer of silica sand in Asia is China, which supplies the country's vast glass and ceramics industries. Vietnam, Indonesia and Malaysia all supply domestic markets, and are significant exporters particularly as demand picks up in the region. Australia's silica sand producer, Cape Flattery is an important exporter supplying a significant proportion of Japanese silica sand requirements. In most cases, local sources of silica are used in preference to expensive imports. However, certain high-grade low iron and micronised grades are imported, sometimes from European or US producers.

Competition to supply upgraded silica sand and silica flour in the Middle East is increasing as the region experiences increased demand growth. Suppliers include India, Turkey and the more local producers in Saudi Arabia, Iran and Jordan. Some European exports are also made to the region, although these tend to be high-grade silicas. The total market for silica flour in the region is estimated at 50,000 tpa, whilst the demand for silica sand is currently in the order of 450,000 tpa. In the Far East, Australia is a major supplier of silica sand to Japan whilst Malaysia and Indonesia also supply export markets as well as their own industries.

China is the giant in Asia in terms of both ceramic and glass production. It is also by far the biggest supplier of silica sand, much of which satisfies the veracious appetite of the country's domestic glass and ceramics industries. Until relatively recently, all silica sand deposits were allied to a particular end use. For example, silica sand produced for the manufacture of flat glass was controlled by the (SABMI). The sand produced was not used in any other applications, and other deposits for foundries, ceramics, etc., were controlled by other Ministries. This has now changed, although many glass producers still have mining rights to specific deposits. Today, deposits developed by glass manufacturers provide their own secure and consistent raw material supply. However, a number of smaller independent producers are now supplying grades on the open market.

Table 16: Selected Independent Producers of Chinese Silica Sand Producers

Company	Location	Comments
China Standard Sand Factory	Pingtan, Fujian	Capacity 100,000 tpa
Hunan Shimen Silica Sand Mine	Shimen, Hunan	Capacity 250,000 tpa, output 100,000 tpa
Jilin Shuangliao Qikeshu Silica Sand Industry Co	Shungliao, Jilin	Capacity 220,000 tpa of washed sand, 160,000 tpa of refined sand
Jinjiang Shenhu Xifeng Quartz Sand Works	Jinjiang, Fujian	Capacity 160,000 tpa
Shandong Weifang Hongyang Quartz Sand Co Ltd	Changyi, Shandong	Capacity 200,000 tpa
Wenchang Longma Quartz Sand Mine	Wenchang, Hainan	Capacity 120,000 tpa
Xiangtan Silica Sand Mine	Xiangtan County, Hunan	Capacity 120,000 tpa
Zhuhai Prosperity Metals & Minerals Co	Jida, Zhuhai, Guangdong	

Many silica sand deposits occur along the eastern seaboard of the country, and in inland river and lake deposits. The deposits in Hainan are generally considered the highest quality deposits in China.

Japan is an important consumer of high quality silica sand.

Malaysia: The gathering momentum of **Malaysia's** glass and ceramic industries over the last ten years has fuelled a requirement for high quality silica sand, which has largely been fulfilled by local sources and developments. There are two established silica sand operations in mainland Malaysia, and another on Sarawak. Silica sand is also produced in Terengannu State in the north east of the country. Syarikat Sebangun Sdn Bhd is based in Sarawak whilst Perniaggaan Usahasama Membalak Sdn. Bhd (PUM) and Johor Silica are both based in Johor. All three mainly supply glass markets, but some material is sold into other sectors.

18 FOUNDRY SANDS

Foundry sands used to make moulds and cores have been very important to foundry men since metal casting began hundreds of years ago. They are now used in two basic ways, either in an uncured green state, grain–bonded with clay, or in a set cured state achieved with sand that, mixed with resins or oils, is cured by baking or by chemical reaction.

The term sand, as generally used in foundry applications, is best defined as material composed of granular particles of mineral matter, ranging in size from 0.5 to 2 mm in diameter. The particulate nature of the material may be the result of natural desegregation or result from crushing and screening of rock or ceramic materials; crushed and screened products are sometimes referred to as “manufactured sand.” Based on their origin, the raw materials for foundry sands will vary in grain shape, grain composition, relative surface, grain size, and grain distribution patterns. These properties, in addition to their chemical analyses, sintering point and expansion characteristics play an important part in the choice of sands used as the base moulding or core aggregate in metal casting. Sands with different origins may be blended to produce specific compositions and grain size distributions.

Early raw material requirements based on silica sand were simple, but as sand/core/mould technology became more sophisticated and binder technology continued to be developed, the physical properties of foundry sands became more critical. Silica sand is composed of quartz, along with, in most cases, small amounts of feldspar, mica, clay, and other common minerals. Although silica sand is still by far the most widely used base material in production of moulds and cores used in metal casting, other natural mineral sands have their own unique characteristics and fill an important niche in special applications. As a result, the term sand, as applied to raw materials used in metal casting, has been logically extended to include granular materials composed of a group of minerals other than quartz. With increased use in advanced foundry technology, natural sands composed predominantly of zircon, chromite, staurolite, or alumino silicate minerals and of granular chromite or olivine, have become more than just alternate materials and are now commonly classified as sands when the grains are sand–sized. Foundry sand may therefore be considered under two categories: silica sands and non–silica sands.

18.1 MODES OF OCCURRENCE

Silica sand deposits occur naturally as a result of such geologic processes as weathering and erosion of pre-existing quartz–bearing igneous and sedimentary rocks, glacial gouging, and transportation to the site of deposition. Disaggregated rock and mineral particles may be carried hundreds of kilometres from their ultimate source by fluvial, glacial, glaciofluvial, marine, and eolian processes. The composition of minable deposits depends on the nature of the rocks that were eroded, the intensity and time–scale of weathering, the distance and agent(s) of transportation, the manner of deposition, and post–deposition history. Deposits may be reworked by natural processes and redeposited under similar or entirely different depositional conditions.

Silica sands accumulate along channels and flood plains of rivers and streams, in lake and lake shore deposits, and are deposited under marine conditions in seacoast environments. Geologically young deposits are unconsolidated or semi–consolidated. Ancient sand bodies, which became buried under great thicknesses of younger sediments and consolidated, are termed sandstone. Subsequent uplift, due to the heaving and shifting of the earth's surface, can result in complete cessation of sedimentation and the initiation of widespread erosion and exhumation of previously deeply buried formations. Those that either crop out at the surface or have only a thin layer of overburden can be readily mined. Repeated cycles of weathering, erosion, transportation, size–sorting, and deposition results in well–sorted, high–purity sandstone deposits from which practically all minerals heavier than quartz have been winnowed out.

18.2 ADVANTAGES AND DISADVANTAGES

Silica sand has the advantages of abundance, ease of bonding with organic or inorganic binders, low cost, and ability to be reclaimed for reuse by wet, dry, or thermal methods. However, it also possesses certain disadvantages when used in the production of metal castings. The major disadvantage of silica sand is its characteristic high thermal expansion. This expansion behaviour causes casting quality problems, e.g., rat–tails, buckles, and scabs and contributes to other expansion–type defects. The typical thermal expansion of various silica materials and depicts alpha quartz, the polymorph characteristic of silica sand, expanding at a constant rate until a temperature of approximately 573°C is reached. As the temperature increases above this point, a sudden expansion takes place due to the change in crystal form, from alpha to beta quartz. This high thermal expansion requires carefully controlled additions of cushioning materials (e.g. cellulose additives) to minimise the deformation and rupture of mould surfaces in contact with molten metal. In addition, silica sand is unable to resist metal penetration and reactions that occur in quartz when in contact with casting surfaces. These problems arise where there are sharp angles in hot spot areas of large iron and steel castings and, in Hadfield's austenitic manganese steel castings, when the steel contains high amounts of manganese that attack (wet) the silica sand mould surfaces. In addition, continuing environmental concern about respirable silica as a potential cause of silicosis works as a disadvantage.

18.3 CLASSIFICATION OF SILICA SANDS

Silica sands used in foundry practice vary in grain size distribution, purity, structure, grain shape, and refractoriness. However, two broad classifications are generally applied to foundry moulding sands, naturally bonded sands and un-bonded sands.

Naturally Bonded Sand. Naturally bonded mouldings sands are water deposited sands that are naturally combined with clay that serves as a bonding agent. The well known Albany naturally bonded sand, from the Albany, NY, area, was deposited in a glacial lake from glacial melt–water. Naturally bonded sands occur with a wide range of grain fineness and clay content, depending upon their source and geologic history.

Processing. The processing of naturally bonded moulding sands consists primarily of screening to remove oversized particles, roots, and other deleterious material. For some sands, this is all that is required to meet specifications. Other sands are dried to approximately 6.0% moisture and may then be passed through mullers, cage mills, or dry pans to mill the sand and distribute the natural clay bond. Sands with dissimilar compositions, from different pits or from different strata in the same pit, are often blended to produce a range of sands having consistent, uniform properties. Sand with a wide range of properties can be produced and specifications are negotiated between producer and consumer.

Foundry Use. Fine grade naturally bonded sands are generally used as shipped in the casting of aluminum, light copper–based alloys, and light gray iron. Use is becoming more and more restricted to smaller, less mechanised foundries. Heavy, naturally bonded sands and gravels are used in the moulding of large iron castings. Applications for all naturally bonded products have declined in favour of synthetic formulations.

18.4 UN-BONDED SANDS

PROCESSING — Washed, graded, and dried (clay free) silica sands are prepared for use in casting production by being bonded with the required amounts of binders, additives, and the necessary amounts of temper water. The total sand mixture is prepared in the sand muller in order to gain uniform distribution and dispersion of the clay and additives over and around the individual sand grains.

FOUNDRY USE — Medium–grade sands are used predominantly for casting of steel and heavy, grey and ductile iron; fine–grade eastern silica sand is used in making precision castings. The St. Peter Sandstone is a popular washed and dried product because its roundness of grain promotes flowability, and, due to smoothness of grain, this sand requires less bonding material.

PROCESSING — after stripping, the sand is hauled to the plant. A front-end loader dumps the sand into a hopper from which it is conveyed to a rotary screen with 12.7 mm openings to remove roots. Some screened sand is dried and shipped without any further processing and meets the specifications as a system sand addition and as a synthetic sand base; some is washed to produce a cleaner and more consistent product.

The sand to be washed is dropped into a surge bin to assure a uniform feed. The sand is then conveyed to a tank where it is mixed with water and then pumped to a scalping screen where fine roots and organic materials are removed. The scalped sand is pumped to a de-slimer to remove the clay and silt, freshwater is added, and the sand slurry is either pumped to a second de-slimer and then to ground storage, or it may be fed to banks of screens and separated into a fine particle size and a course particle size. Each sand grade is then collected in a sump, mixed with water, pumped to a de-slimer and dewatering cyclone, and piled for drainage and storage. The sand is then dried, cooled, and passed over a final scalping screen after which it is conveyed to storage bins prior to shipment.

FOUNDRY USE.— Fine bank sand is used as a base for moulding sand in medium– to small–sized, grey iron castings typical of those used in casting hardware and hand tools and for casting aluminium and copper–based alloys.

Lake Sands. The term lake sands has been applied to sands of the type dredged from lakes or dug from the dunes bordering lakes; the dune sands have been shifted by the wind but are still a part of the lake sand deposit. During the depositional process, some natural classification by grain size, grain composition, and specific gravity can take place. In general, the degree of purity of these materials is the result of their geologic history and processing.

PROCESSING — In a typical lake sand processing operation, the overburden is stripped and a front end loader is used to mine the sand and feed a hopper that discharges to a portable screen by means of which deleterious material is removed. The hopper and screen can be moved along a field conveyor as required. Conveyor belts transport the sand to the plant site for further processing and/or blending.

FOUNDRY USE — Lake sands in large quantities are used in the production of automotive and farm machinery castings.

19 FUTURE PROSPECTS

19.1 SUPPLY–DEMAND CONSIDERATIONS

The future for moulding sand is strongly growing in the Asia region including China. The increase in automotive castings is the main driver. Thailand and Indonesia are both increasing dramatically as China has been for over a decade now. South Korea has a large automotive sector and this represents more than half of the foundry sand usage.

Although the sand used in both green sand (clay bonded) and bonded sand moulds and cores is reclaimed for reuse, the normal foundry procedure of constructing a mould of sand, clay and other binders, and additives for a single casting can be viewed as extremely inefficient. Permanent ceramic moulds, with cordierite or other refractory material as the primary raw material, could possibly reduce moulding sand use in some applications. However, maintenance of precise dimensions may be a problem as the permanent mould is used.

19.2 NEW TECHNOLOGY AND PRACTICES

Despite environmental pressures, silica sand will continue to dominate foundry sand practice in the foreseeable future, but it is anticipated that advancements in metallurgy, increased use of light metals, and requirements for more uniform and higher finishes will require increased use of non–silica sands and the implementation of new technology, some not yet on the drawing board.

Sibelco has been offering special grades of Silica for specialty uses.

SIKRON®

SIKRON® is the brandname given to our micronised ultra-fine silica flours. It has become the performance standard in the manufacture of glass fibre, heavy-duty paint, coatings and silicones.

Several grades are available: M300, M400, M500 and M600.

Average particle size: 14, 7, 3 and 3 µm respectively.

MILLISIL®

MILLISIL® is the brand name for our series of coarse silica flour grades. MILLISIL® is produced by iron-free grinding and controlled sieving by means of air-separators. Selected silica sand with a SiO_2 content of over 99% is used as the raw material. Purity, controlled particle size distribution, chemical inertness, optical properties and hardness make MILLISIL® the performance standard in ceramics, tile-glues, special mortars and coatings.

Several grades are available: M4, M6 or M6.1 and M10.

Average particle size: 50, 35 and 22 µm respectively.

M4, M6 and M10 are obtained by grinding M32 sand.

M6.1 is obtained by grinding the extremely pure MAM 1 sand.

Cristobalite is a high purity silica produced by the calcination, at high temperature, of selected and treated quartz grains. The modified crystal structure is stabilised by fast cooling. With its narrow particle size distribution, excellent optical properties, constant whiteness and chemical inertness, cristobalite is a highly prized raw material in many performance industries, such as silicates, plastics, coatings, precision-casting, ceramics, etc.

Sibelco's cristobalite product is known as SIBELITE® and MINBLOC® M: It is available in some 20 standard qualities, graded according to particle size and surface treatment.

Cristobalite is named after the place where it was discovered: "Cerro San Cristobal" (Mexico). It is an extremely rare natural deposit which was created by volcanic activity.

SIBELITE®

Sibelco supplies cristobalite under the brandname SIBELITE®, in some 20 standard qualities, graded according to particle size and surface treatment.

Cristobalite is a high purity silica produced by the calcination, at high temperature, of selected and treated quartz grains. The modified crystal structure is stabilised by fast cooling. With its narrow particle size distribution, excellent optical properties, constant whiteness and chemical inertness, SIBELITE® is the raw material of choice for many performance industries, such as silicates, plastics, coatings, precision-casting, ceramics, etc.

MINBLOC® M

Sibelco supplies cristobalite under the brand name MINBLOC® M, in 2 standard qualities, graded according to particle size.

Cristobalite is a high purity silica produced by the calcination, at high temperature, of selected and treated quartz particles. The modified crystal structure is stabilised by fast cooling.

MINBLOC® M offers a unique combination of optical refractive index and particle morphology and is developed for high clarity - high gloss PP, LDPE, and LLDPE film applications. MINBLOC® M is certified for indirect food contact applications.

NEPHELINE SYENITE – an alternative to silica where potential for silica dust inhalation is a problem.

MINEX® is the brand name of micron fine ground Nepheline Syenite. Optical properties, hardness, purity and controlled particle size distribution, make MINEX® a functional additive, filler or pigment extender in paints, plastics and coatings. Several grades are available: MINEX® 4, 7 and 10 or MINEX® S 10, S 20, S 30 and S 40.

Average particle size between 2 and 11 µm.

NEPHELINE SYENITE or “anhydrous sodium potassium alumino silicate” is one of the purest aluminium sources for ceramics, glazes and glass.

MINEX® is the brand name of micron fine ground Nepheline Syenite. Optical properties, hardness, purity and controlled particle size distribution, make MINEX® a functional additive, filler or pigment extender in paints, plastics and coatings.

Several grades are available: MINEX® 4, 7 and 10 or MINEX® S-10, S-20 and S-40.

Average particle size between 2 and 11 µm.

19.3 BEVERAGE FILTRATION

Sibelco recently developed a range of pure silica products with proven advantages in mechanical filtration of beer: Filtrasil®.

The main technical advantages are related to the chemical purity and the constant particle size distribution. A constant and ultra low iron oxide content improves stability in time and there is a significantly lower absorption of flavours when the classical mineral filter-aid is spaced by Filtrasil®.

Iron-free grinding and sieving by means of air-separators are the engineering techniques to produce the different grades, each with their typical and constant particle size distributions.

We distinguish four standard grades: the M002, M006, M0010 and M3000, each with an average particle size of 80, 40, 30 and 15 µm.

It is important that the filter-aid is chemically pure, which is not always the case for other filtration minerals. Experiments on industrial scale demonstrated clearly that mixing the body-feed diatomite with pure Filtrasil® results in an improved and performing filter aid.

The best filtration results are obtained by the synergy of the two silica products, having the same density, the same particle size distribution and the same flow behaviour in the liquid.

19.4 AUXILIARY MATERIALS

Quartz sand is used in water filters, on golf courses and sports fields, in well drilling and as braking sand for trams and trains. Silica sand is used as a cleaning aid and for sand blasting. In the oil industry, frac sand is an essential product, distinguished by its physical properties such as its very coarse round grains. Other examples of everyday uses for quartz sand include aviaries and aquariums.

19.5 TECHNICAL ADDITIVES

Due to its proven antiblock- and thermal barrier properties, as well as its long term stability in PP and PE, MINBLOC® M4000 has proved to be an ideal all-round additive for transparent plastic film.

19.5.1 Antiblock silica for transparent plastic film

MINBLOC® M4000 is generally used as an antiblock in transparent PP - and PE film. Due to the comparable indices of optical refraction of MINBLOC® and most polyolefinic films, this additive has almost no effect on the optical properties of the film. For special applications, such as ultra thin or co-extruded films, finer grades are required: MINBLOC® M6000.

As well as excellent antiblock, re-block, haze and gloss properties, MINBLOC® gives:

- Enhanced long-term stability
- Improved colour performance
- Good free-flowing bulk-handling properties.

19.5.2 IR Absorber for Transparent Plastic Film

SIBELITE® M4000 is commonly used as an IR absorber in green- house film.

Vegetable growth is directly related to the total amount of light received - the higher the total light transmission, the better. To limit the temperature drop in greenhouses during the night, an IR transmittance between the wavelength 7 and 14 µm is crucial. The lower the loss of radiation energy, thermicity, the better.

Where visual inspection of vegetable growth through plastic film is required, it is necessary to ensure a high direct light transmission.

20 SILICA BASED INDUSTRIES IN MALAYSIA

The report commences by giving a background on silica sand in Malaysia with its occurrence in two forms, natural and man-made and their areas of deposits in the country. The glass industry in Malaysia is the main user of silica sand in Malaysia.

Typical Asian Silica specifications:

- Quartz sands (silica sands) high purity grade: SiO_2: 99.95% min-99.8% min Fe_2O_3: 3 ppm max - 30 ppm max, size: 2-200 mesh.
- Medium grade: SiO_2:99.8% min-99.0% min Fe_2O_3: 50 ppm max-0.03% max, size: 2-325 #.
- Natural crystal powder SiO_2: 99.90% min -99.99% min, size: 2-325 mesh.
- Fused quartz ingot SiO_2: 99.9% min Fe_2O_3: 50 ppm max, Al_2O_3: 0.03% max, size: 5-100#.
- Quartz in lump Special grade: SiO_2: 99.9% min.
- 1st grade: SiO_2: 99.8% min Fe_2O_3: 0.004% max.
- 2nd grade: SiO_2: 99.7% min,Fe_2O_3: 0.008% min.
- 3rd grade: SiO_2: 99.5% min Fe_2O_3: 0.03% min.
- Micro-silica powder SiO_2: 99.5% min-99.0% min, Fe_2O_3: 0.02% max, Al_2O_3: 0.3% max, size: 200-800#.
- Fused quartz powder SiO_2: 99.9% max, Fe_2O_3: 50 ppm max, size: 2-325 #.

Table 17: Estimated Silica Flour Consumption in Selected Asia for Frits, & Industrial Ceramics in glaze/engobe

Country	Est. Consumption (K mt/yr)			Sibelco Market-share	
	Ceramics	Frits	Total	(K mt)	%
Taiwan	15	28	43	29	67
Indonesia	12.5	10	22.5	14.5	64
Malaysia	2.9	0	2.9	2.4	82
Thailand	8.3	8	16.3	2.5	15
Vietnam	2.5	0	2.5	0.8	32
Laos*	0.2	0	0.2	0.1	50
Total	41.4	46	87.4	49.3	56

** Slowly emerging market.*

Comments:

- Total Market for Silica Flour is ~ 87.4 K mt /yr.

- In Frits producing countries (Indonesia, Thailand & Taiwan), ~ 50% of Silica Flour is used in frit.
- Acceptable quality Silica Flour is relatively easy to produce and price is low in domestic market.
- In Indonesia & Thailand approximate price is USD. 85-100/mt.
- Silica Flour for paint and other uses is generally <1,000 mt/yr therefore not included.
- In summary silica flour is difficult to export due to relatively high freight component.

Pure Silica sand and flour, with over 99.5% SiO_2, is the main raw material for high-grade industrial applications including float glass, glass fiber, fused silica, quartz crystal lenses, ceramics and sodium silicate. It is the ore used to produce silicon metal which forms the cores of integrated circuits. In some specialist high-tech applications, crystalline silica is irreplaceable, for example, in optical data transmission fibres and in precision casting.

High purity silica flours with consistent particle size distribution, low levels of iron and good refractive elements offer more uniform batch chemistry for greater control over critical quality parameters like viscosity, colour and clarity.

Benefits of silica flour are:

- To helps in controlling shrinkage.
- To help regulate the co-efficiency of thermal expansion in bodies and glazes.
- To strengthen the body.
- To regulate the melting point and controls viscosity in glazes and enamels.

21 FILLERS IN RUBBER, ADHESIVES, PAINT & PLASTIC (RAPP)

As the continuous advancement of technology, fillers and extenders increasingly take on a “functional” role to modify and enhance the hardness, durability, flow, colour, impact resistance and other physical properties.

The hardness and low surface area of the silica flours offer minimal oil absorption for high loading and stiffness. Chemically pure, silica flour serves as an excellent non-conductor in electrical assembly potting compounds and a non-combustible filler in thermal insulating or fire retardant applications.

21.1 CRISTOBALITE (CALCINED SILICA)

Cristobalite is a crystalline structure of SiO_2. It has a constant white colour, high hardness, excellent optical properties, chemical inertness and low oil absorption, etc.

For industrial application, Cristobalite is a valued raw material in many performing industries such as plastics, silicone rubber, coatings, glues, ceramics, rubbers, precision-casting, silicate chemistry, etc.

21.2 Microcrystalline Silica Flour

Microcrystalline silica fillers are produced from naturally occurring alpha quartz with a unique grape-like morphology. Easily wetted and dispersed in either solvent or water-based systems, microcrystalline is selected for its excellent tint retention, durability over prolonged exposure and resistance to dirt and weathering.

21.3 Indonesia

The spectacular growth in Indonesia's industrial base during the 1990s increased domestic demand for most basic and many specialty chemicals to a point where local manufacturing has become an increasingly viable proposition.

21.4 Japan

Tokusil (launched in 1960), Finesil, and Florite-and fumed or fused silica such as Reolosil and Excelica. Both types have won worldwide acclaim for their quality and technological sophistication. The department's amorphous synthetic silica products are in widespread use as rubber reinforcing fillers. Tokusil is used in industrial rubber, shoe rubber, and tires, for example, while Reolosil is used extensively as a form of silicon rubber. In fact, amorphous synthetic silica is being used in an ever-wider range of applications, including paints, agricultural chemicals, pharmaceutical and cosmetic products, ceramics, resins, and paper.

Table 18: Silica & Derivatives Product lines

Trade Name	Uses
Tokusil	Rubber (tires, shoes, industrial), agricultural chemicals, resins
Finesil	Paint and ink, data record sheets, resins
Florite	Pharmaceutical carrier, absorber carrier, free flow agent, anti-caking agent
Magnesium carbonate	Natural rubber, fertiliser, agricultural chemicals
Reolosil	Silicon rubber, sealant, paint, and ink
Reolosil surface treatment	Silicon rubber, sealant, paint, and ink
Excelica	Epoxy resin

21.5 THAILAND

Table 19: High Purity (HP Grade) Silica Flour

Chemical Analysis By X-Ray Fluorescence	%	**Mineralogy by X-Ray Diffraction**	
SiO_2	98.53	Quartz	96.00 %
TiO_2	0.00	Albite..............................	2.00 %
Al_2O_3	1.06	Orthoclase..........................	1.00 %
Fe_2O_3	0.04		
CaO	0.04		
MgO	0.02		
K_2O	0.25		
Na_2O	0.11		
LOI	0.15		
P.S.D. (Sedigraph) % Cumulative Mass Finer Than		% Sieve Residue on 45 micron 11.35 %	
< 20.0 microns	74.48 %		
< 10.0 microns	47.53 %	Fired Properties	
< 5.0 microns	27.28 %	Fired Colour, 1220^{O}C	
< 2.0 microns	12.18 %		
< 1.0 micron	6.15 %	Brightness	92.19
< 0.5 micron	2.67 %	(L)	97.68
		(a)	0.35
		(b)	1.31
COMMENTS: Dry milled in alumina-lined ball mills.			

21.6 SAUDI ARABIAN SILICA FLOUR

Raw silica sand with a high content of SiO_2 and low content of impurities is used for the production of industrial white silica sand with a SiO_2 content of 99.5% in weight. The grain size ranges from 0.125 mm to 2.00 mm, with customers assured sizes of their choice.

Industrial silica sand has applications in glass manufacturing including float-glass, pattern glass and bottle glass; the manufacture of glass-reinforced pipes, foundry sand for high-precision castings, water filtration and purification, oil-well drilling, construction chemicals, sealants and paints.

The production of sodium silicate follows the rotary furnace process. By fusing high silica content sand with soda ash in a rotary furnace at a temperature of 1,300°C, various SiO_2/Na_2O ratios are produced. When the molten matter is cooled, a clear glass of sodium silicate, which varies from colourless to slightly greenish blue, is obtained. It emerges as a premium product with high quality (a maximum of 0.3% metal oxides).

Sodium silicate glass is used in detergents and paints, ceramics, oil-well drilling, foundry, and construction chemicals. By using a steam pressure dissolver with in-line filtration, glass dissolves in exothermic action and gives an exceptionally clear solution with a long shelf life.

Various grades of solution combined with densities ranging from 1.36 gm to 1.60 gm per cu cm and a viscosity ranging from 150 to 7,500CP are manufactured. The solution is used in detergents, foundries, the preparation of titanium dioxide, adhesives, construction chemicals and recycled paper.

Through the hydrothermal process or “wet process”, silicates are manufactured directly in solution form. The silicate emerges from silica flour under pressure by the action of concentrated caustic soda solution. The process lends itself to the production of crystalline silicate solution.

For potassium silicate, the same facilities, rotary furnace and dissolving unit are used to manufacture glass and to produce a clear solution with weight ratios ranging from 2:15 to 2:20. Densities ranging from 1.38 to 1.42 gm per cm^3 and viscosity ranging from 250 to 1,200CP are prepared. Potassium silicate is predominantly used in the making of welding electrodes.

While soluble silicates are completely inorganic and non-inflammable, non-explosive and relatively non-toxic, they do present a slight hazard being alkaline in nature. Suitable gloves, protection glasses and an overall suit are recommended when handling these products.

State-of-the-art technology is used to manufacture an exceptionally stable solution of sodium aluminate (stabilised) with a minimum of one-year shelf life. An online filtration unit is used to ensure that a very clear solution is obtained. The solution has applications as a flocculant in water treatment and as an element in the manufacture of molecular sieves and paper.

Each required raw material and finished product is statistically sampled and analysed in the laboratory to confirm it meets the specified quality standards. Continuous chemical and physical analysis is conducted during production to ensure stability of specifications.

Adwan Chemicals company quality policy, has adopted four basic principles throughout its business activities:

- Placing quality first in manufacturing.
- Clearly defining customer requirements and ensuring they are met at all times.
- Creating an environment for continuous improvement in the quality of products.
- Achieving business success through profitable growth and enhancing customer satisfaction.

Table 20: Typical Specifications of Silica Flour chemical Analysis

Chemical component	Wt %
SiO_2	98.40-99.00
Fe_2O_3	0.03-0.04
Al_2O_3	0.06-1.00
TiO_2	0.05-0.09

Table 21: Micronised Silica Grade MS100

Description	
This grade of micronised silica flour is manufactured from the superfine silica sand having a SiO_2 content of up to 99%.	
Recommended Applications: Construction, Ceramics, Filler materials, Fine glass industries & Adhesives.	
Typical Properties	
Bulk Density	1.03 g/cm^3
Oil Absorption	24g/100g
Specific Surface Area	0.92m^2/g
PH	7
Hardness	7 Moh's
Minimum Brightness	90
Chemical Composition	
SiO_2	98.8-99.1%
Fe_2O_3	0.025-0.04%
Al_2O_3	0.50-1.00%
TiO_2	0.04-0.09%
Up to 99% of the product pass through the 100-micron sieve.	

Table 22: Micronised Silica Grade MS75

Description	
This grade of micronised silica flour is manufactured from the superfine silica sand having a SiO_2 content of up to 99%.	
Recommended Applications	
Ceramics, Where it is deal for the glazing process. Filler material used in paints, Polymers, Concrete bricks and Mortar.	
Typical Properties	
Bulk Density	0.9g/cm^3
Oil Absorption	25g/100g
PH	7
Hardness	7 Moh's
Minimum Brightness	90
Chemical Composition	
SiO_2	98.8-99.1%
Fe_2O_3	0.025-0.04%
Al_2O_3	0.50-1.00%
TiO_2	0.04-0.09%
Up to 99% of the product pass through the 75-micron sieve.	

Table 23: Micronised Silica Grade MS63

Description	
This grade of micronised silica flour is manufactured from the super fine silica sand having a SiO_2 content of up to 99%.	
Recommended Applications	
Ceramics, Construction chemicals & filler Materials.	
Typical Properties	
Bulk Density	0.82 g/cm^3
Oil Absorption	26g/100g
PH	7
Hardness	7 Moh's
Minimum Brightness	90
Chemical Composition	
SiO_2	98.8-99.1%
Fe_2O_3	0.025-0.04%
Al_2O_3	0.50-1.00%
TiO_2	0.04-0.09%
Up to 99% of the product pass through the 63-micron sieve.	

Table 24: Micronised Silica Grade MS45

Description	
This grade of micronised silica flour is manufactured from the superfine silica sand having a SiO_2 content of up to 99%.	
Recommended Applications	
Filler materials, Construction Chemicals, Fibreglass and Chemicals.	
Typical Properties	
Bulk Density	0.79 g/cm^3
Oil Absorption	27g/100g
PH	7
Hardness	7 Moh's
Minimum Brightness	90
Chemical Composition	
SiO_2	98.8-99.1%
Fe_2O_3	0.025-0.04%
Al_2O_3	0.50-1.00%
TiO_2	0.04-0.09%
Up to 99% of the product pass through the 45-micron sieve.	

Applications include:

1. CERAMIC
   - Pure Quartz Sand, Flour, & Cristobalite Flour for Body & Glaze
   - Refractory bricks
   - Wall bricks
   - Sanitary ware
   - Table ware
   - Tiles.
2. CHEMICAL INDUSTRIES
   - Pesticides
   - Fertilisers
   - Pharmaceutical preparations.
3. CONSTRUCTION
   - Decorative stone
   - Cement tiles
   - Sand stone
   - Cellular concrete
   - Self levelling floors
   - Bricks
   - Roof tiles
   - Road asphalt
   - Bituminous roofing
   - Interior decoration.
4. FILLER MATERIAL (45 & 25 micron flours)
   - Paints
   - Polymer concrete
   - Silicon cement
   - Brick motor
   - Deco plaster & tile adhesives.

Table 25: Example of Silica Flour - finely ground crystalline quartz

CHEMICAL ANALYSIS		**TECHNICAL DATA**	
SiO_2	99.3-99.4%	Colour	White
Al_2O_3	0.2-0.3%	Specific Gravity	2.65g/cm^3
TiO_2	0.045%	Hardness (Mohs)	7
Fe_2O_3	0.03-0.035%	Loss on Ignition	0.17%
Cr_2O_3	0.0004%	Brightness	85-86%
CaO	trace	Oil Absorption	23g/100g
MgO	trace		

PARTICLE SIZE DISTRIBUTION Passing % Weight			
MICRONS	**GRADE 20**	**GRADE 63**	**GRADE 75**
100		99	98
74		98	96
63		95	92
40		89	83
32		75	68
20	100	47	45
12	92	25	22
8	75		
6	60	15	13
4	47	9	9
3	39		
2	28	5	5
1.5	14		
1	9	2	2
Surface area CILAS cm^2/g	8056		
Average particle size	4.4 microns		

PACKING - 25 kilo paper bags on pallets of 1000 kilos.

Table 26: DKI Quartz Flour 74/200 is a ground crystalline quartz for use in resin systems

CHEMICAL ANALYSIS		**TECHNICAL DATA**	
SiO_2	96.3%	Colour	Off-white
Al_2O_3	2.5%	Specific Gravity	2.65g/cm^3
Fe_2O_3	0.2%	Hardness (Mohs)	7
CaO	0.06%	Loss on Ignition	0.04%
MgO	0.05%		

PARTICLE SIZE DISTRIBUTION	
MICRONS	**PASSING % WEIGHT**
180	100
125	98
90	94
63	84
45	68
20	44

PACKING - 25 kilo paper bags on pallets of 1000 kilos.

MIN-U-SIL® is a high purity, high quality natural crystalline silica that is available exclusively through U.S. Silica Company. This ground silica sand is inherently bright, white, low in moisture, inert and at least 99.2% $Si0_2$. MIN-U-SIL is available in five uniform size distributions -5, 10, 15, 30 and 40 microns — and features unmatched fineness and consistency of particle size due to a special processing technique developed by U.S. Silica Company.

This special processing technique assures controlled particle size distribution which means the elimination of excessively coarse or fine particles. These properties combined with inertness and inherently low cost, make MIN-U-SIL the best quality filler/extender for a range of applications including paints and coatings, sealants, silicone rubber and epoxy.

The easy reference chart below identifies the applications and advantages of MIN-U-SIL. The charts on page three identify all U.S. Silica grades of MIN-U-SIL and list important information. The map on page four indicates the locations of the MIN-U-SIL producing plants. For coarser ground silicas, ask for our SIL-CO-SIL® brochure.

ARCHITECTURAL PAINTS

MIN-U-SIL is an inert, low-cost, functional extender that can effectively space TiO2 for added opacity in both waterborne and solvent-borne systems. Its hardness yields improved wear, burnish resistance, and durability in both interior and exterior coatings. Other important properties include low resin demand, anti-foaming properties, the ability to control sheen and excellent color acceptance.

POWDER COATINGS

Replaces up to 50% TiO_2 in formulations with no significant loss of hiding power. Inert and compatible with all known powder coating formulations, MIN-U-SIL is a high-quality, low-cost powder coatings filler.

TRAFFIC PAINT

High durability, inertness, abrasion resistance, color acceptance, high loading and low cost make MIN-U-SIL an outstanding traffic paint filler.

PROTECTIVE COATINGS

MIN-U-SIL offers superior resistance to corrosion, acid and heat. Also it's chemically inert.

SILICONE RUBBER

MIN-U-SIL is an excellent semi-reinforcing filler for silicone rubber. Inert, dielectric, MIN-U-SIL permits high loading and is compatible with all colloidal silica fillers. Does not adversely affect peroxide vulcanizing.

WIRE AND CABLE COATING COMPOUNDS

MIN-U-SIL delivers excellent resistance to heat. It's chemically inert and low cost.

ADHESIVES AND SEALANTS

MIN-U-SIL gives fine elastomer extension, requiring less power consumption for mixing equipment. It's inert and costs less. Use in polyester, epoxy and urethanes. Compatible with phenolics.

PLASTICS

As a filler in thermoplastics, MIN-U-SIL supplies uniformity, heat resistance, inertness and lower thermal expansion, all at a low cost. Offers excellent uniformity, low expansion rate and low cost in thermosets. Compatible with most resins, including polyester and epoxy.

CERAMICS

The high quality and consistent fineness of MIN-U-SIL can reduce or eliminate grinding time of ceramic glazes. In whiteware bodies, the fineness of MIN-U-SIL helps produce stronger products.

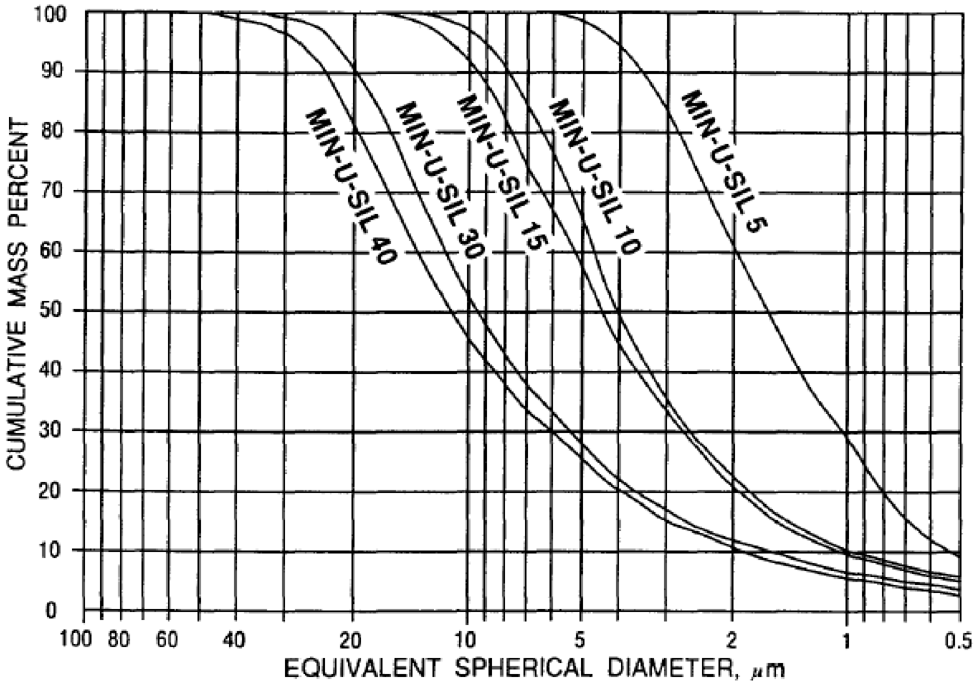
HIGH TEMPERATURE INSULATION

MIN-U-SIL is naturally heat resistant, chemically inert and provides high loadings.

EPOXY CASTINGS

MIN-U-SIL provides the durability and inertness necessary to enhance the physical strength of large epoxy castings such as laboratory countertops and other chemical resistant laboratory components. Enables high loading in electrical applications such as epoxy castings for circuit boards and ignition coils without compromising performance.

Typical Particle Size Distribution



Typical Properties And Chemical Analysis

Typical Properties	MIN-U-SIL 40	MIN-U-SIL 30	MIN-U-SIL 15	MIN-U-SIL 10	MIN-U-SIL 5
Particle Size (Sedigraph) Topsize Median Size	 40 11.5	 30 8.0	 15 4.8	 10 4.1	 5 1.7
Oil Absorption (D-1483)	22.0	23.0	33.0	33.3	42
Hegman Grind	4.5	5.25	6.75	7.0	7.75
Bulk Density Tapped Untapped	 — —	 63.0 48.5	 51.8 46.0	 44.8 42.7	 40.7 35.7
Specific Gravity	2.65	2.65	2.65	2.65	2.65
Pounds/Gallon	22.07	22.07	22.07	22.07	22.07
Optical Properties Hunter - Reflectance (Y) Hunter – Yellow Index	 88.6 4.1	 89.0 3.6	 92.0 2.8	 91.5 3.9	 92.5 4.1
PH	7.8	7.8	8.0	7.5	7.0
Chemical Analysis %					
$Si0_2$	99.6	99.6	99.7	99.5	99.2
Fe_20_3	0.03	0.03	0.01	0.03	0.06
Al_20_3	0.08	0.07	0.08	0.11	0.24
TiO_2	0.02	0.02	0.02	0.02	0.015
CaO	0.024	0.018	0.013	0.025	0.023
MgO	<.01	<.01	<.01	<.01	<.01
L.O.I.	0.16	0.15	0.19	0.23	0.34

21.7 VIETNAM

Table 27: Vietnam Silica Flour Physical & Chemical Properties

Appearance	White powder less than 75 mm (200 mesh)
Specific gravity	2.63 g/cm^3
Bulk density	1.12 t/m^3 (70 lb/cu.ft)
Absolute Volume	0.0456 gal/lb (0.4m^3)
Moisture Content	max 1% max.
HCl solubility	max 1%, max.
SiO_2 (by weight)	>= 98% by weight
pH	7-8

1. Recommended Treatment

DMC - SILICA FLOUR can be added in concentrations up to 50% (by weight of cement depending on the specific requirements. To produce optimum properties, approximately 35% by weight of Silica Flour is used. Normally silica flour is dry-blended with cement.

2. Packaging

DMC - SILICA FLOUR is packaged in 50 kg multi-wall Polypropylene sacks.

Table 28: Specification of Vietnam DMC Silica Flour

Chemical composition (Typical)	
CaO	0.50%
MgO	0.50%
Loss on Ignition	0.50%
Fe_2O_3	0.10%
SiO_2	95%
Volatile matter at 105^{o}C	0.5% Max.
Al_2O_3	0.5%
Physical Characteristics (Typical)	
Specific Gravity	2.65
pH (OF 10% Slurry)	7
Mean Refractive Index	1.55
Bulk Density (tapped) gms/cc	0.8
% Residue on 400 Mesh Sieve	0.5

Table 29: Health & Safety Aspects of Crystalline Silica Dust Exposure

Main industries and activities around the world in which silica exposure is likely		
Industry or activity	**Operations & tasks**	**Source materials**
Mining and related milling operations	Most occupations (underground, surface, mill) and mines (metal and non metal, coal), rock drilling, dredging	Ores, associated rock
Quarrying and related milling operations	Crushing stone, sand and gravel processing, stone monument cutting and abrasive blasting, slate work (e.g. pencil manufacturing), diatomite calcination	Sandstone, granite, flint, sand, gravel, slate, diatomaceous earth
Construction	Abrasive blasting of structures and buildings, highway and tunnel construction, excavation and earth moving and digging, masonry, concrete work, demolition, dry sweeping and brushing, pressurised air blowing, jack hammering, laying railroad track, removing rust or paint, sanding and scaling, replacement of asphalt roofing, and hauling, pouring, mixing, or dumping silica-containing materials	Sand, concrete, rock, soil, mortar, plaster, shingles
Glass, including fibreglass	Raw material processing, refractory installation and repair	Sand, crushed quartz, refractory materials
Cement	Raw material processing	Clay, sand, limestone, diatomaceous earth
Abrasives	Silicon carbide production, abrasive products fabrication	Sand, tripoli, sandstone
Ceramics, including bricks, tiles, sanitary ware, porcelain, pottery, refractories, vitreous enamels	Mixing, moulding, glaze or enamel spraying, finishing, sculpting, firing	Clay, shale, flint, sand, quartzite, diatomaceous earth
Iron and steel mills	Refractory preparation and furnace repair	Refractory material
Silicon and ferro-silicon foundries (ferrous and nonferrous)	Raw materials handling, casting, moulding and shaking out, abrasive blasting, fettling, furnace installation and repair	Sand, refractory material
Metal products, including structural metal, machinery, transportation equipment	Abrasive blasting	Sand
Shipbuilding and repair	Abrasive blasting	Sand
Rubber and plastics	Raw materials handling	Fillers (tripoli, diatomaceous earth)
Paint	Raw materials handling, site preparation	Fillers (tripoli, diatomaceous earth, silica flour)
Soaps and cosmetics	Manufacturing or occupational use of abrasive soaps and scouring powders	Silica flour
Roofing asphalt felt	Filling and granule application	Sand and aggregate, diatomaceous earth
Agricultural chemicals	Raw material crushing, handling, bagging; or dumping products or raw materials	Phosphate ores and rock

Main industries and activities around the world in which silica exposure is likely		
Industry or activity	**Operations & tasks**	**Source materials**
Jewellery	Cutting, grinding, polishing, buffing, etching, engraving, casting, chipping, sharpening, sculpting	Semiprecious gems or stones, abrasives, glass
Arts, crafts, sculpture	Pottery firing, ceramics, clay mixing, kiln repairs, abrasive blasting, sand blasting, engraving, cutting, grinding, polishing, buffing, etching, casting, chipping, sharpening, sculpting	Clays, glazes, bricks, stones, rocks, minerals, sand, silica flour
Dental material	Sand blasting, polishing	Sand, abrasives
Boiler scaling	Coal-fired boilers	Ash and concretions
Automobile repair	Abrasive blasting, sanding, removing paint and rust	Sand, metals, priming putty

22 APPENDIX - SPECIFICATION FOR COVERGLASS, ETC.

22.1 EXAMPLE OF A BUYER'S SPECIFICATION FOR LOW IRON GLASS SAND

1. These guidelines outline the general requirements for Silica Sand suitable for the manufacture of float glass within the NSG Group. The prime requirement is for a consistent, controlled and reliable material. The source and its associated processing must be sufficient to meet this need. A material which does not meet the quoted limits should not be automatically rejected, but should be discussed with the Technical Centre.

2. The following indicative figures give a quantitative indication of the desired material.

A. Chemical composition

		Limits	Maximum Variation.
Silica	(SiO_2)	97.0% min	± 0.3%
Aluminium Oxide	(Al_2O_3)	1.6% max*	± 0.1%
Ferric Oxide	(Fe_2O_3)	0.0080% max** (0.0050% pref)	± 0.005%
Calcium Oxide	(CaO)	0.1% max	± 0.05%
Sulphate	(SO_3)	0.02% max	
Carbon	(C)	0.02% max	
LOI		0.3% max	

*Where dry sand is used the maximum allowable alumina content may need to be lower to reduce the risk of segregation.
**The maximum iron may need to be lower if we are using a higher iron dolomite and/or limestone.
The material must not contain the following metallic elements or compounds of these elements at levels which could be detrimental to glass manufacture; Cr, Co, Cu, Mn, Ni, V.

B. Physical Properties

Moisture Content:

In some Pilkington plants only dry sand can be currently used due to batch plant design or climate. In the other plants the moisture content of the sand as received must not exceed 5%, and to achieve this mean value should be less than 4.3%, with a standard deviation of less than 0.35. The sand should have drained to around its natural moisture content. There must be no major shifts of moisture between deliveries.

Particle Size: Cumulative % Retained

Size	1000 µm	710 µm	600 µm	500 µm	425 µm	125 µm	105 µm	90 µm
ASTM Mesh			30 Mesh		40 Mesh		140 Mesh	
	Nil	0.2 max		2 max		95 min		99 min
Guide for USA			0.7 max		5 max		98 min	

D50 180 µm – 270 µm
Note - In exceptional circumstances products outside these limits may be considered, but they are likely to affect furnace life and/or glass quality.

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