LEVELTON ASSOCIATES CONSULTING ENGINEERS

RICHMOND SURREY ABBOTSFORD VICTORIA NANAIMO COURTENAY PRINCE RUPERT CALGARY

HYDROGEOLOGICAL STUDY

Proposed Quarry off of Ward Road
Sumas Mountain, BC

Prepared for:

Mr. David Vernon
Mr. Bruce Vernon
c/o West Coast Aggregates Ltd.
P.O. Box 1408
Aldergrove, BC
V0X 1A0

Prepared by:

B.H. Levelton & Associates Ltd.
Willowbrook Business Centre
#103 - 19292 - 60th Avenue
Surrey, BC
V3S 8E5

Ray Koenig, P.Geo.
Senior Environmental Hydrogeologist

PROFESSIONAL GEOSCIENTIST PROVINCE OF BRITISH COLUMBIA R. M. KOENIG 01/30/95

Reviewed by:
David Kneale, Hydrogeologist

January 19, 1995
File: 894-324

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INTRODUCTION

Levelton Associates was contacted by Mr. David Vernon of West Coast Aggregates to prepare a report intended for BC Ministry of Energy, Mines and Petroleum Resources. This application by West Coast Aggregates is to obtain a permit for a rock quarry off Ward Road on Sumas Mountain. This report will deal with the hydrological and hydrogeological aspects of the permit requirements.

SCOPE

This report will address two areas of concern. The first area is the impact of the proposed quarry on existing domestic water wells in the area surrounding the site. The wells reviewed are located immediately surrounding the site, concentrating on the shallow, down gradient, receptors.

The second area is the water management system during the quarry operation. This is restricted to collecting and diverting storm runoff and ground water seepage on the quarry site and any water courses entering or exiting the quarry site.

REGIONAL SETTING

The area of the proposed quarry is located in the southwest quadrant of Sumas Mountain, east off Upper Sumas Mountain Road and just north of the end of Ward Road. Sumas Mountain rises 400m out of the Central Fraser Lowlands. Sumas Mountain is formed of Pre-Tertiary and Tertiary bedrocks that are unconformably overlain by glacial deposits of the Sumas Drift and clastic sediments of the Huntingdon formation.

The Tertiary sedimentary rocks are sandstone, siltstone, mudstone, shale and conglomerate. The Pre-Tertiary rocks are mainly plutonic, granitic and associated metamorphic rocks that have had significant exposure to weathering. These post emplacement processes have created a network of fractures and faults that are interconnected and provide both the storage reservoir and recharge pathways for ground water at depth.

The Sumas Drift deposits consist of unconsolidated sand, silt and gravel deposited by a piedmont (valley) glacier. The thickest accumulations are found along the valley floors or as local proglacial deltas or meltwater streams along the slopes. The sand and gravel deposits are discontinuous water bearing zones and function as conduits for the movement and storage of large volumes of ground water. These deposits overlie the bedrock and are in direct communication with the upper boundary of the bedrock.

An average annual precipitation of 1640mm falls in the Sumas Mountain area. Precipitation is the main source of recharge for both the shallow surface and the deeper bedrock aquifers. Recharge occurs as precipitation infiltrates downward into the sand and gravel and further infiltrates into the underlying bedrock entering the fracture system below. The fracture system is likely very complex in nature, composed of discontinuous fractures and microfractures of varying size, length and hydraulic conductivity.[1]

SITE DESCRIPTION

A linear topographic bedrock high trends northwest - southeast. On either side of this ridge are fault related, narrowly confined water courses, also oriented in similar northwest - southeast altitudes.

The proposed quarry property is a top this elongated ridge. The ridge is split by a gentle saddle-shaped valley oriented perpendicular, east - west, to main rock high. Outcropping bedrock ridges rise to the north and south, and a smaller bedrock bluff rises to the west.

The slopes in the area average 20 percent in the lower portions of the valley, and steepen with increasing height up the ridge. The valley and mid slopes are overlain with glacial sands and gravels up to 2.8m in depth.

The valley was logged previously about 50 years ago. Second growth cottonwood has recently been removed in the valley area, leaving the site partially cleared.

PART I WELL INVESTIGATION

A location search of existing domestic water wells was conducted in the immediate area surrounding the proposed quarry site. Mr. Mike Gallo of the Ministry of Environment, Ground Water Section was contacted to obtain the records of existing wells held by the Ministry. Mr. Gallo was able to supply a total of twelve well records. Of these, five were determined to be probably the most influenced in the immediate surrounding area. These five records indicate three shallow dug wells and two deeper, drilled wells are present or were constructed.

Levelton Associates also conducted research of the surrounding properties to ascertain the number of well users in the surrounding area. On two different occasions, written notices were left in the mail boxes of residences in the study area. The search was to gather information on the type of well construction (shallow dug or deep drilled), the depth to water in both the dry and wet season, usage problems and approximate location of the well in relation to the proposed quarry site.

Some of the property owners chose not to respond and consequently no information is available. The approximate well locations are indicated on the legal plan. Four property owners did respond, three south of the proposed quarry and one to the north.

A combined summary of all well information is presented in Table 1. The table outlines the location, the type of well, the depth to water, the depth of the well and the year of construction. Missing information was either not available or because contact was not made with the property owner. In summary, three of the surrounding wells are drilled, five are shallow excavations, and one is unknown.

HYDROLOGY

Surface runoff from storm precipitation is split by the main northwest - southeast orientated ridge. The majority of the runoff is directed either northeast into McKay Brook or southwest into a tributary of Lonzo Creek that flows along side of Upper Sumas Mountain Road. Runoff into the small valley that splits the ridges is drained west into McKay Brook, and east into the low lying area south of the proposed quarry site before continuing down the rest of the mountains natural drainage course. The reference map indicates the local flow direction of storm runoff influenced by existing topography.

These surface flows are directly related to the precipitation events of the area and consequently are cyclical in nature and magnitude. During the summer months, these flows diminish significantly and for the most part disappear entirely.

The most significant flow in the area is McKay Brook. Measurements taken during peak lowest periods indicate average flow of 425,000 m^3/day.[2]

HYDROGEOLOGY

Two types of aquifers dominate Sumas Mountain. Shallow wells extract water from an unconfined water table within the overlying glacial materials. Deeper drilled rock wells obtain water from the interconnected fracture paths within the crystalline bedrock. Flow volumes and recharge capability for either aquifer is affected by several different factors such as catchment area, aquifer thickness, fracture frequency persistence, aperture and hydraulic conductivity. Due to the wide range of factors affecting a well, each well's ability is usually site dependant. That is, because of the variability in the aquifer system, no two wells will be identical even if in close proximity.

The proposed quarry plan (refer to drawing number 294-104, Page 3) prepared by Lang Engineering indicates a proposed pit floor elevation of 194.0m. The removal of material from the areas outlined on Page 3 of this plan will cause only minor changes in the drainage over the site area. Drainage will remain into the central area of the property and exiting out the southwest corner. A minor reduction in storm runoff into McKay Brook will occur from the regrading the east side of the quarry floor.

QUARRY IMPACT

Shallow Wells

The proposed removal of the material from the quarry will have a pronounced affect on the shallow aquifer in the proposed site. In effect, the final floor elevation of 194m will have removed, likely entirely, the shallow sand and gravel aquifer presently overlying the bedrock in that area.

Two, possibly three shallow wells exist to the north of the site, none to the east, and one to the west. These wells do not obtain water from the shallow aquifer in the area of the proposed quarry, subsequently no impact will occur to these wells. This is because these existing shallow wells draw from an aquifer separated by bedrock highs from the aquifer in the proposed quarry site.

To the southwest, two shallow wells are within the same aquifer body as that proposed for removal from the quarry site. If a final floor elevation of 194m is adopted, these wells are predicted to be affected in the following manner.

1) Loss of Recharge Area

The direction of surface and subsurface flow is from the quarry property southwest towards these wells. During the dry months as water levels drop and precipitation is minimal, the sand and gravel aquifer that fills the valley acts as a storage reservoir and source of recharge for water being withdrawn from these wells. During the wet months, runoff from the rock highs shed water from the southeast slope towards the wells for recharge. The quarrying of these features will reduce to some degree the area available for water to be shed in that direction.

2) Deforestation Will Increase Runoff and Reduce Water Used in Evapotranspiration

Clearing the property will effect two changes to the water system. Firstly, the degree of runoff will increase during precipitation because of the loss of humus layer which offers quick infiltration rates. Secondly, evapotranspiration will decline significantly for the quarry area because of the loss of vegetation, consequently more water will be available in a different form.

3) Loss of Filtration

The shallow aquifer is composed of sand and gravel, This media acts as a natural filter removing suspended solids and chemical constituents of infiltrating precipitation. Removal of the portion of the aquifer in the proposed quarry, may result in reduced filtration of the ground water, possibly affecting the water quality.

Drilled Wells

At least three wells are known to be drilled into underlying crystalline bedrock around the quarry site. Unlike shallow wells which are more location dependent, the influence on deep rock wells is more difficult to predict. This is because of the unknown nature of the fracture paths, how they interconnect, and where they intersect the surface and the well.

Likely the impact of the quarry site will be non-existent on nearby deeper wells. The only remote possibility would be if a major fracture recharge zone is present below the limited shallow aquifer that is in direct communication with the overlying sand and gravel. This is not believed likely since the major fracture lineaments trend northwest - southeast and the valley containing the shallow aquifer is perpendular to that trend.

Water Quality

The igneous rocks in the proposed quarry area are believed to be ultra-alkaline plutonic rocks. These medium to coarse grained rocks often contain mineral assemblages with high ferromagnesian content, such as biotite, pyroxenes, magnetite and nesosilicate olivine. As the minerals are exposed to fresh meteoric and slightly acidic rain water, iron may be released into solution. It is possible that rock flour from the quarry operation may shift the chemistry of the water infiltrating the ground. This is further dependent upon pH, temperature, the availability of host minerals and the length of time that water would contact these minerals. Besides iron, other undesirable minerals known to occur in the area that affect water quality are fluorite, boron and sulphate.

Any maintenance or fuel storage within the quarry area presents the possibility of fuel spills or leaks seeping into the aquifer.

In summary, the shallow wells to the southeast will be impacted to some degree based on the quarry plan presented by Lang Engineering. The impacts relate to the potential loss of upgradient aquifer storage area, increased runoff, loss of filtration effectiveness, change in water chemistry and the possibility of hydrocarbon contaminants entering the system. No impact to shallow wells to the north are predicted to occur.

Impacts on drilled wells are difficult to predict, but are expected to be minimal.

RECOMMENDATIONS

Much of the predicted impact may be mitigated by a phased approached to the quarry operations (refer to reference map). An initial floor elevation of 200m to the west sloping upwards to 215m in the east is proposed rather than elevation 194m. These higher elevations would leave the bulk of the shallow aquifer intact in the base of the valley alleviating the concerns dealing with loss of aquifer storage and filtrative capacity. Prior to excavation below elevation 215m to the 200m level, a second and more comprehensive investigation of the aquifer should be undertaken. By conducting field studies of the aquifer's characteristics and studying seasonally low water levels, a more accurate predication for down gradient receptor impact can be made. It is quite conceivable that within the next 10 to 15 years, municipal water services may be available along Upper Sumas Mountain Road to provide an alternate source of supply.

The remaining potential impacts may be lessened by the installation of a large siltation pond at the southwest corner of the property. The pond would serve to maintain a constant head boundary for water supply to the shallow aquifer, south of the proposed quarry property. The pond would also serve to reduce the impact of runoff by removing suspended sediment to improve water quality, and detaining surface and seepage flows for release at a controlled outflow rate.

Monitoring of ground water samples form the pond should be performed on a quarterly basis to determine any effects on water quality. These should be compared to background analysis performed prior to the quarry operation commencing. A leachate extraction analysis of the rock flour would reveal any negative constituents infiltrating into the water supply.

If maintenance and fuel storage is to be established in the quarry area, it should be bermed and lined with a compacted impermeable clays or artificial liner to prevent seepage. Fuel tanks should be locked to prevent tampering. An emergency spill response plan should also be commissioned.

It is noted that the overburden in the area proposed for the crushing and screening plant will need to be stripped down to the bedrock. The area is small and at the upper edge of the overburden such that no negative effects are predicted.

PART II WATER MANAGEMENT SYSTEM

Site clearing, overburden removal and quarry operation will have the combined effect of increasing surface runoff and siltation. Ponded water will also occur on the pit floor since very limited infiltration will occur into the bedrock.

Page 3 of Lang Engineering's drawing "Rehabilitation Plan" showing the proposed final elevation of the pit floor and indicates a permanent swale draining to the west. During the various stages of the quarry's development, steps must be taken to collect and direct storm runoff and seepage flow into a detention pond system. This is necessary to ensure that flooding does not occur on the topographically lower properties to the southwest.

The size of the detention pond should be designed to accommodate two features. Firstly, the ability to adequately store storm surge volumes based on a specified rainfall intensity. This will likely require the impact of the City of Abbotsford engineering department to determine this value. Secondly, the pond must have the ability to adequately allow for settlement of suspended solids prior to discharge along the existing drainage course. This drainage course ultimately flows into the Sumas River at the base of Sumas Mountain.

RECOMMENDATIONS

1) The quarry floor be sloped at minimum 0.5% from the east side to the west. This will require a total fall of about 4m. Ditches to intercept seepage may be required around the crushing plant.

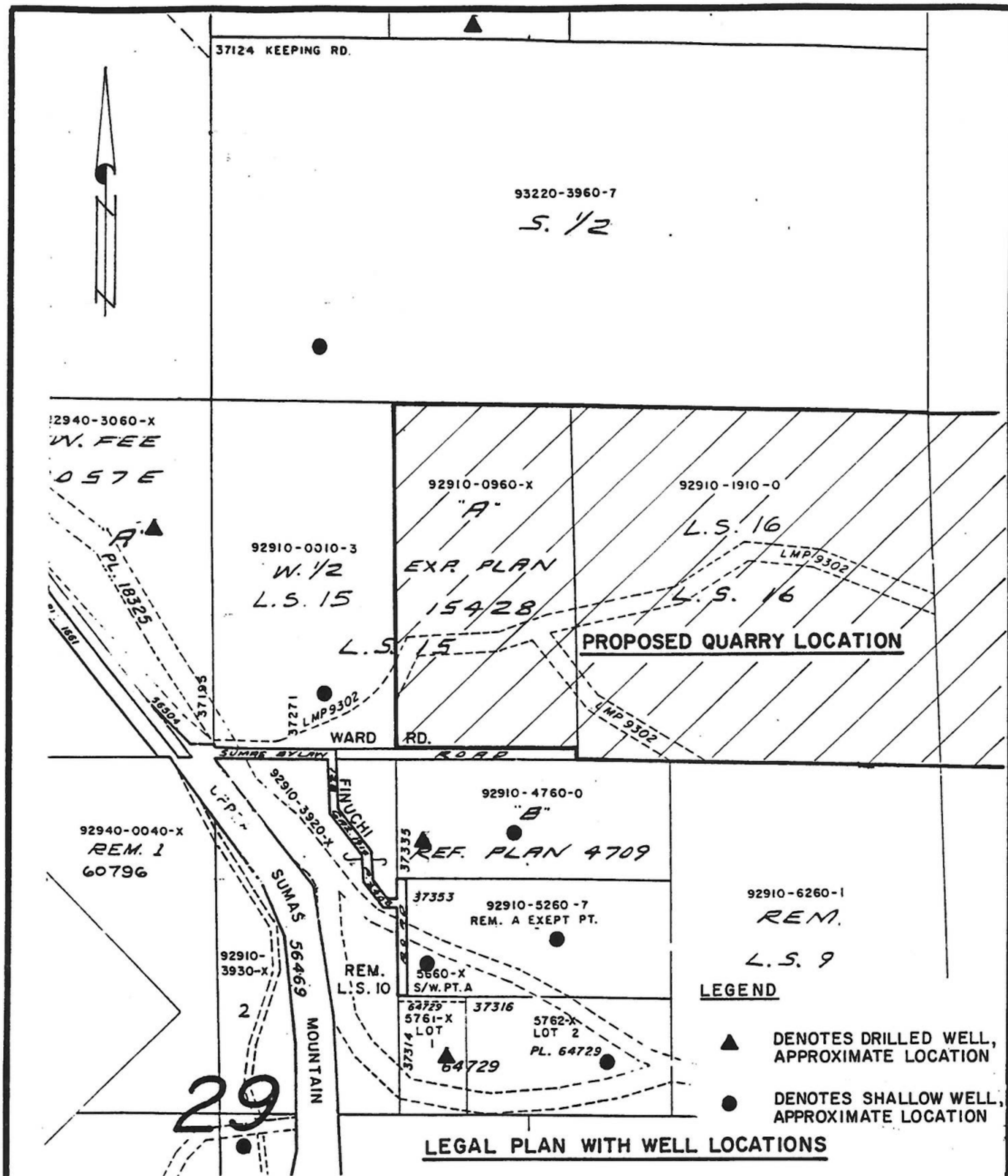
2) The detention pond should be constructed based on rainfall intensity values as determined by either the Ministry of Mines and Energy or the Engineering Department, City of Abbotsford. Adequate material exists on site to construct such a pond.

3) The geometry of the pond should be designed to allow for adequate settlement of suspended solids prior to discharge into the existing drainage course. The drainage course flows into the Sumas River.

REFERENCES

(1) Koenig, R., 1994, A Comparison of Water Quality Between Aquifers in Glacial Deposits and Fractured Bedrock - Sumas Mountain. Proceedings Mountain Hydrology, Canadian Society for Hydrological Sciences, 12p.

(2) Levelton Associates Consulting Engineers, 1993, Water Supply Report; Ministry of Environment, Habitat Management.



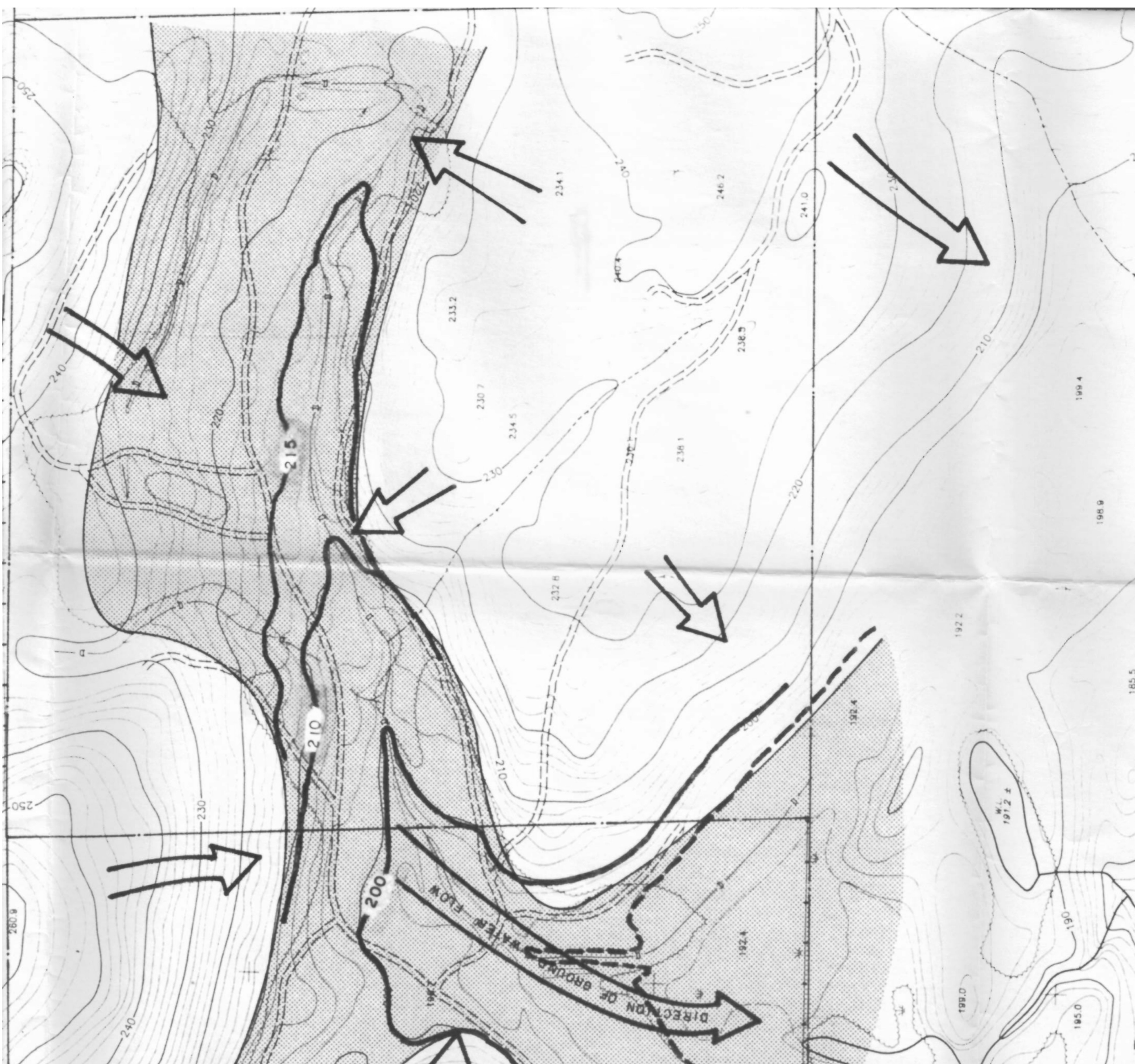
SEAL	CLIENT: WESTEX CONTRACTING	
	PROJECT: HYDROGEOLOGICAL IMPACT ASSESSMENT – PROPOSED QUARRY SUMAS MOUNTAIN OFF WARD ROAD, ABBOTSFORD, B.C.	
	LEVELTON ASSOCIATES CONSULTING ENGINEERS RICHMOND VICTORIA NANAIMO SURREY PRINCE RUPERT ABBOTSFORD 103-19292-60th AVE., WILLOWBROOK BUSINESS CENTER, SURREY, B.C. V3S 8E5 PHONE (604) 533-2992 FAX (604) 533-0768	FILE NO. 894 – 324 DATE JAN. 27, 1995

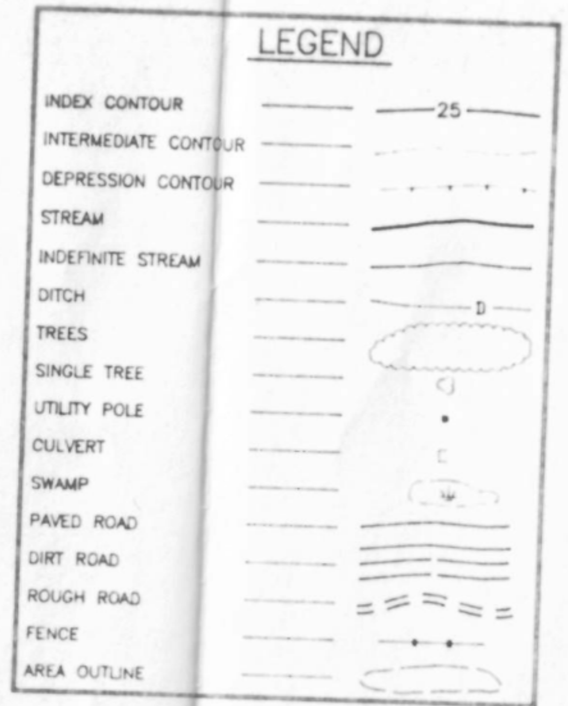
West Coast Aggregates

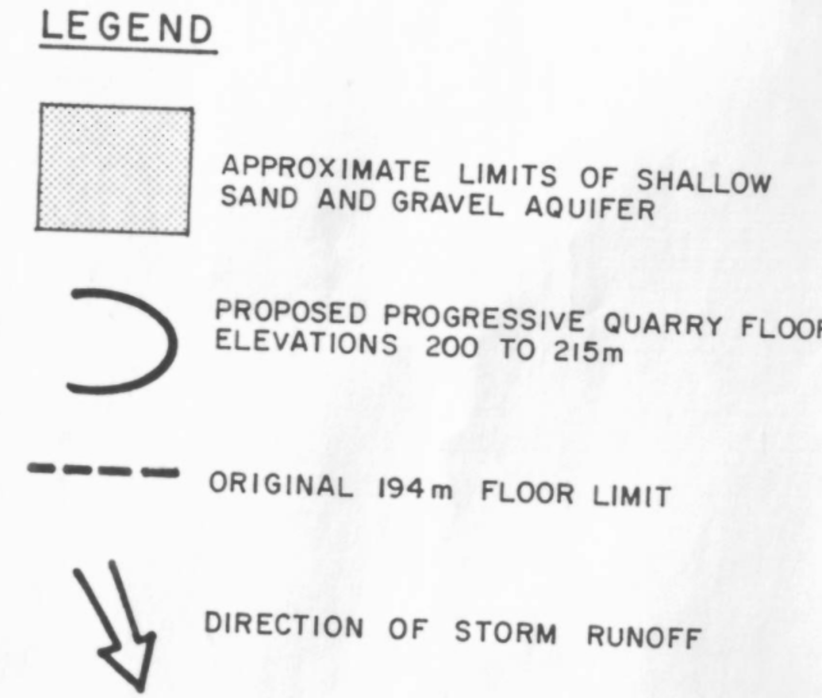
Table 1

Address	Relative Location to Proposed Quarry	Type of Well Construction	Depth of Well (m)	Depth to Water	Year of Construction	Comments on Notes on Well Records
37314 Ward Road	Southeast	Drilled and cased	61.5	0.6m	1983	Estimated flow 2 gpm from 55m
37316 Ward Road	Southwest	Supplied by the above well				
37353 Ward Road	Southwest	Dug, concrete rings	3	N/A	N/A	Insufficient in dry season additional dug well noted on property
37335 Ward Road	Southwest	Drilled and cased	67	N/A	81	Pump set at 61m
2nd Well on Property	Southwest	Dug	3.3	1.8	N/A	Close to brook
37271 Ward Road	West	Dug	4.5	N/A	N/A	
37195 Ward Road	West	Drilled	N/A	N/A	N/A	N/A
37171 Ward Road	North	Dug	4	N/A	N/A	Insufficient in dry season
37124 Keeping Road	North	Dug	2.4	N/A	N/A	30m from Hunters Brook
37223 Keeping Road	North	Drilled	N/A	N/A	N/A	
37326 Keeping Road	North	N/A	N/A	N/A	N/A	N/A

N/A - Not Available


DIRECTION OF GROUND WATER FLOW
215
210
200
194
5 436 000 N
5 435 800 N
5 435 600 N





REFERENCE

CONTOUR PLAN – EAGLE MAPPING SERVICES LTD. (94-80)
SITE PLAN – LANG ENGINEERING (1988) LTD. DWG. NO. 294-104, DEC. 14, 1994.

NO.	DATE	REVISION	BY	APPROVED

AQUATERRA CONSULTANTS LTD.

3297 PONDEROSA STREET, ABBOTSFORD, B.C., V2T 5G2 TEL: (604) 850-3521 FAX: (604) 850-3542

November 23, 1998

Toews Bros. Bulldozing Ltd.
P.O. Box 19
Mt. Lehman, BC V4X 2P7

Attention: Mr. Kelly Toews

Re: Clarification Of 200 Metre Floor Elevation

Dear Sir:

As requested AquaTerra Consultants Ltd. will attempt to clarify the origin of the 200m floor elevation recommended by Levelton Associates for the Emerson quarry site presently operated by Summit Sand and Gravel.

Between 1993 - 1995, while in the employ of Levelton Associates, I conducted several hydrological studies of the quarry site to the north of your property. Initially, that northern property was being proposed for residential development by Mr. Gary Emerson, the owner. Later, Mr. Emerson decided to apply for a permit to quarry sand, gravel and rock from the site. In late 1994, on behalf of Messers Bruce and David Vernon, of West Coast Aggregates, I completed a hydrogeological study of the property to examine the potential for impact to water quality in the area in response to activities from the proposed quarry. A quarry plan had been developed by Lang Engineering for that site. The Lang plan proposed a final floor elevation of 194m.

The area proposed for the quarry consists of a shallow, bow shaped, valley, with sand and gravel as a base. The sand gravel is between 1 and 3 metres in thickness, overlying the rock base and runs down the central valley floor. The hydrological study revealed that a small water course ran through the valley, and then towards three properties to the south. These three properties either obtained their drinking water from shallow wells dug in the sand and gravel, which acted as an aquifer for those wells, or took water directly from the stream.

The proposed final floor elevation by Lang Engineering of 194m for that site would have resulted in removing much of the sand and gravel material that acted as the aquifer for the three homes to the south. To preserve the aquifer material, I recommended in the hydrological study, that the final floor elevation be raised to 200m. This is the only reason why that quarry site has a 200m floor limit at this time.

With respect to a 200m floor limit for the proposed quarry on your property, conditions are very much different. The key differences are explained below as to why it not necessary at all to consider such a floor elevation for your quarry. To begin:

- Your site consists of a south facing slope and is not a valley topography.
- The south slope is a rock face with extremely limited sediment cover and does not have any aquifer potential in the slightest.
- Surface runoff from your site is opposite, directed away from the three properties affected by the quarry to the north of your property and will not impact that hydrological setting.
- In 1997, a representative from The Ministry of Mines spoke, by telephone, to me directly on this point, seeking the same clarification and were satisfied that a similar floor elevation was not needed for your site.

In conclusion, the origin of the 200m floor elevation is site specific to Mr. Emerson's quarry site and is solely based on the need to preserve the quality of a drinking water source to other affected properties. Should this water source no longer be needed by those properties, i.e. another is found or supplied, then there would be no need at all for a 200m floor limit on the Emerson property. Your site requires no such arbitrary floor elevation, other than the one agreed to between yourself and the Ministry of Mines.

I trusted this information is satisfactory to your current needs. Should you require additional explanation, a copy of the study, entitled **"HYDROLOGICAL STUDY Proposed Quarry off of Ward Road, Sumas Mountain, Levelton Associates. File # 894-324. January 1995"** would likely by obtainable from the Ministry of Mines through the Freedom of Information Act.

Sincerely yours,
AquaTerra Consultants Ltd.

Ray Koenig, P.Geo.
97019

AQUATERRA CONSULTANTS LTD.

3297 Ponderosa Street, Abbotsford, B.C., V2T 5G2 Tel: (604) 850-3521 Fax: (604) 850-3542

November 16, 1998

RECEIVED
NOV 23 1998
MINES BRANCH
NANAIMO

Western Rock Quarry
c/o Toews Bros. Bulldozing Ltd.
P.O. Box 19
Mt. Lehman, BC V4X 2P7

Attention: Mr. Kelly Toews

Re: Sumas Mountain - Whispering Pines Quarry

Dear Sir:

As per your request, please find below the recommendations for additional drainage works/modifications for the quarry proposed at the above referenced site.

The site was revisited on November 6th, 1998 and activities consisted of a walkover of the entire property, including the pipeline right of way to the south, and inspection of the existing drainage ditches and detention ponds. The site was again revisited and walked over on November 15th, after the area had received several days of rainfall.

The walkovers failed to reveal any notable impacts to the site or the right of way area, south of the proposed quarry. No erosion, slumpage, or debris flows on the property were observed to have occurred since last visited by the author, 18 months earlier. The site was well drained, with much of the runoff infiltrating into the fractured rock and the remainder being retained in the constructed ponds.

Based upon the observations of these site visitations and those in an earlier report of the property (Hydrogeological Study, 1997 prepared by AquaTerra Consultants Ltd.), the following recommendations are made for the site in preparation for quarry operations. Please refer to the accompany drawing for the location of the described works.

1) WORKS TO BE COMPLETED PRIOR TO COMMENCEMENT OF OPERATIONS

Item A

The detention pond in the southeast corner of the property will require cleaning out of the silt material that has accumulated on the base. This should be done as soon as possible , before the pond begins to accumulate water and should be performed on an annual basis. The southeast outlet valve should remain closed unless emergency conditions exist and the pond requires maintenance.

Item B

The ditch along the north side of the main southern access road will require improvements. These improvement would consist of deepening and widening to the extent that the ditch has an average configuration of 1500mm in width and 800mm in depth.

2) WORKS TO BE COMPLETED DURING THE SUMMER OF 1999

Item C

Three detention ponds exist in the south west corner of the site, identified as 1, 2, and 3 (east to west). Ponds 1 and 2 should be upgraded as follows. Pond 1 should be increased in retention volume by adding material to the berm, on the south side. The pond should also then be cleaned of any silt lining it's base. Two - 100mm culverts should be installed connecting pond 1 to pond 2. These culverts should be aligned such that there is a 1.5 m elevation differential between the lower culvert and the upper culvert. This will allow for additional flow from pond 1 to pond 2 to occur under high volume conditions.

Item D

A portion of the south access road crosses a narrow ravine area. Above this area is a large brush pile from earlier clearing activities. Presently this pile acts to block the ravine above the road. When this pile is burned or removed, it will again allow water to flow unrestricted down the ravine. Upon removal of the pile, that area should be excavated to create a small 6m X 6m X 1m pond to act as retention. The pond should exit into the ditch north of the road. It is also advisable to consider at that time, to upgrade the section of road by adding two - 100mm diameter culverts (spaced 2 metres apart horizontally) under the road crossing to allow for unimpeded water passage and to decrease the chance of washout.

Pipeline Right of Way

An inspection of the right of way that runs along the south boundary of the site did not reveal any recent signs to indicate that runoff from the site are creating any significant erosion problems. Swales that cross cut the right of way or serve to deflect water moving down the right of way, were functioning appropriately. This area should be visually monitored each month as a precaution.

In conclusion, from a technical view point regarding drainage, detention or runoff, the author can see no reason to delay commencing this project.

Sincerely,
AquaTerra Consultants Ltd.

Ray Koenig, P.Geo.

PROFESSIONAL PROVINCE OF R. M. KOENIG BRITISH COLUMBIA GEOSCIENTIST

attachment

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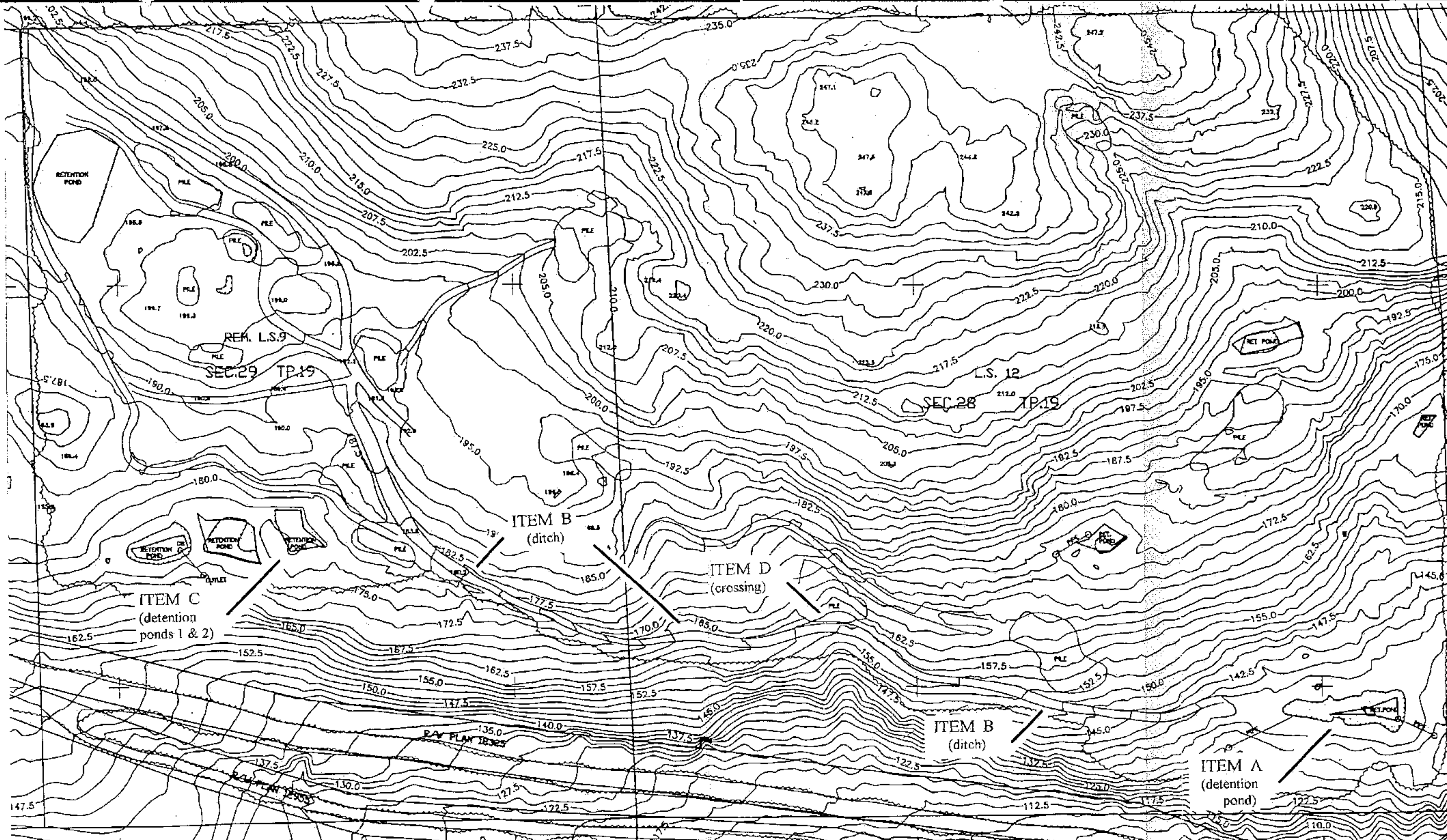


AQUATERRA CONSULTANTS LTD

3297 ABBOTSFORD, B.C. V2T 5G@
PHONE (604) 850-3521 FAX (604) 850-3542

DRAINAGE ENHANCEMENT

CLIENT: TOEWS BROS. BULLDOZING LTD.

PROJECT: PROPOSED WHISPERING PINES QUARRY

FILE No. 9715

DATE: NOVEMBER 1998

FIGURE 1

0700663

ABBOTSFORD

Abbotsford Spirit of BC

MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES SOUTHWEST REGION
REC'D SEP 12 2007

September 10, 2007

File: 5260-20/AT

Ministry of Energy, Mines and Petroleum Resources
PO Box 9320, Stn Prov Gov't
Victoria, B.C. V8W 9N3

Attention: Mr. Ed Taje
Regional Manager Mining and Exploration
Health, Safety and Underground Coal Specialist

Dear Mr. Taje:

Re: Slope Stability Analysis of Sumas Mountain Truck Route Rock Slope

I am pleased to forward to your Ministry, a copy of the Trow Consulting report entitled Baseline Assessment, Rock Cut Slope Eastern Boundary Western Rock Products, Western Rock Products Haul Road, Abbotsford , B.C. Rev 1.0. This report specifically addresses the rock slope stability in the cut section, in the southeast corner of LS 12, which is adjacent to the s.22

A copy of this report will also be provided by the City, to s.22 . I trust that this report satisfactorily addresses the slope stability concerns.

Yours truly,

Phil Blaker, P. Eng.
Manager of Projects

Enclosure (1)

c. Kiejoon Kim

Trow
50 YEARS

7025 Greenwood St.
Burnaby, BC
V5A 1X7

Tel: (604) 874-1245
Fax: (604) 874-2358

Buildings

Environment

Geotechnical

Infrastructure

Materials & Quality

August 3, 2007 Reference: 051-01695

City of Abbotsford
323-3215 South Fraser Way
Abbotsford, B.C., V2T 1W7

Via E-Mail

Attention: Mr. Phil Blaker

Baseline Assessment
Rock Cut Slope Eastern Boundary Western Rock Products
Western Rock Products Haul Road
Abbotsford, B.C.
Rev 1.0

Dear Mr. Blaker:

1.0 INTRODUCTION

As requested Trow Associates Inc. (Trow) has carried out a detailed baseline assessment of the bedrock cut slope along the eastern property boundary of Western Rock Products. This portion of the property was excavated for construction of an onsite haul road. The purpose of the assessment was to map as-built rock cut slopes and determine potential for failure of the existing rock cut slopes into the property adjacent and to the east of the study site. The subject area is located within the City of Abbotsford on the south side of Sumas Mountain (see Drawing 051-01695-01).

The road was constructed for use as a private haul road for gravel and other rock products produced by Western Rock Products Ltd. and other aggregate operators in the area. The road is gated and locked at times when Western Rock Quarry is shut down.

2.0 WORK SCOPE

The geotechnical site assessment included detailed mapping of rock structure along accessible as-built bedrock cut slope areas, production of a Digital Terrain Model (DTM) of the subject area and a site walkover reconnaissance along the crest of the rock cut for obvious visible evidence of rock mass instability. Detailed mapping was conducted over three days in May and June 2007 and added to structural data collected previously from the subject area. Data collected in the field was used to determine properties of exposed discontinuities, and to carry out stereographic analysis of mapped geological structure (Kinematic analysis). Stereonet software (DIPS) was used to identify discontinuity sets and assess their potential influence on overall stability of the bedrock cut slopes.

Detailed mapping of rock structure was conducted along the base of the rock cut and along a bench near the upper portion of the slope. This structural data was added to data obtained during construction of the rock cut. Hand scaling was carried out by a professional scaler prior to installing protective slope mesh over a limited area of the rock slope. However, hands scaling was not been carried out on the remaining slope areas. As such, potential for small dislodgments of rock fragments and face debris did not permit safe rope access to these rock slope face areas by field staff.

3.0 SITE DESCRIPTION

The haul road is located within the City of Abbotsford on the south side of Sumas Mountain with the subject area lying along the eastern property boundary of Western Rock Products Ltd. The haul road in this area is generally oriented in a north-south direction with production-blasted rock cuts along both sides of the road. Rock cuts along the eastern side of the road are the subject of this report.

The subject rock cut varies in height from about 20 metres to 65 metres with the maximum height located near the northeast corner of the haul road excavation where the roadway alignment turns to the west and away from the property boundary (see Drawing 051-01695-02). The bedrock in the subject area generally consists of an altered volcanic breccia with occasional mafic dykes and ranged in rock strength from medium to strong. Some metasediments were noted in the northern portion of the subject area. Numerous shear zones were noted throughout the bedrock with widths ranging from a few centimeters up to 0.5 metres with high persistence. Jointing within the bedrock was generally closely spaced with low to moderate persistence. Due to the method of blasting (production), blast damage of excavated rock cut faces was prevalent and consisted of blast-induced opening of tight joints and fractures and loosened rock fragments. Maintenance of the rock cut slopes will require regular review and cleanout of the catchment ditches and benches over the life of the haul road.

Overall cut slope inclinations varied from approximately 47° to 56° with some localized areas being as steep as 80° to accommodate geological structure during advancement of the rock cuts. Benches were constructed at various locations along the cut slopes as a mitigative rockfall control measure, particularly in the northern and southern portions of the subject area. Maximum bench width in the northern portion is greater than 10 metres with bench widths in the southern portion generally being less than 8 metres to absent where unfavourable geological structure was encountered.

The area behind the crest of the rock cut slope was vegetated with widely spaced trees and thick underbrush. A thin soil covering (less than 1 metre) overlies bedrock with the topography sloping moderately to the south. A minimum horizontal distance of approximately 5 metres was measured by hand from the crest of the cut slope to the survey markers identifying the eastern property line.

4.0 DISCUSSION

A stereonet analysis of potential failure modes (toppling, wedge sliding and planar sliding) was conducted. As the bedrock in this area is considered to have medium to strong rock strength erosion is not considered to be an important mechanism for slope regression. A brief discussion of each potential failure mode is presented below. Three discontinuity orientations have been identified as being statistically significant. J1 has an orientation of 80/268 (dip/dip direction), J2 has an orientation of 82/311 and J3 has a general orientation of 53/242; however J3 appears to have highly variable orientation with respect to dip direction.

Toppling - Potential toppling failures appear to be most probable in areas where the cut slope is oriented with a north to northeasterly trend (bearing from about 0° to 30°). As such the area likely to be affected by toppling failures can be defined approximately by stationing 51+15 to 51+50. A review of structural mapping data in this area indicates there are a few discontinuities present which may topple. However since a rock mass on a surface with a dip of at least 60 degrees is considered to have toppling potential,

Trow 50 YEARS

this mode of failure is considered unlikely to affect the adjacent property since a surface originating within a few metres elevation of the slope crest would daylight west of the adjacent property boundary. Furthermore, it is considered unlikely that a toppling failure would originate at an elevation lower than that described above based on the determination of persistence and termination of mapped discontinuities. Persistence is the measure of the continuous length or area of the discontinuity and termination is the identification of discontinuities truncated by other discontinuities or terminating in rock. Discontinuity mapping revealed low to very low persistence and terminations consistent with observed irregular block shape. This condition is not considered favourable for toppling mode of failure.

Planar Sliding – Numerous mapped discontinuities indicate potential for planar sliding. However we are of the opinion that as the discontinuities involved have a highly variable orientation, it is unlikely that a failure event along an individual low-persistence discontinuity will result in sufficient material loss to retrogress into the adjacent property. A prominent shear zone forms the backwall of the cut slope in the area of station 51+10 and was exposed during construction. The shear zone precluded the establishment of the design slope cut in this area. However the lower areas of this discontinuity do not dip steeply enough to fall within the daylight envelope of most of the cut slope and therefore is unlikely to experience further large scale failures.

Wedge Sliding – The potential for a wedge failure exists with the intersection of J1 and J3. Due to the highly variable nature of the dip direction of J3 the intersection of these joint sets is also expected to vary significantly. Due to the limited persistence and variable nature of J3 we are of the opinion that a large volume wedge failure is unlikely. As such, a wedge mode failure event with sufficient material loss to extend beyond the property boundary is considered unlikely.

It is our opinion that failures within the exposed bedrock cut will mainly consist of raveling irregular blocks up to medium in size that were loosened during production blasting and excavation. Individual failure events of the required scale to encroach onto the adjacent property are considered unlikely. As part of the maintenance plan for the road, regular inspections of the rock face and the crest of cut slope should be undertaken to review rate and extent of slope crest retrogression that may occur as the rock cut slope weathers over time.

Seismic Considerations – In the case of a large magnitude seismic event, we are of the opinion that it is unlikely to trigger a large scale failure within the rock mass that would affect the adjacent property for the reasons provided above. However, we feel that such a seismic event would likely result in the dislodgement of numerous rock fragments loosened by blasting during construction of the slope. Benches and catchment ditches should be reviewed to confirm the continued effectiveness of these mitigative measures. In addition a thorough visual review of the crest of the cut slope should be conducted by a qualified Geotechnical Engineer after the seismic event to evaluate the stability of the cut slope.

5.0 CLOSURE

This report was prepared for the exclusive use of our client, City of Abbotsford and their designated consultants or agents, and may not be used by other parties without written consent of Trow Associates Inc. This report contains our Interpretation and Use of Study and Report. These interpretations form an integral part of this report and should be included with any copies of this report.

Please do not hesitate to call the undersigned if there are any questions regarding this report.

Yours truly,

Trow Associates Inc.

PROVINCE OF E. G. SYKES BRITISH COLUMBIA Aug 3/07

Evan Sykes, P.Eng.
Project Engineer

Reviewed by:

James Wetherill, P.Eng.
Engineer

Distribution: Mr. Phil Blaker, City of Abbotsford

Enclosures: Interpretation and Use of Study and Report

Drawing	**Drawing No.**
Location Plan	051-01695-01
Site Plan	051-01695-02
Stereonet Analysis	051-01695-SN01
Sections	051-01695-SEC01 thru SEC02
Detailed Structural Mapping Data	

ES/es

INTERPRETATION & USE OF STUDY AND REPORT

1. STANDARD OF CARE

This study and Report have been prepared in accordance with generally accepted engineering consulting practices in this area. No other warranty, expressed or implied, is made. Engineering studies and reports do not include environmental consulting unless specifically stated in the engineering report.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF THE REPORT

The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS "APPROVED USERS". The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report, or any portion thereof, available to any party without our written permission. Any use which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. We accept no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT

a. Nature and Exactness of Descriptions: Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations, or building envelope descriptions, utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b. Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the report as a result of misstatements, omissions, misrepresentations or fraudulent acts of persons providing information.

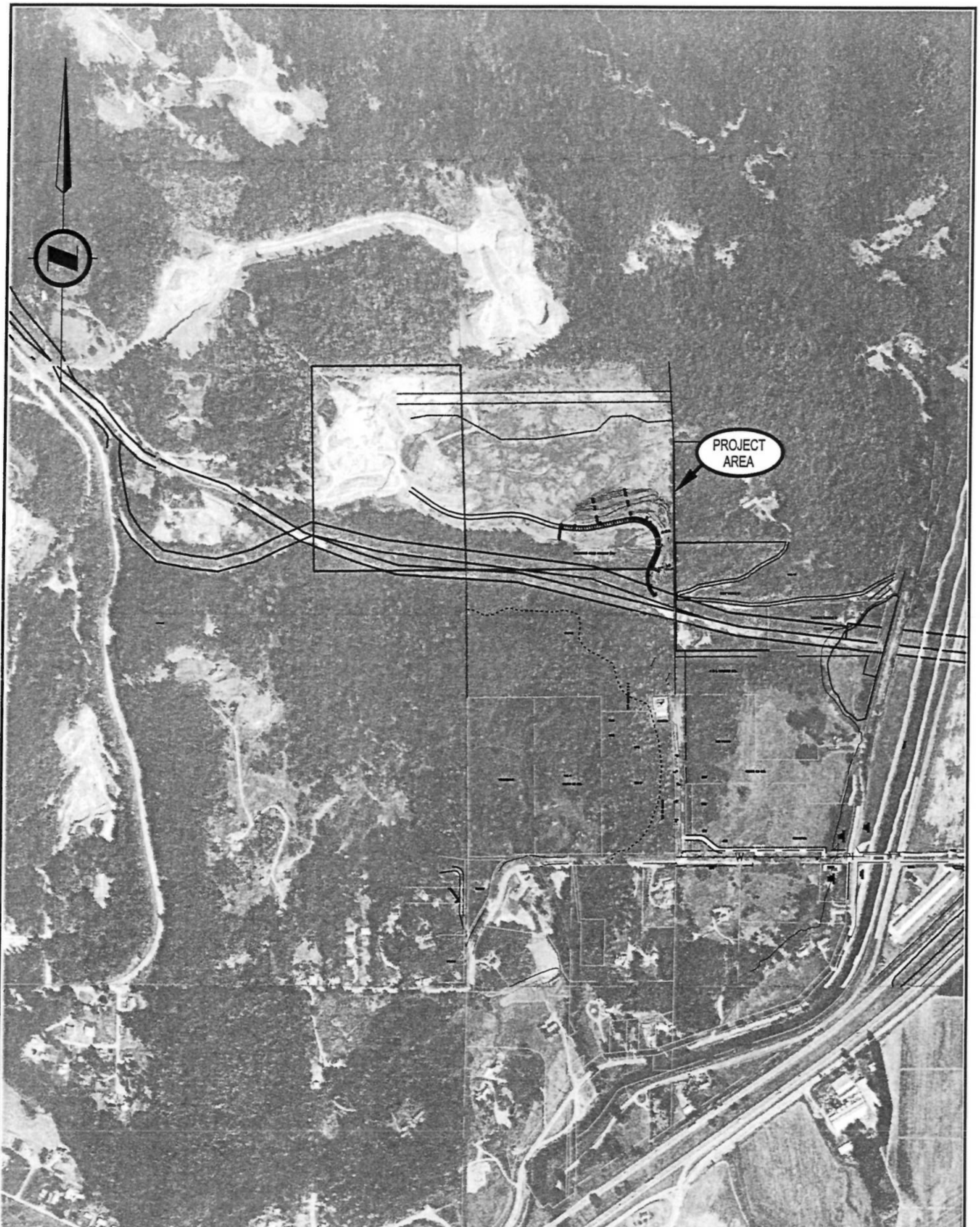
c. To avoid misunderstandings, Trow Associates Inc. (Trow) should be retained to work with the other design professionals to explain relevant engineering findings and to review their plans, drawings, and specifications relative to engineering issues pertaining to consulting services provided by Trow. Further, Trow should be retained to provide field reviews during the construction, consistent with building codes guidelines and generally accepted practices. Where applicable, the field services recommended for the project are the minimum necessary to ascertain that the Contractor's work is being carried out in general conformity with Trow's recommendations. Any reduction from the level of services normally recommended will result in Trow providing qualified opinions regarding adequacy of the work.

6.0 ALTERNATE REPORT FORMAT

When Trow submits both electronic file and hard copies of reports, drawings and other documents and deliverables (Trow's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by Trow shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancy, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by Trow shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of Trow's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Trow. The Client warrants that Trow's instruments of professional service will be used only and exactly as submitted by Trow.

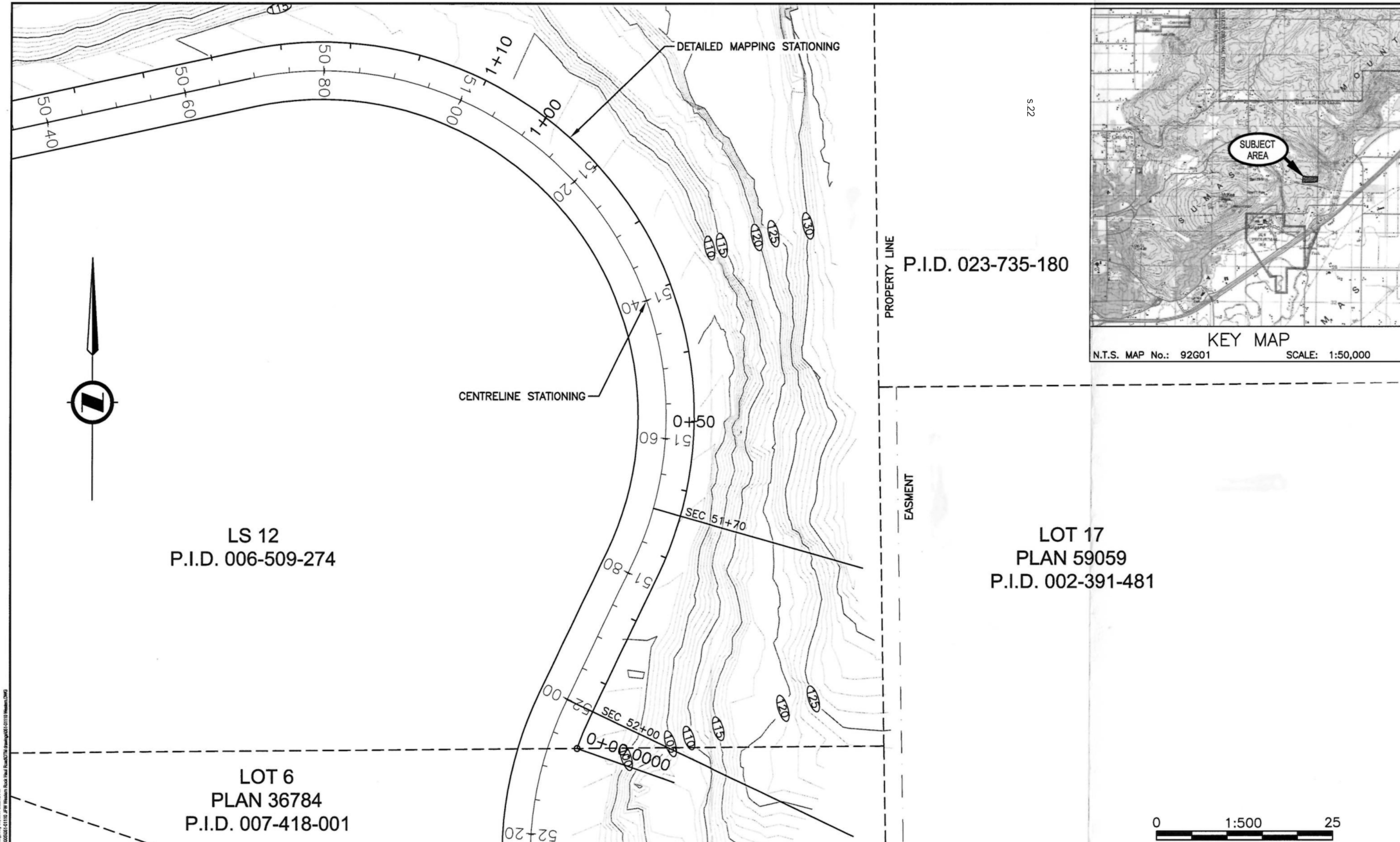
The Client recognizes and agrees that electronic files submitted by Trow have been prepared and submitted using specific software and hardware systems. Trow makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.



CLIENT			TITLE:		
CITY OF ABBOTSFORD			LOCATION PLAN		
PROJECT WESTERN ROCK QUARRY HAUL ROAD ABBOTSFORD, B.C.					
PROJECT NO. 051-01695	DFTR. PDL	DSGN. EGS	CHK. JFW	DATE JULY, 2007	SCALE: 1:10,000	DWG NO. 051-01695-01

TROW ASSOCIATES INC.

Jul 12, 2007 – 4:34pm O:\2005\051-01110 JFW Western Rock Haul Road\DTM drawings\051-01110 Western.DWG



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TROW ASSOCIATES INC.
7025 Greenwood Street, Burnaby,
British Columbia, V5A 1X7
Telephone: 604–874–1245
Fax: 604–874–2358

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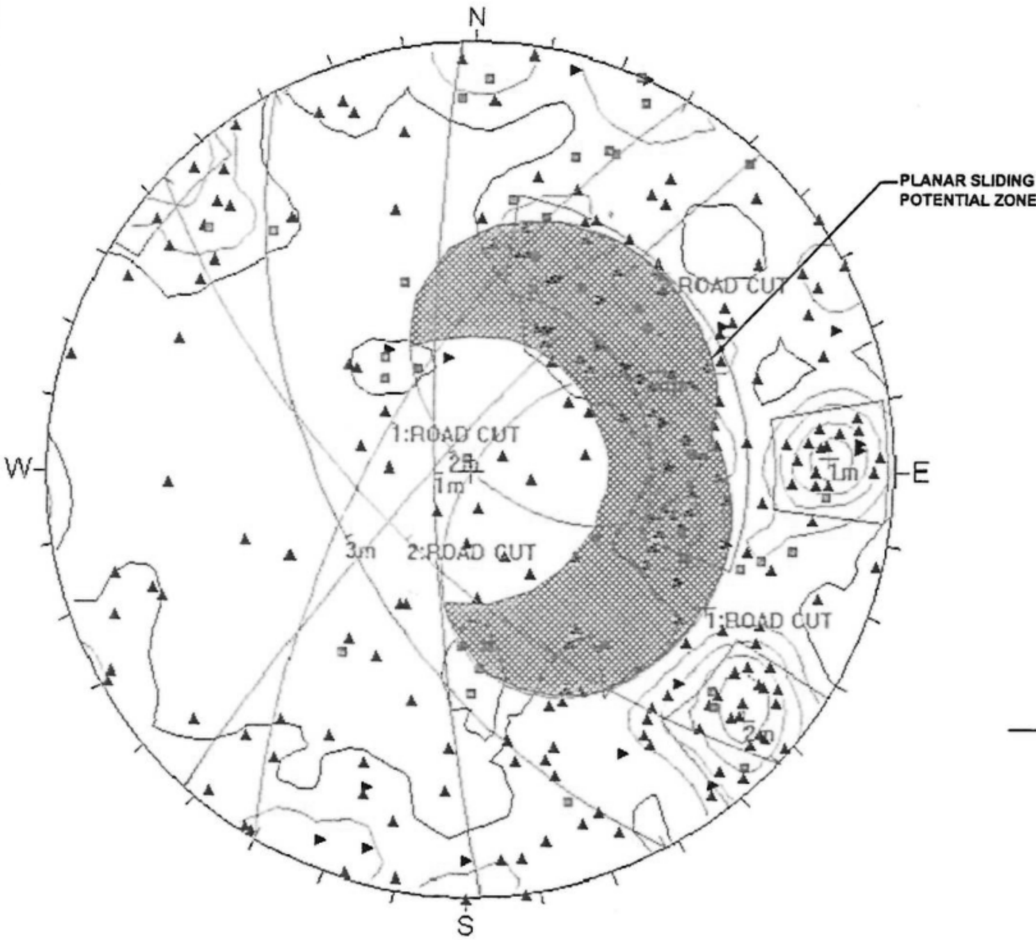
REVISIONS		
No.	DESCRIPTION	DATE

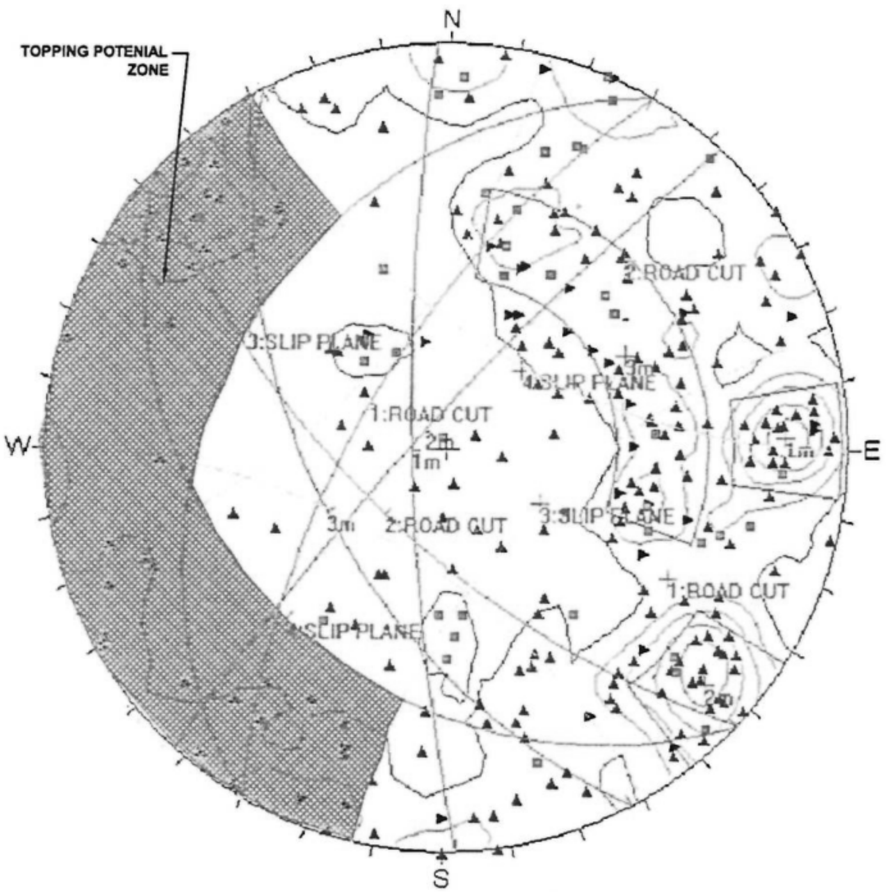
CLIENT	CITY OF ABBOTSFORD
PROJECT	WESTERN ROCK QUARRY HAUL ROAD ABBOTSFORD, B.C.
PROJECT NO.	051-01110
DFTR.	PDL
DSGN.	EGS
CHK.	JFW
TITLE:	SITE PLAN
DATE	JULY, 2007
SCALE:	1:500
DWG NO.	051-01695-02



Traverse

■	1 [54]
▲	2 [200]
►	3 [31]

Equal Angle
Lower Hemisphere
285 Poles
285 Entries



Traverse

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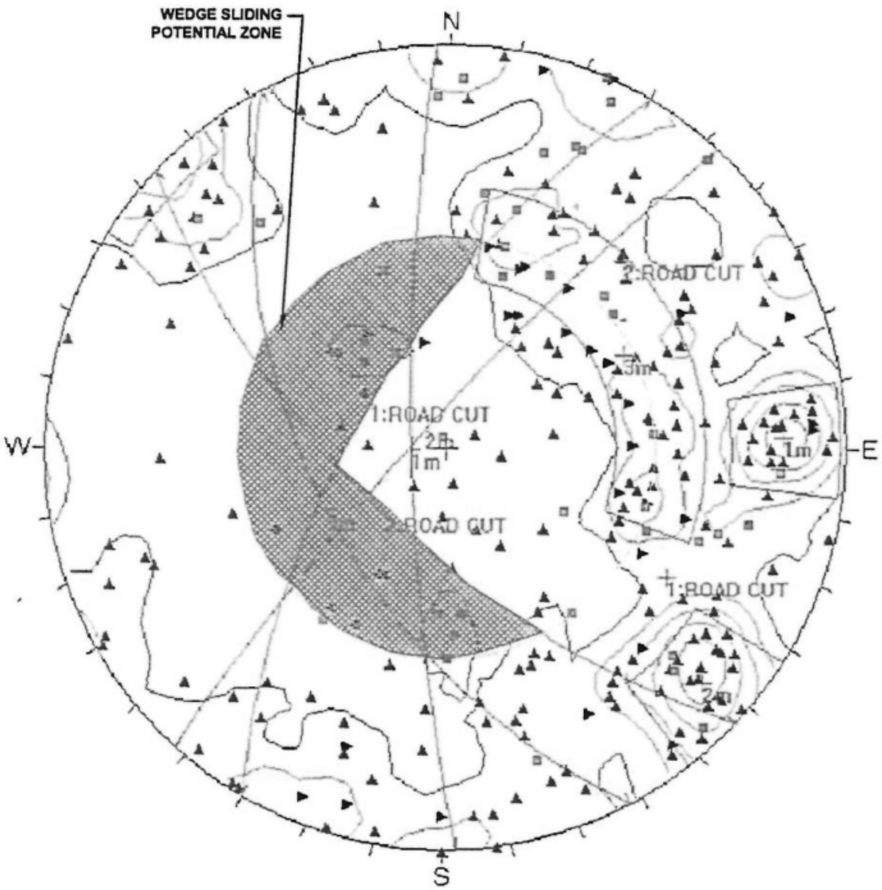
Equal Angle
Lower Hemisphere
285 Poles
285 Entries



Traverse

▪	1 [54]
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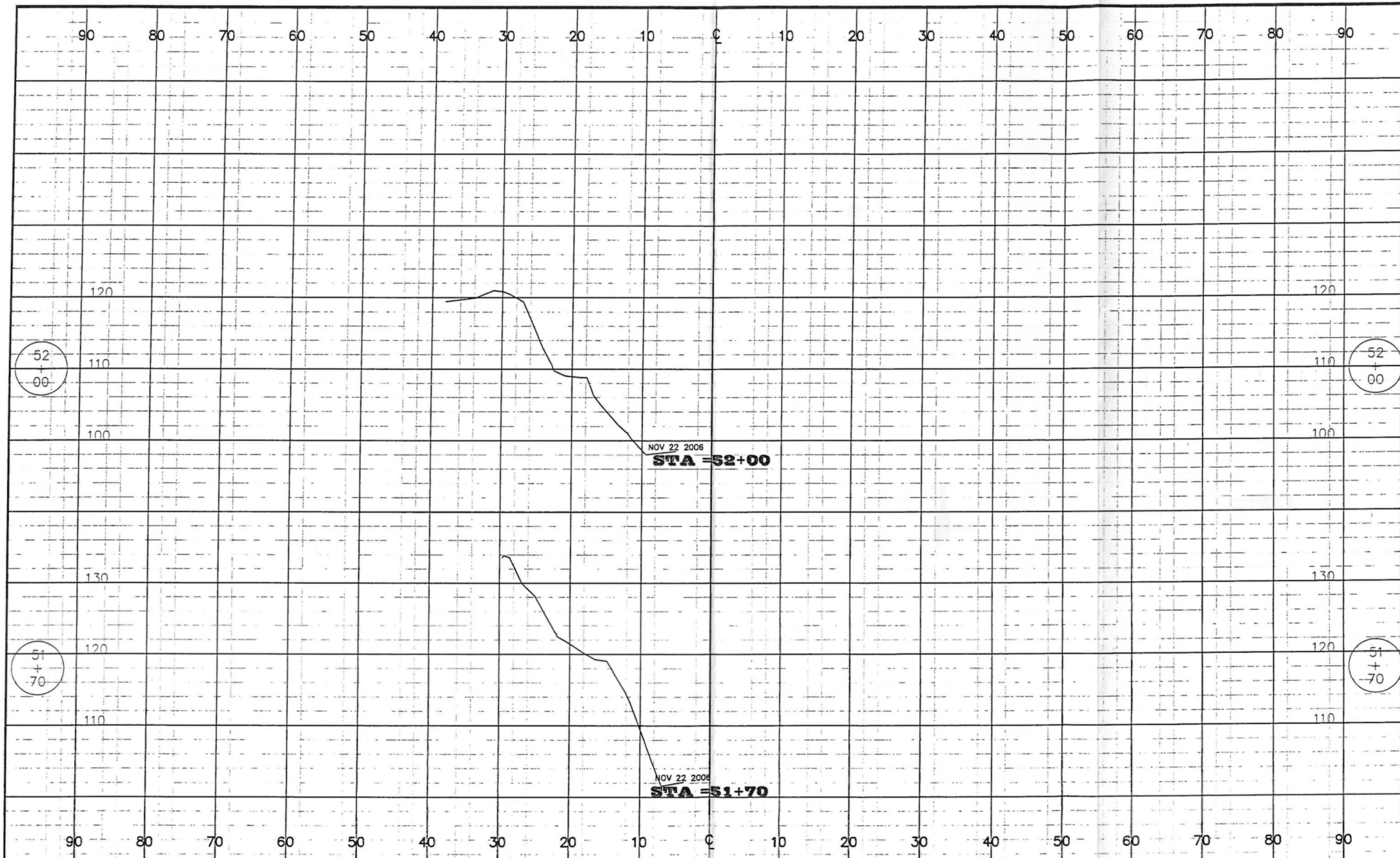
Equal Angle
Lower Hemisphere
285 Poles
285 Entries



TROW ASSOCIATES INC.
7025 Greenwood Street, Burnaby, British Columbia, V5A 1X7
Telephone: 604-874-1245
Fax: 604-874-2358

REVISIONS

No.	DESCRIPTION	DATE

CLIENT: WESTERN ROCK PRODUCTS INC.

PROJECT: 90617BC LTD. C/o WESTERN ROCK QUARRY HAUL ROAD ROCK SLOPE, ABBOTSFORD B.C.

TITLE: CROSS SECTIONS ROCK QUARRY AREA

PROJECT NO.	DFTR.	DSGN.	CHK.	DATE	SCALE:	DWG NO.
051-01695	PDL	EGS	JFW	JULY, 2007	1:500	051-01695-SEC-01

Dip	Dip Direction	Traverse	Set	Persistence	Type	Roughness	Waviness	Spacing	Comments	Filling	Aperture
64	304	3	3	L	S	Rg	Und	N/A	altered intrusive	Wlrsi	1-3
38	163	3		L	J	Rg	Und-W	Mod	sl. altered intr.	CCl	0.1-1
58	316	3		M	J	Rg	Und-W	?	blast damaged	CCl	1-3
90	222	3		M	J	Rg - VRg	W	Close	altered intrusive	CCl	0.1-1
30	186	3		L	J	Rg - VRg	W	Close	altered intrusive	Ca	0.1-1
85	285	3	1	L	J	SlRg - Rg	Und - W	Close	altered intrusive	Ca	
45	244	3	3	M	J	SlRg - rg	Pl - Und		altered intrusive	C	
51	220	3	3	H	S	Rg	W		forms backwall exc	CWlr	
52	221	3	3	H	S	Rg	W		forms backwall exc	CWlr	
70	333	3	2	M	J	SlRg	W	V Close	blast damaged	Ca	3-10
41	226	3	3	M-H	J	Rg - VRg	W			Ca-C	3-10
40	223	3	3	M-H	J	Rg - VRg	W			Ca-C	3-10
50	274	3	3	H	J	SlRg	Pl - Und	V Close	Backslope to crest	C	0.1-1
50	274	3	3	H	J	SlRg	Pl - Und	V Close	Backslope to crest	C	0.1-1
50	287	3	3	H	J	SlRg	Pl - Und	V Close	Backslope to crest	C	0.1-1
49	260	3	3	H	J	SlRg	Pl - Und	V Close	Backslope to crest	C	0.1-1
53	235	3	3	H	J	SlRg	Pl - Und	V Close	Backslope to crest	C	0.1-1
86	340	3		M	J	SlRg	Pl - Und	Close		Ca	0.1-1
55	303	3	3	L	J			Wide	wedge with 20		
85	33	3		M-H	J	SlRg	Pl - Und	Wide		Ca	0.1-1
48	302	3	3	M	J	Rg - VRg	W	Wide		Ca	0.1-1
85	18	3		M	Contact	Rg	W	Wide	Contact	Ca	
47	254	3	3	M	J	SlRg	Pl - Und	Close		C	3-10
76	36	3		L	J	SlRg	Pl - Und	Close		CCa	
68	258	3		M	J	SlRg	Und	Close	Int Contact	C	
74	349	3		H	Contact	SlRg	Curvy			Ch	1-3
54	210	3		H	S	Rg	Und - W		slickensided		
88	212	3		H	J	SlRg - Rg	Und - W	Close	blast damaged	CCa	1-3
85	284	3	1	M	J	SlRg - Rg	Und - W	Close		CCa	1-3
85	267	3		L	J	Rg	Und	Close	Intrusive	C	1-3
86	40	3		H	J	Rg - VRg	Und - W	Close		CCa	1-3
79	284	2	1	M	J	Slrg	Und	C		Ca,Fe	0.1-1
73	344	2		L	J	Slrg-Rg	Und	0.5		Ca	T
35	327	2		L	J	Slrg-Rg	Und-W	C		C	0.1-1
78	290	2	1	L	J	Slrg-Rg	Und	M		Ca,Fe	1
89	163	2		L	S	Slrg-Rg	Und-W		Slickensided	Ca,Cl	1
83	323	2	2	L	S	Slrg-Rg	W		Slickensided	Ca,Cl,Fe	1-3
80	321	2	2	L	S	Slrg-Rg	Und-W		Slickensided	Ca,Cl	1-3
50	298	2	3	M	J	Slrg	Und	VW	Blast Damaged	Ca	1-3
52	300	2	3	M	J	Slrg	Und	VW		Ca	1-3
52	300	2	3	M	J	Slrg	Und	VW		Ca	1-3
71	342	2		L	J	Slrg	Und	0.5		Ca,Fe	0.1-1
35	234	2		L	J	Slrg-Rg	W			Cl	0.1-1
89	301	2		L	S	Rg	W		Slickensided	Ca,Cl	1-3
63	244	2	3	L	J	Sm	Pl-Und	0.1-0.2		Fe	0.1-1
81	357	2		L	J	Slrg	W	0.4-0.5		C	0.1-1
34	261	2		L	J	Slrg-Rg	W			C	1-3
83	179	2		L	S	Slrg	Und-W			Ca	10
55	212	2	3	VL	J	Slrg-Rg	Und-W	0.1		Ca,Fe	0.1-1
75	316	2		L	J	Slrg	W	0.1		Ca,Fe	1-3

Dip	Dip Direction	Traverse	Set	Persistence	Type	Roughness	Waviness	Spacing	Comments	Filling	Aperture
28	142	2		L	J	Slrg	Und	0.2		Ca,Fe	0-0.1
66	22	2		L	J	Slrg-Rg	W	0.1		Ca	0.1-1
73	306	2		M	J	Slrg-Rg	Und-W	01-0.2		Ca	1-3
60	359	2		M	S?	Slrg	Und	0.3		Ca	3-10
75	344	2		H	J	Slrg	Und-W	0.1-0.3		Ca,Cl	0.1-1
38	44	2		L	J	Slrg-Rg	Und-W	0.2-0.4		Ca	0.1-1
55	262	2	3	L	J	Rg	Und-W	0.2-0.3		Ca	0.1-1
81	324	2	2	L	J	Slrg-Rg	Und	0.3-0.5		Ca	0.1-1
80	331	2	2	L	J	Slrg-Rg	Und-W	0.06-0.1		Ca,Fe	1-2
79	281	2	1	M	J	Slrg	Und-W	0.1-0.3		Ca	1-2
42	148	2		L	J	Rg	Und	0.35			0.1-1
85	282	2	1	L	J	Rg	Und			Ca	0.1-1
52	54	2		L	J	Rg	Und-W	1		Ca	1-3
80	284	2	1	L	J	Slrg-Rg	Pl-Und	0.3		Ca,Fe	0.1
86	330	2	2	M	S	Rg-Vrg	W			Ca	2
31	348	2		L	J	Slrg-Rg	Und	0.25		Ca	<0.1
82	92	2		L	J	Rg	Und-W	0.15		Ca	0.1-1
70	320	2	2	L	J	Slrg	Und	0.2		C	1-2
76	143	2		M	S	Rg-Vrg	W			Ca,Cl	50
76	325	2	2	L	J	Slrg-Rg	Und	0.15		Ca	0.1-1
38	227	2	3	L	J	Slrg-Rg	Pl-Und	0.1		Fe	0.1-1
50	83	2		L	J	Slrg	Und	20		Ca,Fe	0.1-1
90	259	2		L	J	Slrg	Und	0.45		Ca	<0.1
70	46	2		L	J	Rg	Und	0.15		Ca	0.1-1
82	308	2		L	J	Slrg	Und	0.15		C	0.1-1
82	201	2		L	J	Slrg-Rg	Und	0.1		C	0.1-1
80	30	2		L	J	Slrg	Und	0.2		Ca	0.1-1
84	257	2		L	J	Rg	Und-W	0.25		Ca,Fe	0.1-1
86	137	2	2	L	S	Slrg	W	0.15		Ca	8
39	46	2		L	J	Slrg	Und	0.15		C	0.1-1
88	79	2		M	J	Vrg	Und-W	0.4		Fe	0.1-1
60	289	2	3	L	J	Slrg-Rg	W	0.2		Fe	1-3
88	57	2		L	J	Slrg	Und	0.1		Ca	0.1-1
66	232	2	3	L	J	Slrg	Und	0.2		C	0.1-1
84	86	2		L	J	Slrg	Und	0.15		C	0.1-1
58	354	2		L	S	Slrg	Und-W			Ca,Cl,Fe	2-3
78	186	2		L	J	Slrg	Und	0.3		C	1-3
89	78	2		L	J	Rg	Und-W	0.2		Ca	1-3
74	132	2		L	S	Rg	Und-W			Ca,Cl	10
77	88	2		L	J	Slrg	Und	0.1		Ca	0.1-1
76	86	2		L	S	Slrg-Rg	Und-W		Slickensided	Ca,Fe	30
76	147	2		L	J	Slrg-Rg	Und	0.1		C	0.1-1
54	279	2	3	L	J	Rg	Und-W	0.15		Ca,Fe	1-3
89	35	2		L	J	Slrg	Und	0.25		Ca	1-3
54	280	2	3	L	J	Slrg-Rg	Und-W	0.15		Ca,Fe	0.1-1
70	3	2		L	J	Slrg	Und-W	0.15		Ca,Cl,Fe	0.1-1
66	282	2	3	L	J	Rg	Und-W	0.17		Ca,Fe	0.1-1
66	224	2	3	L	J	Slrg	Und			Ca,Fe	0.1-1
82	154	2		L	J	Slrg	Und	0.1		Fe	1-3
65	264	2	3	L	J	Slrg	Und-W	0.09		Ca	0.1-1

Dip	Dip Direction	Traverse	Set	Persistence	Type	Roughness	Waviness	Spacing	Comments	Filling	Aperture
60	277	2	3	H	S	Slrg-Rg	W			C	1-3
62	272	2	3	H	S	Slrg-Rg	W			C	1-3
89	329	2	2	M	S	Slrg	Und		Slickensided	Stwlr	3-10
65	10	2		M	S	Slrg	Und		Minor Slickensides	Cl	3-10
87	341	2		M	S	Slrg	Und			Ca	1-3
80	328	2	2	M	S	Slrg-Rg	Und			Ca	1-3
83	144	2		M	S	Slrg	Und-W			Ca	3-10
80	284	2	1	L	J	Rg	Und-W			FeCa	
82	66	2		H	S	Rg-Vrg	Wav	C		Corwlrcy	10-50
89	50	2		H		Rg-Vrg	Wav		Slickensided, Major Structure	Corwlrcy	10-50
78	58	2		H		Rg-Vrg	Wav			Corwlrcy	10-50
89	50	2		L	J	Sm	Und-W			FeCa	T
76	325	2	2	L	J	Slrg	Und			Ca	T
81	150	2		M	S?	Slrg	Und			Ca	1-3
57	284	2	3	VL	J	Rg-Vrg	Wav			Ca	0.1-1
52	45	2		L	J	Rg	Und	C		C	0.1-1
62	264	2	3	VL	S?	Rg	Und-W		Cut Face, Slickensided	Ca	
72	55	2		L	J	Rg	Und			C	<0.1
62	294	2	3	M	J	Slrg-Rg	Und-W			C	T
72	162	2		M	S?	Slrg	Und	W	Slickensided	Ca	1-3
75	234	2		L	J	Slrg-Rg	Und-W	C		FeCa	T
69	294	2		L	J	Slrg-Rg	Pl-Und	C		FeCa	T
58	32	2		L	J	Slrg-Rg	Wav	C		C	T
33	14	2		M	S	slrg	Und-W			Wlrslwr	3-10
75	231	2		L	J	Slrg-Rg	Pl-Und	C		FeCa	0.1-1
82	263	2		M	J	Rg-Vrg	Wav	C	Cut Face		T
90	252	2		M	J	Rg-Vrg	Wav	C			T
70	258	2		M	J	Rg-Vrg	Wav	C			T
60	356	2		M	S	Slrg	Und	W?		Ca	1-3
55	298	2	3	M	J	Rg	Und-W	C		Ca, Fe	0.1-1
78	296	2		L	J	Slrg	Und			Ca	
62	323	2		H	J	Slrg-Rg	Und	C-M		Ca	1-3
80	324	2	2	M	S?	Slrg	Und	M		Ca	1-3
71	106	2		VL	J	Slrg	Und-W	C		C	
58	91	2			J	Slrg	Und-W	C		C	
61	200	2		VL	J	Rg	Und-W	C		Ca	T
77	283	2	1	L?	J	Slrg-Rg	Und	C		C	
65	222	2	3	M	J	Rg	Und-W			C	0.1-1
48	270	2	3	VL	J	Slrg-Rg	Und-W	W		Ca	
60	351	2		H	S	Slrg-Rg	Und-W	C	Slickensided	Ca,Wlr	3-10
66	240	2	3	L	J	Rg	Und-W	C		C	
83	6	2		H	J	Rg	Und-W	C		Ca	0.1-1
90	10	2		H	J	Rg	Und-W	C		Ca	0.1-1
85	280	2	1	M	J	Slrg	Und	C		Cl	0.1-1
85	338	2	2	H	S	Rg-Vrg	Und			Stwlr	3-10
90	18	2		M	J	Slrg-Rg	Und-W	VC	Blast Damaged	C	1-3
88	196	2		M	J	Slrg-Rg	Und-W	VC	Blast Damaged	C	1-3
85	13	2		M	J	Slrg-Rg	Und-W	VC	Blast Damaged	C	1-3
82	270	2		L	J	Rg	Und	C		C	
68	304	2		H	S	Rg	Und-W		Slickensided	Corewlrcy	150-300

Dip	Dip Direction	Traverse	Set	Persistence	Type	Roughness	Waviness	Spacing	Comments	Filling	Aperture
87	146	2	2	M	J	Slrg-Rg	Und	VC	Blast Damaged	Fe,Ca	3-10
65	181	2		L	J	Slrg-Rg	Und-W			C	
85	332	2	2	H	S	Slrg	Und-W		Slickensided, gouge	Corewlrcy	150-300
78	336	2	2	H	J	Slrg	Pl-Und	VC		Cl	0.1-1
70	340	2		H	J	Slrg	Pl-Und	VC	some gouge in fill	Vl	0.1-1
70	218	2		L	J	Rg-Vrg	Und-W		some sulphides	C	
30	120	2		L	J	Slrg	Pl-Und	VC		C	0.1-1
78	288	2	1	H	Contact	Slrg-Rg	Und		Contact with mafic dyke about 1 m wide		Ca
87	288	2	1	H	Contact	Slrg-Rg	Und		some shearing	Ca	3-10
62	224	2	3	M	J	Slrg-Rg	Und	C	Blast Damaged	C	0.1-1
73	2	2		H?	S?	Slrg	Und-W	S h	Shear - splaying out near bottom in dyke		Ca
85	158	2	2	H?	S	Slrg	Und-W		joins shear above	Ca	1-3
85	178	2		M	J	Slrg-Rg	Und	C		C	0.1-1
50	263	2	3	L	J	Rg-Vrg	Und	C		C	0.1-1
31	252	2		L	J	Slrg-Rg	Und	C		C	T
89	206	2		L	J	Slrg-Rg	Pl-Und	VC		C	0.1-1
58	266	2	3	M	J	Rg	Und	VC-C		C	
88	286	2	1	L	J	Slrg-Rg	Und	C		C	T
85	10	2		M-H	J?	Slrg-Rg	Und-W	?		C	1-3
85	174	2		M	J	Rg	Und	?		C	
88	28	2		M	J	Rg-Vrg	Und-W	VC	Blast Damaged	Cl,Ca	1-3
75	286	2	1	L	J	Rg	Und	M	Blast Damaged	Ca	1-3
48	344	2		M?	J	Slrg-Rg	Pl-Und	?		C	1
82	282	2	1	L	J	Slrg-Rg	Und	W		Ca	
24	356	2		M	J	Slrg	Und	?		minor Ca	0.1-1
70	336	2	2	M	J	Slrg	Und	VC-C	Blast Damaged	Cl	0.1-1
85	244	2		M-L	J	Slrg-Rg	Und	C		C	
30	280	2		M	J?	Vrg	Und-W	M		Wlrsi	3-10
68	1	2		M	S?	Slrg	Und-W	C	Blast Damaged	Wlr	1-3
80	290	2	1	M	J	Slrg-Rg	Und	M		Ca	
40	242	2	3	L	J	Slrg-Rg	Und	M		Ca	
70	340	2		M	S	Slrg	Und-W			Wlrsi	3-10
16	296	2		M	S	Slrg-Rg	Und	M	Parallel to Jointing	Wlrsi	3-10
85	330	2	2	M	S	Slrg	Und-W			Wlrsi	3-10
60	282	2	3	VH	F?	Slrg-Rg	Wav		Forms Backwall of Slip	Plane	3-10
55	17	1		M	S	Rg-VRg	Und-W			WLR	3-10
37	316	1			J	Slrg-Rg	Und-W			CCL	<0.1
85	200	1		L	J	Slrg-Rg	Pl-Und			CA	1
57	310	1	3	M	S	Rg	Und			WLRSLWRI	10-50
65	206	1		M	J?	Rg-VRg	Und-W				
3	179	1		H	J	Slrg-Rg	Und-W	M-W		CA	1-3
30	170	1			J	Slrg-Rg	Und-W	M-W		CA	1-3
87	223	1		H	J	Rg-VRg	Und-W	C		MINOR CA	
90	221	1			J	Rg-VRg	Und-W	C		MINOR CA	
88	240	1			J	Rg-VRg	Und-W	C		MINOR CA	
80	292	1	1	L	J	Slrg-Rg	Und	C		CA	
50	178	1		M-H	J	Slrg-Rg	Pl-Und	C to M		CA	
72	158	1		H	S?	Slrg	Pl-Und			CA	1-3
45	20	1		M	J	Slrg	Pl			CA	1-3
68	308	1		M	S?	Rg	UND-W	C?	Slickensided	Ca	

Dip	Dip Direction	Traverse	Set	Persistence	Type	Roughness	Waviness	Spacing	Comments	Filling	Aperture
75	330	1	2	M	S?	Rg	UND-W	C?	Slickensided	Ca	
55	304	1	3	M-H	J	SIRg	Pl-Und	C-M		Ca	1-3
71	305	1		M	S	SIRg	Pl-Und	C	Sheared area, slickensided	Ca	
76	302	1		M	S	SIRg	Pl-Und	C	Sheared area, slickensided	Ca	1-3
55	284	1	3	L-M	J	SIRg	Pl-Und			C	1-3
57	244	1	3	M	J	Slrg-Rg	Pl-Und	C?	Sheared zone	Ca	
77	332	1	2	M-H	J	Slrg-Rg	Pl-Und	C-M	0+39 to 0+46	Ca	<0.1
56	249	1	3	M?	J	SIRg	Und	?		Ca	
82	196	1		L	J	SIRg	Pl-Und	C		Ca	3-10
78	222	1		M	J	Slrg-Rg	Pl-Und	?	Wall to shear area - slickensided	C	1-3
37	160	1		M	S	Slrg	Und-W	M-W		WLRsi	3-10
33	154	1		M	S	Slrg	Und-W	M-W		WLRsi	3-10
78	1	1		L	J	Slrg	Und	C		Ca	1-3
63	214	1	3	H	J	Rg-VRg	W	VC-C?	Blast backwall upper area	C	
53	229	1	3	H	J	Rg-VRg	W	VC-C?	Blast backwall upper area	C	
75	216	1		H	J	Rg-VRg	W	VC-C?	Blast backwall upper area	C	
55	214	1	3	H	J	Rg-VRg	W	VC-C?	Blast backwall upper area	C	
80	150	1		M	J	Slrg	Und	VC		Minor Ca	0.1-1
55	340	1		M	J	Slrg-Rg	Pl--Und	VC	edge of mesh	Ca	
48	216	1	3	M	J	Slrg-Rg	Und	VC		Minor Ca	0.1-1
50	15	1		L-M	J	Slrg	Pl-Und	VC-C		C	1-3
55	53	1		L	J	Slrg	Pl-Und			C	3-10
45	12	1		L-M	J	Slrg	Pl-Und	VC-C		C	0.1-1
78	221	1		M	J	Slrg	Pl-Und			Ca	
87	335	1	2	M	S	Slrg	Und	small shear		WLRsi	1-3
55	293	2	3		J	R	P	K	ANDS	W	B
73	283	2	1		J	R	U	L	ANDS	W(A)	B
60	210	2			J	V	P	L	ANDS		A
67	259	2			J	R/S	P	M	ANDS	W	B
88	336	2	2		J	R	P	H	ANDS	W	B
74	22	2			S	V	P	H	ANDS	W	A
88	155	2	2		J	S	P	-	ANDS	A/W	C
70	255	2			J	R/S	U	-	ANDS	W	B
10	5	2			J	R	P	J	ANDS		A
78	52	2			J	R	P	J	ANDS		A
62	224	2	3		J	R	P	K	ANDS	W	A
60	234	2	3		J	R/S	P	K	ANDS	W	B/C
84	325	2	2		S	R	P	I	ANDS	W	B
76	332	2	2		S	R	P	H	ANDS	A/W	B/C
41	268	2	3		J	R	P	K	ANDS	W	A
22	110	2			J	S	P	K	ANDS	W	A
85	355	2			S	S	U	J	ANDS	A/W	C
66	326	2			J	R	P	I	ANDS	W	A
50	310	2	3		S	R	U	-	ANDS	A/W	B
50	348	2			S	R/S	U	J	ANDS	A/W	B
65	240	2	3		J	V	P/S	I	ANDS	W	A
85	260	2			J	R	P	J	ANDS	W	A
79	232	2			S	S/R	U	-	ANDS	A/W	C
79	252	2			J	R	P	J	ANDS	W	A
14	58	2			J	R	P	-	ANDS	W	B

Dip	Dip Direction	Traverse	Set	Persistence	Type	Roughness	Waviness	Spacing	Comments	Filling	Aperture	
82	0	2			J	S	P	G	ANDS	W	B	
70	270	2			J	R/V	P/U	I	ANDS	W	A	
9	262	2			J	R	P	-	ANDS	W	A	
80	155	2			J	S	P	G	ANDS	W	B	
40	149	2			S	R	P	-	ANDS	A/W	C	
56	203	2			J	V	U	M	ANDS	W Ep	A	
70	210	2			J	R	P	G	ANDS	W	B	
76	330	2	2		J	V	U	J	ANDS	W	B	
76	319	2	2		J	R	P	J	ANDS	WR	A-D	
69	9	2			J	R	P	I	ANDS	W	B	
77	36	2			J	R	P	K	ANDS	W	B	
74	290	2	1		J	S	P	M	ANDS	WF	A	
72	38	2			J	R	P	H	ANDS	W	B	
40	247	2	3		J	V	P	H	ANDS	C	A	
50	316	2			J	R-S	P-U	-	ANDS	W	B-C	
19	20	2			J	R	P	-	ANDS	WA	C	
81	330	2	2		J	R-S	P	M	ANDS	W	C	
89	124	2			J	S	P	H	ANDS	W	B	
50	306	2	3		J	R	P	H	ANDS	W	A	
77	323	2	2		J	R	P-U	J	ANDS	W	B	
89	49	2			S	S	U	-	ANDS	WK	D	T