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GRAVEL INVESTIGATION
AREA 9 (KIMEA PIT)
SIERRA-YOYO-DESAN ROAD AREA GRAVEL INVESTIGATION
NORTHEASTERN, BC

Submitted to:

New Ventures Branch
Ministry of Energy and Mines
Victoria, British Columbia

Submitted by:

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TABLE OF CONTENTS

Page #

LIST OF FIGURES (INCLUDED IN APPENDIX A)

LIST OF TABLES

LIST OF CHARTS

LIST OF APPENDICES

ATTACHMENTS

1.0 INTRODUCTION

The British Columbia Ministry of Energy and Mines (MEM) retained AMEC Earth & Environmental Limited (AMEC) to conduct gravel investigations in the Sierra-Yoyo-Desan Road (SYD Road) area in northeastern British Columbia. This report details the findings of the Level 1 (detailed) Gravel Investigation for Area 9 (Kimea Pit) in the general SYD Road area. The area is also referred to by the Ministry of Transportation (MoT) as Gravel Reserve 908053. The scope of services for this work is detailed in AMEC's proposal of 9 January, 2003 to the MEM. Note that the results of the Level 1 (Detailed) Gravel Investigation are also summarized in a separate summary report provided to MEM.

The study area was located south of km 13 of the Wildboy Road that is accessed by driving to the end of the SYD Road (approximately km 187) then to the end of the Highgrade Road (approximately km 18). The existing Kimea Pit is located along the northern side of Kimea Creek. Figures 1 and 2 (Appendix A) show the location of Area 9.

2.0 SCOPE OF SERVICES

AMEC's scope of services was to complete a Level 1 (Detailed) Gravel Investigation for Area 9. The Level 1 (Detailed) Gravel Investigation included the following general tasks:

1) Collection and review of background data
2) Investigation planning
3) Field investigation (test pitting)
4) Laboratory testing
5) Analysis, drafting, and reporting

These tasks are described in more detail in the sections below.

3.0 METHODOLOGY

Seventy Five (75) test pits (TP03-9-01 through 75) were excavated with a Komatsu 400 tracked excavator on February 26, 2003 (TP03-9-01 and 03) and with a John Deere 230LC tracked excavator from March 5 to 10, 2003 (TP03-9-04 to 75). The equipment was provided by Kledo Construction Ltd. The test pits were logged by Bradley Jackman, A.ScT., of AMEC according to the Modified Unified Classification System for soils as shown in Appendix E. Test Pit logs are included in Appendix B.

Typically test pits were terminated at a depth of 3.2 to 4.0 m if granular material was not encountered. For the purpose of this project, granular material was defined as any soil with less than 15% fines (silt and clay) by weight. If granular material was encountered, the test pit was advanced to the full reach of the excavator. Note that in some test pits, sloughing and/or a water table may have limited the depth of excavation.

A photograph of excavated soil was taken at each test pit. All site photographs are included in digital format in a compact disk included with this report. Locations of the test pits were ribboned in the field. Additionally, the test pit coordinates were taken with a hand-held GPS receiver where satellite coverage was available.

At least one bulk soil sample was taken from each test pit, if granular material was encountered. Samples were shipped to AMEC's Prince George Soils Laboratory where 49 wash sieve grain size analysis were conducted to verify the field visual soil classifications (refer to Appendix C for results). Additionally, 3 degradation and 2 sand equivalent tests were conducted on selected samples.

4.0 BACKGROUND/PREVIOUS WORK

Blyth et al. (2003) presented the results of aggregate potential mapping on fourteen 1:50 000 scale maps. The mapping for the Kimea Creek area is shown in Figure 3 (Appendix A). The Kimea Pit area was delimited as having a high aggregate potential.

The MoT (Beeson 1985 and 1985a) detailed the results of a granular resource study conducted following a resistivity survey of the general study area. The study area was divided into 3 areas based on material gradations following the excavation of 48 test pits by Beeson (1985). Note that the test pits were typically only 3.0 to 3.1 m depth. Figure 4 (Appendix A) shows the approximate locations of Area A, B and C. Note that Area C was not delimited in Figure 2 provided in Beeson's (1985) report. MoT test pit logs are included in Appendix B. Soil laboratory test results are summarized in Table 1 on the next page.

Based on the gradations and laboratory testing, Besson (1985) stated that with processing (where applicable) the material would be suitable for:

<u>Area A and B</u>: 50 mm and 25 mm well graded base, select granular sub-base
<u>Area C</u>: 25 mm well graded base, select granular sub-base, winter sand

Table 1: MoT Kimea Creek Prospect Gravel Investigation Results			
Area	**Area A**	**Area B**	**Area C**
Volume Calculations			
Overburden Thickness	0.6	0.2	0.6
Granular Thickness	2.4*	2.9*	2.5*
Overburden Volume	25 000 m^3	4 000 m^3	150 000 m^3
Volume of Granular Material	100 000 m^3*	50 000 m^3*	485 000 m^3*
Material Gradation			
Oversize	16%	26%	9%
Gravel	41%	34%	26%
Sand	40%	36%	60%
Fines (silt and clay)	3%	4%	5%
Aggregate Quality Tests			
Sand Equivalent tests	41-76	26-41	20-59
Degradation tests	27-41	30-41	30-37
Magnesium Sulphate (coarse/fine)**	3.5/9.7	na	na
Bulk Relative Density (coarse/fine)	2.64/2.62	2.63/2.62	na
Absorption (coarse/fine)	1.12/1.28	1.77/1.94	na
Fracture (count/mass)	Na	76/76	na
Petrographic Composition			
Sedimentary	29%	32%	na
Metamorphic	26%	37%	na
Igneous	35%	31%	na
Good	38%	40%	na
Fair	62%	60%	na
Poor	0.2	0	na
Deleterious	0	0	na

*Beeson noted that "as all test pits bottomed in granular soils actual granular depths and volumes may be greater (p.6)."

**Reported in Beeson (1985a)

Following the gravel investigation the Kimea Pit was developed. Subsequent laboratory testing of a stockpile present in the pit indicated the soil had:

Average Material Gradation:
Oversize: none reported, Gravel: 52-63% Sand: 31-38% Fines (silt and clay): 7-10%
Sand Equivalent: 57 (one test)
Degrade Factor: 39 (one test)

Thurber (2001) reported on the results of a granular resource study which indicated that there was approximately 2 140 000 m^3 of granular material remaining within the reserve. The study is considered to be a reconnaissance level study by AMEC considering that only 21 test pits were excavated. Thurber (2001) did not report on granular gradation characteristics or quality, nor did it appear that previous work in the study area had been incorporated into the results of

Thurber's (2001) study. The location of Thurber's (2001) test pits and area delineated as having granular material are also shown in Figure 4 (Appendix A). A copy of Thurber's (2001) test pits logs are also included in Appendix B.

5.0 SITE OBSERVATIONS

5.1 GENERAL

The following airphoto/site observations were made:

1. The existing Kimea Pit was located in the base of the Kimea Creek valley, north of the Kimea Creek channel.

2. The Kimea Creek valley appeared to be a meltwater channel incised during/following the retreat of the last glacier from the general study area as indicated by the "underfit" Kimea Creek channel (i.e. Kimea Creek could not have included the valley, it is too small).

3. The Kimea Creek valley was typically 800 m wide (measured at the valley crest) and 30 to 40 m deep. The Kimea Creek valley side slopes appeared to range from 15° to 30°.

4. The plateau above the Kimea Creek Valley appeared to have gently undulating (slopes typically less than 5°) terrain, which was typically poorly drained, and predominantly muskeg.

5. The study area typically included areas of significant (non-muskeg) timber growth within and on the plateau above the north edge of the Kimea Creek Valley. These areas were interpreted by AMEC as having well draining soils which may indicate granular deposits. The study area was generally bounded by a stream and gully to the west and the Wildboy Road to the east.

6. Areas of granular potential delimited by AMEC within the general study area (refer to Figure 4 and 5, Appendix A) included:

    a. A Kimea Creek terrace located on the north side of the current stream channel. The terrace appeared to range from 8 to 15 m above the elevation of the current Kimea Creek channel.

    b. An area surrounding an unnamed gravel pit on the plateau north of the Kimea Creek valley and Wildboy Road.

7. There was numerous seismic lines in the area (refer to Figure 4, 5 and 6). In addition to the seismic lines, the Kimea Creek terrace surrounding Kimea Pit had a series of exploration trails (assumed to be built for the previous petroleum exploration surveys, MoT resistivity surveys and MoT test pitting). Access to Kimea Pit was via an all-season road that intersects km 13 of the Wildboy Access Road.

Stereo airphoto coverage for the general study area is included in Appendix F (color copies of 1:20 000 scale color airphotos 30BCC97017 no. 143 and 144).

5.2 SUBSURFACE OBSERVATIONS

Table 2 provides a summary of soil conditions encountered by test pitting the Area 9 study area.

Table 2: Test Pit Summary: Area 9 (Kimea Pit)

Test Pit (TP03-E-#)	Depth (m)	Overburden/Non-Granular Material (m)	Granular Material (m)	Description of Granular Material*	Underlying Non-granular Material (m)	Water Table (m)
01	5.0		0.0-5.0	Sand and Gravel, SP		4.0
02	7.0		0.0-7.0	Sand, SP		6.0
03	7.5		0.0-7.5	Gravel and Sand, GW (0.0-2.2) Sand and Gravel, SP (2.2-7.5)		6.0
04	7.0		0.0-7.0	Gravel, sandy, GP-GM (0.0-1.8) Sand, some gravel, SP (1.8-7.0)		6.8
05	4.0		0.0-4.0	Gravel and Sand, GW		2.6
06	6.0		0.0-6.0	Sand and Gravel, SP		
07	6.5	0.0-0.1	0.1-6.5	Sand and Gravel, SW		
08	6.0	0.0-0.1	0.1-6.0	Sand, gravelly, SP		
09	6.0	0.0-0.1	0.1-6.0	Sand, some gravel, SP		
10	6.0		0.0-6.0	Sand, gravelly, SP		
11	6.0	0.0-0.4	0.4-6.0	Sand and Gravel, SP		
12	5.0	0.0-0.1	0.1-5.0	Sand, gravelly, SP		
13	5.0	0.0-0.6	0.6-5.0	Sand, gravelly, SP		
14	5.5	0.0-0.1	0.1-5.5	Sand, gravelly, SP		
15	5.0	0.0-0.1	0.1-5.0	Sand, some gravel, SW		
16	5.5	0.0-0.1	0.1-5.5	Sand, some gravel, SP		5.5
17	6.0	0.0-2.8	2.8-6.0	Sand, SP-SM		6.0
18	5.0	0.0-5.0				4.0
19	5.5	0.0-0.8	0.8-5.5	Sand (SP-SM)		
20	6.5	0.0-6.5		(Silty Sand)		
21	5.0	0.0-1.2	1.2-5.0	Sand, gravelly, SP		
22	6.0	0.0-2.6	2.6-6.0	Sand, some gravel, SP-SM		
23	5.0	0.0-0.1	0.1-1.7	Sand and Gravel, SP	1.7-5.0	
24	6.0	0.0-0.1	0.1-6.0	Sand, SP-SM		
25	5.0	0.0-1.5	1.5-5.0	Sand, SW		5.0
26	4.0	0.0-0.8	0.8-3.6	Sand, SP-SM	3.6-4.0	
27	6.0	0.0-0.1	0.1-3.6	Sand and Gravel, SP-SM	3.6-6.0	
28	6.0	0.0-0.1	0.1-6.0	Sand and Gravel, SW		
29	5.0	0.0-1.3	1.3-5.0	Sand, SP		
30	4.5	0.0-0.1	0.1-4.5	Sand and Gravel, SP		
31	5.0	0.0-0.1	0.1-5.0	Sand, gravelly, SP		
32	4.0	0.0-0.1	0.1-4.0	Gravel and Sand, GW (0.1-3.2) Sand, some gravel, SW (3.2-4.0)		
33	4.0	0.0-0.1	0.1-4.0	Sand and Gravel, SP		
34	4.5	0.0-0.1	0.1-4.5	Sand, gravelly, SP-SM		
35	4.0	0.0-0.1	0.1-4.0	Sand, gravelly, SW		2.8
36	4.0	0.0-0.1	0.1-2.3	Sand and Gravel, SP-SM	2.3-4.0	
37	4.0	0.0-0.8	0.8-1.3	Gravel, sandy, GW	1.3-4.0	
38	4.0	0.0-4.0				
39	3.0	0.0-0.1	0.1-3.0	Sand, gravelly, SP-SM		1.8
40	5.0	0.0-5.0				
41	5.0	0.0-5.0				
42	5.0	0.0-0.1	0.1-5.0	Sand, gravelly, SP		
43	4.0	0.0-4.0				3.6
44	4.0	0.0-0.1	0.1-4.0	Sand and Gravel, SP-SM		
45	3.5	0.0-0.1	0.1-3.5	Gravel**, sandy, GM (0.1-1.2)		

Table 2: Test Pit Summary: Area 9 (Kimea Pit)

Test Pit (TP03-E-#)	Depth (m)	Overburden/Non-Granular Material (m)	Granular Material (m)	Description of Granular Material*	Underlying Non-granular Material (m)	Water Table (m)
				Sand, gravelly, SP-SM (1.2-3.5)		
46	5.0	0.0-0.1	0.1-3.7	Sand and Gravel, SP	3.7-5.0	
47	3.6	0.0-3.6				3.2
48	3.2	0.0-3.2				
49	3.5	0.0-3.5				
50	3.5	0.0-0.1	0.1-1.9	Sand, gravelly, SP	1.9-3.5	
51	2.2	0.0-2.2				2.1
52	2.0	0.0-2.0				
53	3.0	0.0-0.1	0.1-1.3	Gravel and Sand**, GM	1.3-3.0	
54	2.5	0.0-2.5				
55	3.0	0.0-3.0				
56	3.0	0.0-3.0				
57	3.0	0.0-3.0				
58	4.5	0.0-2.4	2.4-4.5	Gravel and Sand, GP-GM		4.0
59	3.2	0.0-3.0	3.0-3.2	Gravel and Sand, GW		
60	4.0	0.0-0.1	0.1-4.0	Sand, gravelly, SP		
61	4.0	0.0-0.6	0.6-4.0	Sand, gravelly, SW		
62	2.8	0.0-2.8				
63	3.6	0.0-0.1	0.1-3.6	Sand, SW		3.4
64	2.0		0.0-0.7	Gravel and Sand, GW	0.7-2.0	0.7
65	6.0		0.0-3.4	Sand and Gravel, SW	3.4-6.0	
66	5.0	0.0-5.0				
67	6.0	0.0-6.0				
68	7.0	0.0-1.1	1.1-7.0	Sand, gravelly, SP		
69	4.0	0.0-4.0				
70	6.0	0.0-0.9 1.3-1.9	0.9-1.3 1.9-6.0	Sand and Gravel, SW (0.9-1.3) Gravel and Sand, GW (1.9-6.0)		
71	6.0	0.0-0.2	0.2-6.0	Sand and Gravel, SP-SM		
72	5.5	0.0-0.9	0.9-5.5	Sand, gravelly, SP		
73	3.0	0.0-3.0				
74	5.0	0.0-2.4	2.4-5.0	Sand, some gravel, SP		
75	4.0	0.0-4.0				

*Note that soils from thin layers (less than 0.5 m thick) may not be included in the description (refer to test pit logs in Appendix B)
**Soils that appeared to contain between 13 and 17 percent fines (silt and clay)
Trace is 1-10% content by weight; some is 11-20% content by weight

AMEC used the information presented in Table 2 to divide the study area into sections using the following general process:

1. Areas with granular material (defined as having less than 15% silt and clay content) were separated from areas where non-granular material (defined as having more than 15% silt and clay content) was encountered. Typically the boundary line was drawn through the bisector of a line drawn between the adjacent granular/non-granular test pits.

2. Following the separation of areas of granular and non-granular material (referred to as Section 2), granular areas with similar granular characteristics (*for example,* areas that are predominately sand from areas that are predominantly gravel) were separated using the method detailed in Item 1 above to determine boundary lines.

Note that other factors, such the presence or absence of a water table and topographic constraints may also be used to delimit sections. As an example, Section 1A was separated from Section 1B by the existing gravel pit and Section 4A was separated from Section 1A/1B by the Kimea Creek valley slope.

Based on the methodology presented above, Area 9 was divided into the following sub-sections detailed in Table 3:

Table 3: Granular Potential, Area 9 (Kimea Pit)

Section	Approx. Area (m^2)	Test Pits within section (TP03-9-)	Potential for granular material	Comments
1A/1B	72 000	65, 68, 70, 71, 72, 74	Yes	Section 1A: Area with granular potential west of existing pit (TP03-9-68 and 70) or on the pit floor of the existing pit (TP03-9-65) Section 1B: Area with granular potential east of existing pit (TP03-9-71, 72 and 74) The soil appears to be predominately sand and gravel, gravelly sand with sand (some, 11 to 20% content by weight, gravel) encountered in TP03-9-74. No water tables were encountered in Section 1A/1B
2	Not measured	17, 18, 20, 37, 38, 40, 41, 43, 47, 48, 49, 51, 52, 54, 55, 56, 57, 58, 59, 62, 64, 66, 67, 69, 73, 74, 75	No	Soils were typically either fine sand, silty sand, silt or clay. Where granular material was found, there was a water table and overburden (TP03-9-17 and 58) greater than 2 m thick.
3A	94 000	09, 16, 19, 61, 63	Yes, but sand	Soils were typically sand with some or trace (1 to 10% content by weight) gravel. A water table was encountered in TP03-9-16, 25 and 63 at 5.5, 5.0 m and 3.4 m depth, respectively.
3B	52 000	15, 24, 25, 26, 29		
4A	190 000	08, 10, 12, 13, 14, 21, 22, 23, 60	Yes	Soils encountered in test pits in Section 4A/4B were predominately gravelly sand with about 5% fines (silt and clay). Note that in TP03-9-23 silty gravelly sand was encountered. Water tables were encountered in TP03-9-01, 02, 35 and 39 at 4.0 m, 6.0 m, 2.8 m and 1.8 m depth, respectively.
4B	154 000	27, 28, 34, 35, 36, 39, 42, 44, 45		
5	138 000	01, 02, 03, 04, 05, 06, 07, 11, 30, 31, 32, 33	Yes	This section was predominately sand and gravel or gravel with up to 40% oversize material with approximately 2% fines. Note that soils appeared to become finer (sandy gravel or sand) with depth in TP03-9-01, 02 and 03. Water tables were encountered in TP03-9- 03, 04 and 05 at depths of 6.0 m. 6.8 m and 2.6 m, respectively.
6	131 000	46, 50, 53	Yes, but thin deposit	Soils were typically sand and gravel or gravelly sand overlying silt and/or clay. Note that these deposits were relatively thin (less than 2 m) and spread out over a large area.

6.0 GRANULAR CHARACTERISTICS

For the purpose of this report, the soil laboratory test results are presented on a section-by-section basis as detailed below. Note that Section 2 contained non-granular material and will not be discussed in this or later sections of this report.

Gradations presented were determined from laboratory wash sieve testing. Cobble and boulder size fractions (>75mm) were estimated from field observations and were not sampled. Appendix C contains the individual sieve test results for each sample detailed below.

6.1 SECTION 1A/1B

Table 4 presents a summary of the wash sieve tests for Section 1A/1B.

Table 4: Summary of Laboratory Testing Results Section 1A/1B*

Test Pit	Depth (m)		Soil Class*	Fines <0.075 mm (%)	Sand <4.75 mm (%)	Gravel (%)		Additional** Oversize >75 mm (%)	Max. size (mm)
	From	To				fine <25 mm	coarse 25-75 mm		
65	1.5	2.5	SW	5	48	33	14	10	200
68	2.0	4.0	SP	4	70	19	7	10	100
70	2.2	4.0	SW	4	57	27	12	0	
71	2.5	4.5	SP-SM	6	56	19	19	5	200
72	2.2	4.0	SP	4	62	24	10	5	150
74	3.0	4.5	SP	5	81	12	2	0	
Averages				***5***	***62***	***23***	***10***	***5***	

* The modified unified classification system for soils was used to classify soil samples. SP= poorly graded sand, SW=well graded sand, SM/SW= well graded sand with 12% to 17% fines, GP=poorly graded gravel and GW= well graded gravel.

** The additional oversize percentage was a field estimate.

Chart 1 details the overall average gradation of samples excluding any oversize material (>75 mm). Chart 2 details the overall average gradation of samples including estimated oversize material (>75 mm).

Chart 1: Section 1A/1B Overall Average Gradation (Excluding Oversize Material)

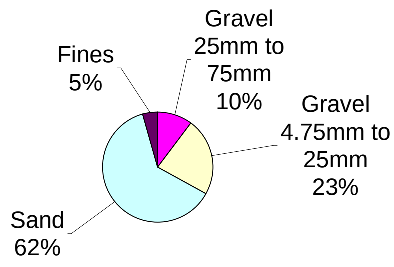
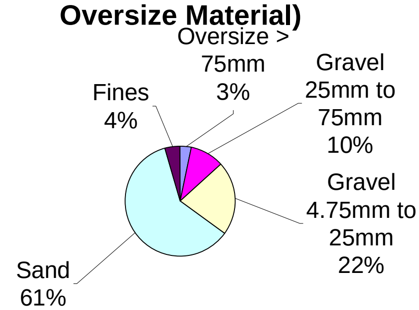


Chart 2: Section 1A/1B Overall Average Gradation (Including Oversize Material)



Appendix D provides a plot of the average gradations curves excluding (Chart D1-1) and including (Chart D1-5) the oversize portion. The resulting overall average gradation of the granular materials indicates the soil is gravelly sand with a trace silt and a trace cobbles (up to 200 mm diameter).

Table 5 details the results of aggregate quality testing done on samples from Section 1A/1B.

Table 5: Aggregate Quality Testing, Section 1A/1B

Section	Test Pit	Sample Depth (m)	Test	Test Result	MoT Specification
1A	TP03-9-68	2.0-4.0	Degradation	40.0	>35 for all aggregates
1B	TP03-9-71	2.5-4.5		20.0	
1B	TP03-9-71	2.5-4.5	Sand Equivalent	49.0	>40 for 25 and 50 mm base course aggregates >20 for sub-base aggregate and surfacing aggregate

Based on the results of the aggregate testing it appears that the degradation test results are below MoT specifications in the TP03-9-71 sample, but above the standard in the TP03-9-68 sample. The sand equivalent test result indicated that the sample from TP03-9-71 contained non-plastic fines and meets the MoT specification for all aggregate materials.

6.2 SECTION 3A/3B

Table 6 presents a summary of the wash sieve tests for Section 3A/3B.

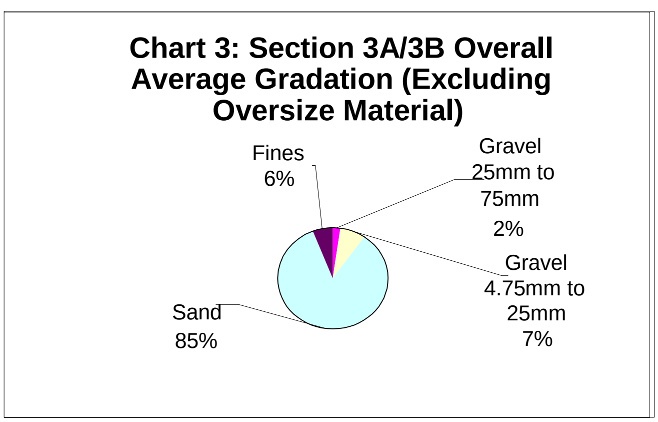
Table 6: Summary of Laboratory Testing Results Section 3A/3B *

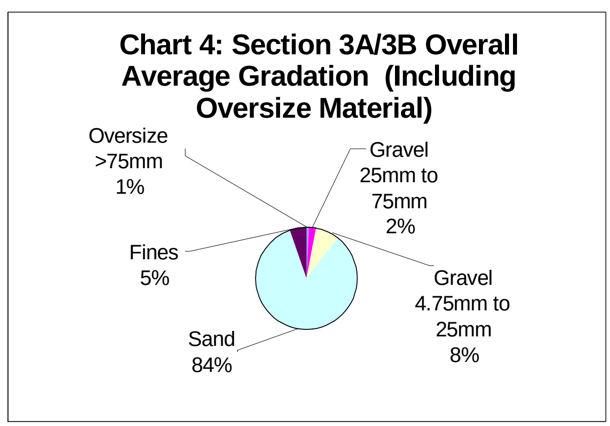
Test Pit	Depth (m)		Soil Class*	Fines <0.075 mm (%)	Sand <4.75 mm (%)	Gravel (%)		Additional ** Oversize >75 mm (%)	Max. size (mm)
	From	To				fine <25 mm	coarse 25-75 mm		
09	1.5	3.0	SP	3	85	11	1	0	
15	2.0	5.0	SW	3	82	11	4	1	150
16	4.0	5.5	SP-SM	7	81	10	2	0	
19	2.5	5.5	SW	9	87	2	2	0	
26	1.5	2.5	SP-SM	10	82	8	0	0	
29	2.0	5.0	SP	3	89	4	4	5	100
63	2.0	3.0	SW	4	90	3	3	0	
Averages				***6***	***85***	***7***	***2***	***1***	

* The modified unified classification system for soils was used to classify soil samples. SP= poorly graded sand, SW=well graded sand, SM/SW= well graded sand with 12% to 17% fines, GP=poorly graded gravel and GW= well graded gravel.

** The additional oversize percentage was a field estimate.

Chart 3 details the overall average gradation of samples excluding any oversize material (>75 mm). Chart 4 details the overall average gradation of samples including estimated oversize material (>75 mm).





Appendix D provides a plot of the average gradations curves excluding (Chart D3-1) and including (Chart D3-5) the oversize portion. The resulting overall average gradation of the granular materials indicates the soil is a sand, a trace gravel, a trace silt and a trace cobbles (approximately 1%).

6.3 SECTION 4A/4B

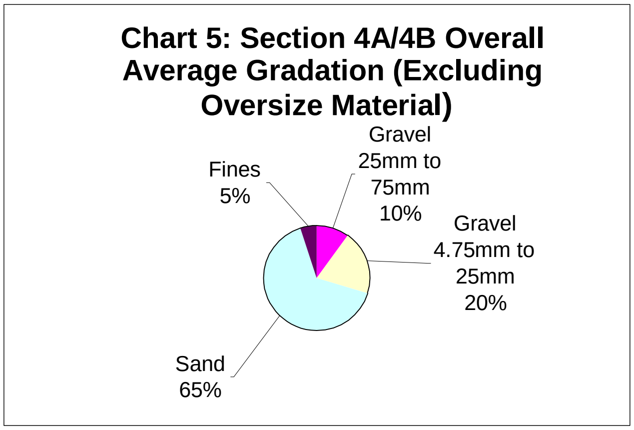
Table 7 presents a summary of the wash sieve tests for Section 4A/4B.

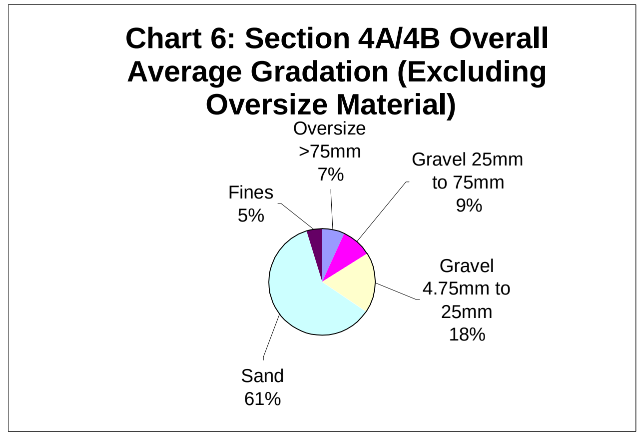
Table 7: Summary of Laboratory Testing Results Section 4A/4B *

Test Pit	Depth (m)		Soil Class*	Fines <0.075 mm (%)	Sand <4.75 mm (%)	Gravel (%)		Additional** Oversize >75 mm (%)	Max. size (mm)
	From	To				fine <25 mm	coarse 25-75 mm		
08	1.0	6.0	SP	4	63	21	12	10	200
10	4.0	6.0	SP	4	72	18	6	1	100
12	1.0	3.0	SP	2	75	12	11	1	100
13	3.0	5.0	SP	3	68	13	16	2	150
14	2.0	4.0	SP	3	75	13	9	5	200
21	1.2	4.0	SP	5	74	16	5	0	
22	1.5	4.0	SP-SM	8	69	8	15	5	100
23***	0.0	5.0	GM	29	44	18	9	5	150
27	1.0	5.0	SP-SM	10	47	31	12	10	200
28	1.0	5.0	SW	3	60	29	8	15	200
34	1.5	2.5	SP-SM	6	62	22	10	15	250
35	2.0	3.0	SW	4	73	16	7	2	150
36	1.2	1.7	SP-SM	7	54	33	6	2	150
39	1.0	2.5	SP-SM	9	58	22	11	2	100
42	1.5	3.0	SP	2	77	12	9	30	200
44	1.4	2.0	SP-SM	6	57	29	8	20	250
45	2.0	3.0	SP-SM	7	60	27	6	5	150
60	1.5	3.5	SP	4	66	13	17	10	150
Averages				***5***	***65***	***20***	***10***	***8***	

* The modified unified classification system for soils was used to classify soil samples. SP= poorly graded sand, SW=well graded sand, SM/SW= well graded sand with 12% to 17% fines, GP=poorly graded gravel and GW= well graded gravel.
** The additional oversize percentage was a field estimate.
*** Not included in overall gradation as soil sample included non-granular material encountered from 1.7 to 5.0 m depth.

Chart 5 details the overall average gradation of samples excluding any oversize material (>75 mm). Chart 6 details the overall average gradation of samples including estimated oversize material (>75 mm).





Appendix D provides a plot of the average gradations curves excluding (Chart D4-1) and including (Chart D4-5) the oversize portion. The resulting overall average gradation of the granular materials indicates the soil is a gravelly sand with a trace silt, a trace cobbles and a trace boulders (to 250 mm diameter).

6.4 SECTION 5

Table 8 presents a summary of the wash sieve tests for Section 5.

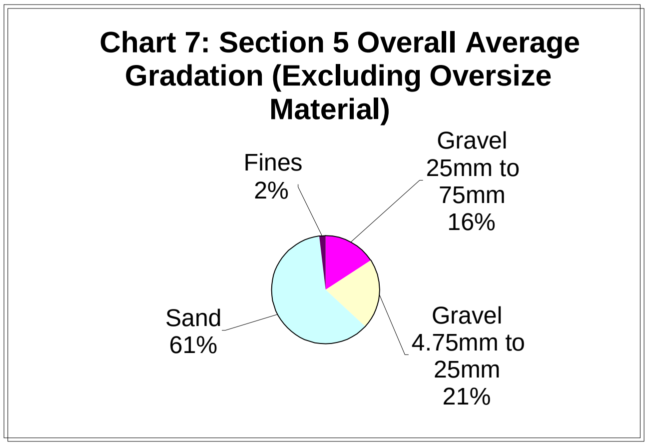
Table 8: Summary of Laboratory Testing Results Section 5 *

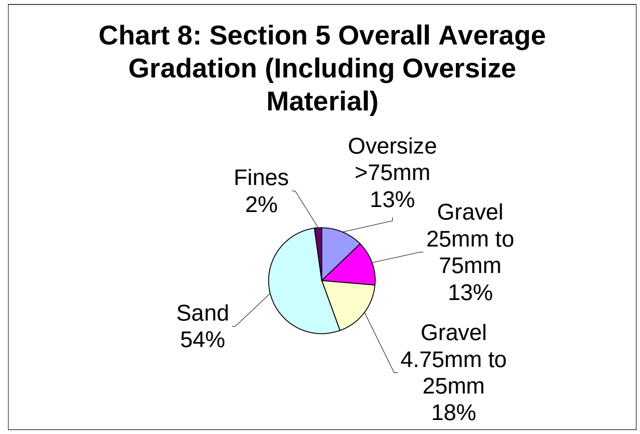
Test Pit	Depth (m)		Soil Class*	Fines <0.075 mm (%)	Sand <4.75 mm (%)	Gravel (%)		Additional** Oversize >75 mm (%)	Max. size (mm)
	From	To				fine <25 mm	coarse 25-75 mm		
01	3.0	4.0	SP	2	64	15	19	5	200
02	0.5 4.5	4.0 5.5	SP SP	2 2	83 73	8 14	7 11	5	200
03	4.5	7.0	SP	3	49	32	16	5	200
04	2.5	5.0	SP	2	84	9	5	5	150
05	2.5	3.5	GW	4	45	42	9	10	200
06	3.0	5.0	SP	3	51	20	26	20	200
07	2.0	5.5	SW	2	62	21	15	20	200
11	2.0	4.0	SP	2	54	23	21	20	200
30	2.0	4.5	SP	2	56	18	24	25	200
31	1.5	4.5	SP	3	66	20	11	20	250
32	1.0	2.5	GW	3	48	24	25	40	300
33	1.0	4.0	SP	3	55	25	17	30	200
Averages				***2***	***61***	***21***	***16***	***17***	

* The modified unified classification system for soils was used to classify soil samples. SP= poorly graded sand, SW=well graded sand, SM/SW= well graded sand with 12% to 17% fines, GP=poorly graded gravel and GW= well graded gravel.

** The additional oversize percentage was a field estimate.

Chart 7 details the overall average gradation of samples excluding any oversize material (>75 mm). Chart 8 details the overall average gradation of samples including estimated oversize material (>75 mm).





Appendix D provides a plot of the average gradations curves excluding (Chart D5-1) and including (Chart D5-5) the oversize portion. The resulting overall average gradation of the granular materials indicates the soil is a sand and gravel, with a trace to some cobbles and a trace boulders (up to 300 mm diameter).

Table 9 provides a summary of the aggregate quality tests conducted on samples from Section 5.

Table 9: Aggregate Quality Testing, Section 5					
Section	**Test Pit**	**Sample Depth (m)**	**Test**	**Test Result**	**MoT Specification**
5	TP03-9-03	4.5-7.0	Degradation	46.7	>35 for all aggregates
		4.5-7.0	Sand Equivalent	46.5	>40 for 25 and 50 mm base course aggregates >20 for sub-base aggregate and surfacing aggregate

Given the amount of testing previously conducted by Beeson (1985), aggregate quality testing was not performed with the exception of one sample from TP03-9-03 which was taken from a depth significantly below the maximum depth of exploration of the original MoT investigation.

The results of the tests indicated that the material met the MoT specifications for both degradation and sand equivalent tests.

6.5 SECTION 6

Table 10 presents a summary of the wash sieve tests for Section 6.

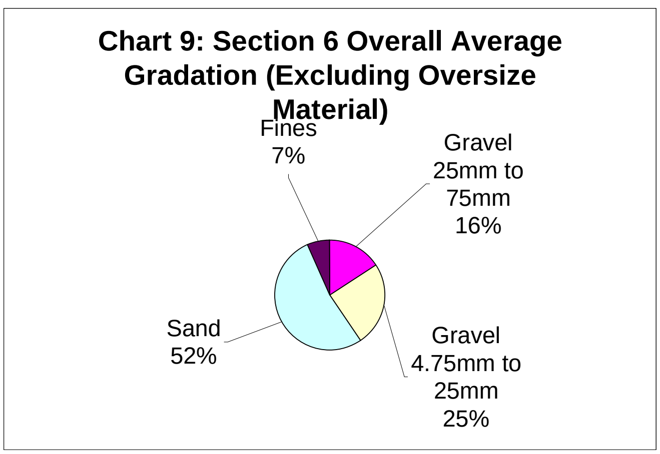
Table 10: Summary of Laboratory Testing Results Section 6*

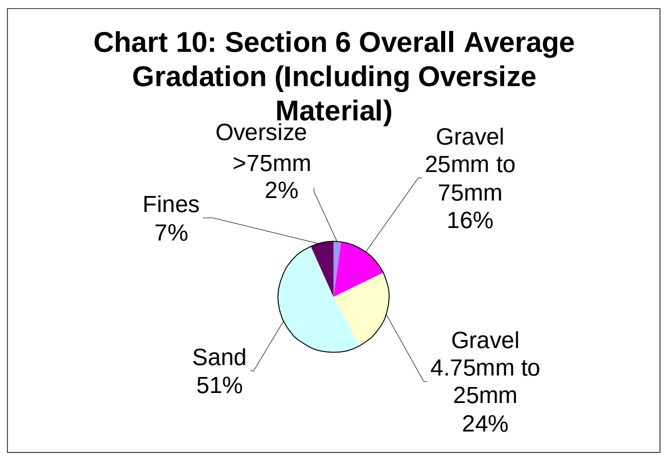
Test Pit	Depth (m)		Soil Class*	Fines <0.075 mm (%)	Sand <4.75 mm (%)	Gravel (%)		Additional** Oversize >75 mm (%)	Max. size (mm)
	From	To				fine <25 mm	coarse 25-75 mm		
46	1.0	2.5	SP	3	55	24	18	3	200
50	1.0	1.5	SP	3	63	30	4	2	150
53	0.8	1.3	SM	14	40	21	25	2	150
Averages				***7***	***52***	***25***	***16***	***2***	

* The modified unified classification system for soils was used to classify soil samples. SP= poorly graded sand, SW=well graded sand, SM/SW= well graded sand with 12% to 17% fines, SP/SW=borderline poorly graded to well graded sand, GP=poorly graded gravel and GW= well graded gravel.

** The additional oversize percentage was a field estimate.

Chart 9 details the overall average gradation of samples excluding any oversize material (>75 mm). Chart 10 details the overall average gradation of samples including estimated oversize material (>75 mm).





Appendix D provides a plot of the average gradations curves excluding (Chart D6-1) and including (Chart D6-5) the oversize portion. The resulting overall average gradation of the granular materials indicates the soil is a sand and gravel with a trace silt and a trace cobbles.

7.0 GRANULAR QUANTITY

Table 11 provides an estimate of potential granular quantity in each section.

Table 11: Potential Granular Material Volumes. Area 9, (Kimea Pit)

Section	Area (m^2)	Type of Granular Material	Average Thickness (m)		Potential Volume (m^3)	
			Overburden	Granular Material	Overburden	Granular Material
1A/1B	72 000	Sand and gravel/gravelly sand	1.2	4.7	86 000	338 000
3A/3B	146 000	Sand with some or trace gravel	0.6	4.3	88 000	628 000
4A/4B	344 000	Gravelly sand	0.3	4.0	103 000	1 376 000
5	138 000	Sand and gravel	0.1	5.1	14 000	704 000
6	131 000	Sand and gravel to gravelly sand	0.1	1.7	13 000	223 000

-Note that these volumes do not include allowances for pit slopes or set backs from roadways etc.
-Volumes do include allowances for a 0.5 m working surface over silt or clay or a water table

The potential granular material quantity is based on the following information and necessary assumptions:

1. The estimate is limited to the maximum depth of exploration of the test pits.
2. AMEC considered that a 0.5 m working surface of granular material would be left at the base of any pit excavation above any silt and clay layer and/or water table encountered. As an example, if gravel were encountered from 0.0 to 3.0 m depth with a water table at 2.5 m depth, then the total granular thickness used would be 2.0 m. This considers that during granular extraction, the gravel from 2.0 to 2.5 m depth would be left as a working surface.
3. There were

4. Depths of overburden and granular thickness are based on the average of all test logs in each section. Volumes were calculated by multiplying the average depth by the section area.
5. There were no setbacks or pit slopes considered in the estimate given that the deposits were located in an area where setbacks did not appear to be required, with the exception of the setback from Kimea Creek. For calculating areas of sections adjacent to Kimea Creek, AMEC used the reserve boundaries that had variable setbacks from the Kimea Creek Channel. In areas adjacent to Kimea Creek, volumes may have to be reduced to account for environmental setbacks from Kimea Creek. Note that the actual environmental setbacks required have not been determined by AMEC.
6. The deposits are continuous within the defined granular sections.

MEM should be aware of the following limitations to the estimated granular volumes provided above:

Water Table:

The water table may be higher during wetter times of the year; therefore, there could be a reduction in the potential volumes of granular material if the reported water tables rise significantly. Additionally, in areas were the water table was not encountered during the field assessment, it may be encountered closer to the ground surface during wetter times of the year.

Coarseness of Test Pitting Grid:

There may be undetected zones where the overburden may be thicker or the underlying silt and clay may be shallower that have not been sampled due to the coarseness of the test pitting grid. If additional areas of silt and clay or other non-granular materials were present, the potential volume of granular material would be reduced.

Depth of Test Pitting:

TP03-9-01 through 05 were excavated at the base of the existing pit at a much lower elevation than the surrounding test pits (approximately 3 to 6 m). Soils encountered within these test pits indicated that granular deposits in other portions of the study area may extend for considerable depths below the depth explored during this field work. Further work (probably drilling) would be required to verify the actual depth of granular deposits.

Topographic Survey:

A detailed topographic survey was not available for the study area. The relative elevations of the test pits and ground surface features were visual estimates. An elevation survey would allow a more refined volume estimate of the potential gravel resource.

8.0 GRANULAR SUITABILITY

The discussion on granular suitability is done on a section-by-section basis as detailed below:

8.1 SECTION 1A/1B

Section 1A/1B contained a gravelly sand with a trace cobbles and had an average of 5% fines (silt and clay). Limited degradation tests indicated that one of the two tests (values of 40 and 20) was below the minimum MoT specification of 35. The sand equivalent on the poorer sample (TP03-9-71) indicated that the soil did not contain plastic fines.

Note that test pit spacing within Section 1B was done at a reconnaissance level with a large spacing between TP03-9-72 and 74. Given the reconnaissance level of the test pitting, only preliminary commentary is given on the potential suitability of granular material.

Select Granular Sub-base (SGSB) Charts D1-2 and D1-6, Appendix D:

Material from Section 1A/AB appeared to be suitable for use as SGSB based on the gradation curves presented in Appendix D (Charts D1-1 through 8). There was approximately 5% oversize up to a maximum size of 200 mm reported during the field program. The oversize material could be incorporated into SGSB if acceptable to the MEM or screened out. Another option would be to crush the material to incorporate the oversize material. Note that crushing the material may generate additional fines.

Based on AMEC's experience in the general study area, despite the marginal durability the gravelly sand in Section 1A/1B it is probably acceptable for use as select granular sub-base given the limited quality and quantity of better material within the SYD Road area.

25 mm Well Graded Base Course Aggregate (WGBCA) Charts D1-3 and D1-7, Appendix D:

The material appeared to be too fine for use as 25 mm WGBCA even with the oversize portion included when the material is crushed. If is unlikely that the specified fracture would be achieved and the final product would probably have in excess of 5% fines with marginal durability.

High Fines Granular Surface Aggregate (HFGSA) Charts D1-4 and D1-8, Appendix D:

If the sand and gravel were crushed with the oversize portion included, it appears that the material would meet the MoT grain-size specification for crushed HFGSA, although some fines would probably have to be added. Given the abundance of fines within the area this should not be an issue, although it would be preferable to select a lower or non-plastic silt deposit.

Section 1A/1B is considered to be an acceptable source of crushed 25 mm HFGSA, although crushing to include all oversize and possibly crushing to a finer maximum size may be required to achieve a specified fracture of 50%. As noted above, the material may not be as durable as typically accepted by MoT standards.

8.2 SECTION 3A/3B

Section 3A/3B was mainly fine to medium sand with a trace to some gravel and an average of 6% fines. Previous aggregate quality testing in the general area conducted by the MoT (Beeson 1985) indicated that the soil could contain plastic fines and could have low durability. Typically sand equivalent test values ranged from 20 to 59 (Beeson 1985). Values of 20 to 40 indicate that there is the possible presence of plastic fines with values over 40 indicating the absence of plastic fines. Typically degradation tests results (Beeson 1985) ranged from 30 to 37 with a minimum of 35 being the MoT specification.

Select Granular Sub-base (SGSB) Charts D3-2 and D3-6, Appendix D:

The material appeared to be marginally acceptable for use as SGSB (Charts D3-2 and D3-7, Appendix D) provided a dirty material (greater than 5% fines) is acceptable (the overall average fines content is about 6%). It should be noted that, although the material may be gradationally acceptable, given that is it primarily fine and medium sand, it may be difficult to place and compact. Additionally, the material may rut under construction traffic. Therefore, AMEC would not consider Section 3A/3B has a preferable source of SGSB, particularly considering better material is available in Sections 1A/1B and 4A/4B.

25 mm Well Graded Base Course Aggregate (WGBCA) and High Fines Granular Surfacing Aggregate (HFGSA):

Section 3A/3B contains predominately sand; therefore, material in Section 3A/3B is not gradationally suitable for use as 25 mm WGBCA (Charts D3-3 and 7, Appendix D) or HFGSA (Charts D3-4 and D3-8, Appendix D).

Other Uses:

Material within Section 3A/3B may be suitable for use as winter sand or a general fill material used as a separation layer between a poor subgrade and SGSB.

8.3 SECTION 4A/4B

The soils encountered in Section 4A/4B were typically gravelly sand with a trace of cobbles and boulders and an average of 5% fines. Previous aggregate quality testing in the general area conducted by the MoT (Beeson 1985) indicated that the soil could contain plastic fines and could have low durability. Typically sand equivalent test values ranged from 20 to 59 (Beeson 1985). Values of 20 to 40 indicate that there is the possible presence of plastic fines with values over 40 indicating the absence of plastic fines. Typically degradation test results (Beeson 1985) ranged from 30 to 37 with 35 being the MoT minimum specification.

Select Granular Sub-base (SGSB) Charts D4-2 and D4-6, Appendix D:

Material from Section 4A/4B appeared to be suitable for use as SGSB based on the gradation. There was approximately 8% oversize up to a maximum size of 250 mm reported during the field program. The oversize material could be incorporated into SGSB if acceptable to the MEM or screened out. Another option would be to crush the material to incorporate the oversize material. Note that crushing the material may generate additional fines.

Based on AMEC's experience in the general study area, despite low durability, the gravelly sand in Section 4A/4B is probably acceptable for use as select granular sub-base given the limited quality and quantity of better material within the SYD Road area.

25 mm Well Graded Base Course Aggregate (WGBCA) Charts D4-3 and D4-7, Appendix D:

The material appeared to be too fine for use as 25 mm WGBCA even with the oversize portion included when the material is crushed. If is unlikely that the specified fracture would be achieved and the final product would probably have in excess of 5% fines with marginal durability.

High Fines Granular Surface Aggregate (HFGSA) Charts D4-4 and D4-8, Appendix D:

If the sand and gravel were crushed with the oversize portion included, it appears that the material would meet the MoT grain-size specification for crushed HFGSA, although some fines would probably have to be added. Given the abundance of fines within the area this should not be an issue, although it would be preferable to select a lower or non-plastic silt deposit.

Section 4A/4B is considered to be an acceptable source of crushed 25 mm HFGSA, although crushing to include all oversize and possibly crushing to a finer maximum size may be required to achieve a specified fracture of 50%. As noted above, the material may not be a durable as typically accepted by MoT standards.

8.4 SECTION 5

The sand and gravel with some cobbles and a trace fines (2%) in Section 5 appeared to be the most favorable area to source crushed products (refer to discussion below). Previous (Beeson 1985) MoT aggregate quality testing indicated that degradation test results typically ranged from 27 to 41 with the MoT minimum standard being 35. Therefore, the aggregate may have a lower than typically accepted durability. The one test conducted by AMEC (TP03-9-03) indicated a degradation test result of 47. Sand equivalent tests, either from previous MoT (Beeson 1985) work or from AMEC exceeded the MoT minimum specification of 40 indicating the absence of plastic fines.

<u>Select Granular Sub-base (SGSB) Charts D5-2 and D5-6, Appendix D</u>:

Material from Section 5 appeared to be suitable for use as SGSB based on the gradation but the 17% average oversize material would have incorporated into SGSB if acceptable to the MEM or screened out. Another option would be to crush the material to incorporate the oversize material. Note that crushing the material may generate additional fines, but given the low average fines of 2%, it is not expected that crushing would generate enough fines to exceed the 5% maximum MoT specification.

The material in Section 5 would require considerable processing to meet the SGSB specification; otherwise, there would be considerable oversize within the material. Therefore, while suitable with processing, AMEC recommends that Section 5 not be used as a source of SGSB, but be reserved as a source of crushed well graded base.

<u>25 mm Well Graded Base Course Aggregate (WGBCA) Charts D5-3 and D5-7, Appendix D</u>:

With crushing incorporating the oversize portion of material, it appears that Area 5 would be acceptable for use as WGBCA. Based on AMEC's experience in the general study area, despite the potentially low durability, the sand and gravel in Section 5 appears acceptable for use as WGBCA given the very limited quality and quantity of better material within the SYD Road area.

<u>High Fines Granular Surface Aggregate (HFGSA) Charts D5-4 and D5-8, Appendix D:</u>

If the sand and gravel were crushed with the oversize portion included, it appears that the material could meet the MoT grain-size specification for crushed HFGSA, although considerable fines would have to be added. Given the abundance of fines within the area (i.e. Section 2) this should not be an issue. Given that there are dirtier deposits within Area 9 which would not require as much processing (adding of fines and crushing to meet the grain size specification), it is not recommended to use the material in Section 5 for HFGSA as it would be a preferred source for WGBCA.

8.5 SECTION 6

Section 6 is a relatively thin deposit with an average gradation of sand and gravel with trace cobbles (less than 2%) and an average of 7% fines. Note that the test pitting in Section 6 would be considered reconnaissance level as there are only 3 test pits within an area of approximately 131 000 m^3. Two test pits indicated that the soil was relatively clean (2% fines) while the third test pit indicated that the soils were dirty (14% fines).

There was no aggregate quality information available for Section 6, but it would be expected to be similar to deposits found elsewhere in Area 9 with potentially lower than usually specified durabilities and the possible presence of plastic fines.

Given the reconnaissance level of the test pitting, only preliminary commentary is given on the potential suitability of granular material. Additional work would be recommended prior to developing Section 6 to better delimit/characterize the granular deposits.

<u>Select Granular Sub-base (SGSB) Charts D6-2 and D6-6, Appendix D</u>: The material appeared to be dirty (greater than 5% fines in one location), but otherwise possibly acceptable for use as SGSB.

<u>25 mm Well Graded Base Course Aggregate (WGBCA) Charts D6-3 and D6-7, Appendix D</u>: Based on the limited information collected, material in Section 6 appeared too fine and in some locations possibly too dirty (greater than 5% fines) to be suitable for use as WGBCA.

<u>High Fines Granular Surface Aggregate (HFGSA) Charts D6-4 and D6-8, Appendix D</u>: Based on the limited information, the material may be suitable for use as high fines aggregate, provided the dirty and clean materials were blended during processing. Additional work would be required to verify the suitability of soils in Section 6 for HFGSA.

9.0 DEGREE OF CONFIDENCE

As requested by the MEM, AMEC has assigned degrees of confidence for each of the sections of granular material defined for Area 9 within this report. Table 12 provides the definition of "degree of confidence" used by AMEC.

Table 12: Degree of Confidence, Definitions

Degree of Confidence	Factors Determining Degree of Confidence		Development Considerations
	Typical Test Pit Density (TP/10 000 m^2)	Typical Soil Conditions	
High	Greater than 0.75	Type of granular material is consistent across entire section, or at least there are sufficient tests pits to characterize any variations across section. Test pit spacing typically ranges from 50 to 150 m.	A high degree of confidence indicates that there is enough information gathered to allow development of a delimited section as a source of granular material.
Moderate	0.25 to 0.75	Type of granular material may vary within section. Typically there are one or two test pits within area that have different and possibly poorer soil conditions. Test pit spacing typically ranges from 100 to 250 m.	A moderate degree of confidence indicates that the section could be developed, but different and possibly poorer soil conditions could be found between test pit locations. Additional test pitting and soils testing would be required to increase the degree of confidence to high.
Low	Less than 0.25	Granular materials within section are typically inconsistent with significant variations in gradations between test pits. Test pit spacing is typically greater than 250 m.	A low degree of confidence indicates that significantly more test pitting and soils testing would be required to increase the degree of confidence to moderate or high. Development is not recommended without additional work.

The degree of confidence is a function of the test pit density and the consistency of the soil conditions within the section delimited. Note that in some sections, if soils were relatively consistent over large areas then the degree of confidence would be increased. As an example, if there is an area where 0.5 test pits were excavated per 10 000 m^2, but the majority test pits encountered sand with a trace gravel with nearly identical gradations, then the degree of confidence would be increased from moderate to high.

Based on the information provided in previous sections, the following degree of confidences are provided in Table 13 for each of the sections of granular material defined within this report.

Table 13: Degree of Confidence for Area 9

Section	Test Pit Density (TP/10 000 m^2)	Degree of confidence	Notes
1A/1B	0.8	High (1A) / Low (1B)	Additional test pitting required in Section 1B to determine the extent and characteristics of granular deposits.
3A/3B	0.7	High	
4A/4B	0.5	High	While test pitting density was relatively low, soil conditions across Section 4A/4B were relatively uniform; therefore, a high degree of confidence was assigned.
5	0.9	High	
6	0.2	Low	Additional test pitting and soils testing required in Section 6 to determine the extent and characteristics of granular deposits.

10.0 PIT DEVELOPMENT

The following considerations are provided for further pit development in Area 9.

Overall Development:

It is understood that the current needs of the MEM are for WGBCA and possibly HFSA. Based on this information, the existing pit face could be mined to provide these aggregates. The existing pit face could be mined towards either the northwest or east in Section 5 to provide a source of WGBCA. The existing pit face adjacent to Section 4A could be mined north to provide a source of HFSA.

If MEM also wished to mine SGSB from Area 9, it is recommended that they consider mining the existing pit in Section 1A/1B to the east and west. This would reduce overall hauling times as Section 1A/1B is slightly closer to the SYD Road.

Overburden/Topsoil Stockpiles:

To avoid the placement of topsoil and/overburden stockpiles over potential granular material, three stockpile/overburden pile locations are recommended:

- Over Section 3, if this area is judged to be unsuitable by the MEM for future development.
- In Section 2 in the areas adjacent to TP03-9- 43, 57 and 58.
- In areas adjacent to TP03-9-67, 69, 75 and 76 adjacent to Section 1A/1B.

Crushing Operations:

The following guidelines are given for the location of crushers, crush material stock pile, reject material stockpiles and oversize material stockpiles:

- It is preferable to have any crushing operation located at the pit site rather than at a remote location as the material gradation can be better controlled/adjusted within the pit site. Given the scarcity and variability of material suitable for WGBCA with the SYD Road area it is recommended that there be full time supervision during any crushing operations.

- The crusher should be set up in the base of the current pit.

- Stockpiled reject material could be located within the existing pit, but would have to be relocated if the existing pit floor was to be lowered during future mining.

- Stockpiles of crush material and oversize should be located on the existing pit floor.