REPORT

SCOPE RESOURCES LTD.

**The Oasis Development,
Stoney Creek, Frankton**

**Natural Hazard
Assessment Report**

Report prepared for:

SCOPE RESOURCES LTD.

Report prepared by:

TONKIN & TAYLOR LTD

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1 Introduction

1.1 General

This report presents the results of a geotechnical and hydrological assessment that has been undertaken by Tonkin & Taylor Ltd (T&T) for the proposed "Oasis" residential development within the Stoney Creek Quarry, Frankton.

This investigation and report was completed for Scope Resources Ltd. (SRL) at the request of Chris Ferguson of Clark Fortune McDonald (CFD), Queenstown. T&T's proposal dated 21 December 2007 outlines the scope of work and conditions of engagement for this report. Permission to proceed with the work described in this report was provided by Mr Grant Hensman, of SRL, on 2 January 2008.

The site visits and investigations for this report were undertaken by T&T staff in November 2007, January 2008 and February 2008.

This report should be read as an addendum to our assessment of the site hazards and geotechnical constraints that is presented in the previously issued T&T report "Proposed Stoney Creek Development Natural Hazards Assessment" dated December 2007 (T&T Ref No 880077.000).

1.2 Previous Geotechnical Reporting

1.2.1 HCL Assessment

Hadley Consultants Limited (HCL) prepared a report on the geotechnical feasibility of the proposed site layout and earthworks in July 2007. This work included a site assessment and a review of the proposed plans.

The HCL report recommended a maximum unretained batter slope for both cut and engineered fill slopes of 1.5H:1V and recognised that additional retaining measures would be required to form the proposed building platforms. Specific engineering advice was recommended where areas of fill and sloping batters fell within the proposed building platforms. The HCL report also recommended appropriate storm water control measures be constructed to protect the batters from erosion and the cut batters be revegetated after formation.

We understand the HCL report was issued to Otago Regional Council (ORC) during August 2007 as part of the application for resource consent . This application was subsequently opposed by ORC due to the potential impacts of natural hazards.

1.2.2 T&T Natural Hazard Assessment

T&T issued a natural hazard assessment report for the Oasis development during December 2007 (T&T Ref No 880077.000). This report identified that small scale landslide/slope instability, flood and debris flow hazards had the potential to affect the proposed development in some way. This report also indicated appropriate remedial/mitigation measures could be designed to mitigate the potential consequences of the natural hazards and manage the level of risk posed to the proposed development to an acceptable level.

ORC reviewed the T&T natural hazard assessment report during early 2008 and advised SRL that they will continue to oppose the resource consent application until additional quantitative analysis of the natural hazards, including, landslides, rock falls, flooding, debris flows, ground shaking and liquefaction, has been completed.

1.3 Scope of Work

The purpose of this report is to confirm the geotechnical feasibility of the proposed Oasis development and where appropriate provide concept designs for works to mitigate and manage the risks that are associated with the natural hazards that were identified in the December 2007 T&T report.

The following scope of work has been completed for the purposes of this report:

- Engineering geological mapping and detailed interpretation of the glacial and post glacial surfical geology.
- An assessment of the medium to large scale landslide hazard that is associated with the site.
- Analysis of the small scale landslide and slope instability hazard within the immediate area of the proposed development.
- Analysis of the site rockfall hazard.
- An assessment of the site liquefaction and ground shaking hazards.
- Analysis of the site debris flow hazard.
- Analysis of the site flooding hazard, and,
- Issue of this report which summarises the results of the above tasks and provides preliminary recommendations and concept designs, as appropriate, for works to mitigate and manage the risks that are associated with the natural hazards.

1.4 Site Description and Development

The site is located on Kingston Road (SH6) approximately 4 kilometres south of Frankton, Otago. The local topography comprises gently to moderately steeply sloping ground located at the base of the Remarkables mountain range. Figure 1, Appendix A, shows the location of the development site.

The site has a northerly and westerly aspect, with natural slopes varying from about 5 to 20^{o} towards the west over the 1.5km distance from the foot of the steep face of the Remarkables down to SH6 .

The site is currently operating as a quarry, extracting gravel from the slopes above SH6 that are traversed by Stoney Creek (Figure 2).

The surrounding area is predominantly rural, with rural subdivisions present to the north and east of the site. Vegetative cover currently comprises grass and tussocks, with stands of exotic trees and areas of regenerating native scrub and bush.

Stoney Creek flows through the development site. The Stoney Creek catchment is approximately 3.5km long and incorporates part of the steep Remarkables mountain range. The catchment area is approximately 147 ha.

The gradient in the upper reaches of the Stoney Creek channel is approximately 50%, reducing to about 15% across the glacial deposits in the 1.5km upslope of the site. The creek channel is deeply incised in bedrock and moderately incised on the glacial deposits, having abandoned multiple channels as incision has increased.

Immediately upslope and across the development site the gradient of the Stoney Creek bed flattens and the creek channel is not well incised, such that flood flows would have diverged in to several channels from a point upslope of the site (see Figure 5). Modification of the site during quarrying, and to provide access to upslope properties, has removed the flood channels across the site. As a result of this the Stoney Creek flood flows now need to be routed into a single main channel. Further discussion on the geomorphic features of Stoney Creek are provided in Section 2.1 below.

Clark Fortune McDonald have provided us with the following development plans which provide details of the proposed development;

- Original Ground Levels (1997) - Drawing 8350_27, dated March 2006
- Original Ground Levels (2005) - Drawing 8350_24, dated March 2006
- Proposed Access ways – Drawing 8350_48, dated March 2006
- The Oasis Scope Resources Ltd. - Sheet 2 – Concept Plan, dated 17 May 2006

The above drawings indicate the proposed Oasis development is to comprise 20 residential dwellings and associated parking building structures, access ways and landscaping features. The residential dwellings will comprise 8 stand-alone villas and 12 semi-detached units, known as the Snake building (see Figure 3).

The plans and cross sections indicate the stand alone villas will, for the most part, be constructed on relatively flat to moderately sloping land, while the units will be constructed against a steep batter face generally comprised of cut ground which slopes at 1.5H: 1V. Fill will be required to complete this batter slope in some locations where gravel has been excavated during quarry operations beyond the design profile.

The concept plan provides details of the proposed vegetation layout and shows an existing and proposed water course passing through the site.

2 Geology and Geomorphology

2.1 Mapping and Air Photo Observations

The published geological map of Wakatipu[1] indicates that the area is underlain by schist bedrock. Quaternary sediments comprising 71,000 to 59,000 year old (Q4) and 24,000 to 14,000,year old (Q2) glacial till material, as well as younger post glacial (PG) lake and flood plain material, comprising gravel sand and mud, are shown to overlie the bedrock.

To assist in the assessment of natural hazards we have produced a 1:10,000 scale interpretation of the glacial geology and geomorphology of the area surrounding the site (Figure 4). Key features of Figure 4 that impact on hazard assessment include:

- The broad slopes from the toe of the Remarkables mountain range to SH6 are formed predominantly by the glacial till of lateral moraines (Q4t), with later (post glacial) erosion modification by surface water runoff and gradual incision of creek channels. The broad slopes are not alluvial fan surfaces, but areas of erosion and incision by the side streams that rise on the flanks of the Remarkables.
- Glacial outwash alluvium (Q2a) has been deposited as erosion modified terraces between the Q4t and valley floor lake deposits (PGl). There are several small remnant hills of Q4t till shown within the outwash alluvium. The outwash alluvium is the deposit being quarried for aggregate at Stoney Creek.
- Alluvial fan deposits are relatively limited in extent, including Q4f incised fans at the foot of the Remarkables, Q2f fans deposited onto the Q2a alluvial terraces, and more wide spread PGf low angle (fine grained) fan deposits onto the valley floor. Several of the Q2f fans are interpreted to still be active (Q2f + PGf).
- Schist foliation dip slope landslides are mapped on the south facing slopes of Stoney Creek and the major creek to the north. The observed scarps are typical of 'creeping' schist landslides, with no evidence for a history of rapid movement of the slide mass.
- The subdued nature of the schist spurs north of Stoney Creek suggests gravitational relaxation (Sakung) during glaciation and ice retreat. The Q4t deposits are providing toe buttress support to the relaxed rock mass and there appears to be no significant postglacial development of active relaxation features such as uphill facing scarps.
- A rockfall field is identified to the south of Stoney Creek, with significant numbers of large schist blocks lying on the lower schist slope and extending out onto the Q4t till surface. Individual large blocks are highlighted on the Q4t surface, but may be 'insitu' till material rather than rocks fallen from the schist slopes above.
- The bed of Stoney Creek and the catchment immediately south are very close where they exit from the face of the Remarkables. Site observations indicate that Stoney Creek could overflow into the southerly catchment at this point, but the reverse cannot occur as the southerly creek is incised at least 5 metres below the level of Stoney Creek. Moving downstream, next to the bedrock landslide both creeks are incised about 8 metres below the general ground level.

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[1] Turnbull, I.M. (compiler) 2000. Geology of the Wakatipu area. Institute of Geological and Nuclear Sciences 1:250 000 geological map 18. 1 Sheet + 72 p. Lower Hutt, New Zealand. Institute of Geological and Nuclear Sciences Limited.

Further geomorphic evidence relevant to flooding and debris flow hazards is provided on Figure 5, an annotated 1:5000 scale portion of the engineering geology map. The major observations on this map include:

- Stoney Creek and the southerly creek are both deeply incised (about 8 to 10 metrtes) for about 800 metres downstream from the point where Stoney Creek can avulse, or 'jump' into the southerly creek bed. Flow from these catchments has eroded channels in the Q4t till between the current creek beds. These channels are now abandoned by the main creeks and would only carry local storm runoff.
- The bed of Stoney Creek for about 600 metres across the Q4t slope is moderately incised (about 3 to 5 metres), with flood flows potentially spreading out to about 20 to 50 metres wide in places.
- Flows from Stoney Creek have deposited alluvial fans (Q2f and Q2f + PGf) immediately upslope of The Oasis site. These fans indicate the maximum extent of debris deposited from Stoney Creek in the past approximately 25,000 years. The main creek bed is incised into the upper part of the fan and appears to no longer flow to the northern Q2f. The small stream channel to the north is also headwards incised into the Q2f deposit, suggesting no significant debris depositing activity on this fan surface in post glacial time.
- The main Stoney Creek channel is poorly defined as it crosses the lower part of the Q2f + PGf. It is likely that debris has been deposited on this fan surface in the recent past. Large floods would have split into the 3 defined channels plus overland flow onto the lower PGf fan surface to the south of the site. The additional channels and overland flow routes have now been excavated out by the southern section of the gravel quarry.

2.2 Quarry and Creek Exposures

The existing quarry walls, cuts for access tracks and eroded creek banks provided exposure of Quaternary materials. Key observations in these areas include:

- The outwash alluvium that is mapped as Q2a predominantly comprises sandy and silty fine to coarse GRAVEL and COBBLES in metre thick indistinct beds. Bedding is sub-horizontal and the deposits are clast supported.
- Lacustrine sandy fine to coarse SILT beds up to 1 metre thick were observed on the edge of the Q2a terrace risers, overlying outwash gravel. In one location possible lake beach gravel overlies the silt deposits.
- Lenses comprising interbeds of SAND, SILT and fine GRAVEL were observed in the quarry walls within the Q2a gravel. Dimensions of lenses from the observed exposures are approximately 2 to 4 metres thick by 5 to 30 metres long and wide. Contacts were both gradational (conventional alluvium), and steep and contorted (glacial ice contact and deposition stage slumping).
- Exposures of till materials from the Q4t lateral moraines vary from silty GRAVEL to gravelly SILT with sand and boulders. The deposits are typically massive and matrix supported on the scale of exposure.

- The surface of the Q2a deposit in the area of the quarry is slightly weathered in the upper 1 metre and carries a very thin silt top soil.
- The Q4f deposit exposed across Stoney Creek at the foot of the Remarkables shows dipping beds of sandy GRAVEL (alluvium and debris flood) and thicker beds of massive sandy and silty GRAVEL (debris flows). There were no exposures observed of the lower level Q2f and PGf fan deposits.
- Fill materials observed in the quarry area comprise a mixture of scalpings form aggregate processing and reject gravels from the borrow areas. The overall composition is gravelly SAND and silty and sandy GRAVEL. The dumped angle of repose is about 35^{o}, and faces cut in this material are standing at an angle between 45 and 65^{o} to a height of between 4 and 5 metres.

2.3 Borehole Investigations

Two boreholes were drilled in the quarry area (see Figure 3) to assess the variation in materials and the depth to groundwater as part of the assessment of liquefaction risk for the proposed development.

Boreholes BH01 and BH02 were drilled to 10.5 and 12m respectively using an air driven down the hole hammer and steel casing. Disturbed samples were taken at 1-metre intervals and the drillers noted any specific change in drilling conditions as the holes advanced. Standpipe piezometers were installed in both boreholes.

The boreholes both encountered silty and sandy coarse GRAVEL over the entire depth of drilling. A boulder was drilled through at approximately 6.1 to 6.4m below ground level in BH02. No groundwater was encountered in either of the boreholes. The piezometers were dipped again on the 6th of March 2008 and again they were both found to be dry. Logs of boreholes BH01 and BH02 are attached in Appendix B.

3 Assessment of Hazards

3.1 Landslides

Engineering geological mapping and interpretation based on aerial photos and site walkover show no visible signs of current or historic slope instability (including landslide movements) occurring on the slopes between Kingston Road (SH6) and the toe of the Remarkables, and for at least 1km to the north and south of the site.

A landslide complex is mapped in schist bedrock on the lower slopes of the Remarkables (Figure 3), with potential to spill debris into Stoney Creek and contribute to debris flow hazard, as discussed in Section 3.7.

The potential for failure of gravitationally disturbed schist in the bedrock spurs east of the site does not pose a conceivable hazard to the proposed development.

3.2 Rock Falls

Rock fall from the face of the Remarkables does not pose a conceivable hazard to the proposed development. A rockfall field is identified below one area of bluffs to the southeast of the site, where maximum run out distance on to the Q4t surfaces is about 300 metres.

Analysis of potential rock fall behaviour on the Remarkables has been undertaken using the computer program ROCKFALL. The results are summarised in Figure B1 (Appendix B) and are in accordance with the observed rock fall activity. In summary individual rocks are capable of travelling 500 metres and more on the steep face of the Remarkables, and may leap some 10's of metres in the air, but they are not capable of travelling any significant distance out onto the gently sloping Q4t surface.

Rock fall or roll of gravel to boulder size clasts from cut and fill slopes of alluvium within the immediate development area is not feasible on the final slopes of less than 1.5(H):1.0(V). Where steeper, or subvertical cuts are proposed adjacent to structures they will be retained by engineered walls as part of the structure design.

3.3 Cut and Fill Slope Stability

3.3.1 General

The proposed Oasis development includes a final landform comprising modified quarry cuts, fills and natural slopes (Figure 3). Lots 1 to 8 are located on flat platforms adjacent to 2(H):1(V) and flatter slopes that are <4 metres high. Lots 9 to 20 form the 'Snake', a building proposed to be constructed on and parallel to a 1.5:1.0 slope ranging from 5 to 15 metres high. Landscaped fill slopes up to about 15 metres high are proposed at 2.0(H):1.0(V), with some cut slopes remaining at >1.0(H):1.0(V).

Slope stability analysis has been undertaken for typical slopes around the development using the limit equilibrium computer program SlopeW. The cross sections used for analysis are sections C to G, as shown on Figure 3. Cross section profiles are discussed in the Sections below and illustrated by typical SlopeW outputs presented in Appendix B.

3.3.2 Shear Strength Parameters

The model shear strength parameters for use in this study have been established from consideration of non-linear shear strength envelopes for the site materials.

In preliminary slope stability assessments and designs for structures such as retaining walls, granular materials like sand and gravel are usually considered to have a linear friction only strength under long term drained conditions and modest overburden depths (low confining pressures). Utilising this type of strength parameter is considered overly conservative for the site materials, which stand in vertical cuts from about 2 to 4 metres high, and up to 12 metres high at >60^{o} in the cut quarry walls.

The basis for non-linear shear strength of the on-site alluvial gravels is the 'interlocking' action of larger gravel and cobble clasts in a dense well graded material. At low confining pressures the clasts have to ride up and over each other, i.e. the soil has to dilate or expand in order to move in shear. The angle of dilation, which adds to the basic grain to grain friction to provide the shear strength, decreases as confining pressure increases. However as confining pressure increases shear strength becomes a combination of friction between grains and cohesion of the mass under confinement. This changing relationship creates the non-linear, or curved shear strength envelope.

In the case of on-site moist silt and silty sand materials, the ability to stand in vertical cuts is partly related to non-linear strength, but primarily to unsaturated void spaces between the grains, which create capillary or suction forces. These negative pore pressures can be accounted for in the material shear strength by including a cohesion term along with the frictional strength.

Shear strength parameters were derived from back analysis of the observed quarry slopes assuming an existing Factor of Safety (FoS). A bi-linear shear strength envelope is derived by considering friction only shear strength for shallow full slope failures and cohesion only shear strength for deeper seated full slope failures. Given the limited range of slope heights and simple drained slope models, a single shear strength parameter was selected approximating the tangential line at about 5 to 10 metres of overburden pressure. For the gravel materials the selected shear strength falls within the range of strengths for compacted rock fills with non linear shear strength behaviour, as described by Charles & Soares (1984) [2].

During the site survey a silt and sand lens was noted in the vicinity of proposed residential lots 15 and 16 and this was modelled in Section C only. Fill was modelled in Section D as the plans show that fill will be required to form the batter on which proposed residential lots 17 to1 9 will be constructed on. The sub-surface profile of Sections E and F consists of gravel material for the full height. Fill was modelled for the full height of Section G. The adopted parameters for the modelled sub-surface materials are provided in Table 3.1 below.

[2] Charles & Soares (1984), Geotechnique 34, No.1, 61-70)

Table 3.1: Adopted Analytical Parameters

Material	Bulk Density (γ, kN/m^3)	Effective Angle of Shearing Resistance (ϕ',degrees)	Effective Cohesion (c′, kPa)
Gravel (in-situ outwash)	18	38	10
Sand and silt (in-situ lens modelled in Section C)	18	32	5
Fill (scalpings and reject gravel, sand and silt)	18	32	5

3.3.3 Stability Criteria

Each cross section was analysed for static conditions and for two seismic cases; the Serviceability Limit State (SLS), which assumes an earthquake with 1:25 year return period Predicted Ground Acceleration (PGA), and; the Ultimate Limit State (ULS), which assumes an earthquake with 1:500 year return period PGA. In all cases the sub-surface materials were considered drained (unsaturated). Table 3.2 summarises the load cases each cross section was analysed for.

Table 3.2: Load cases for slope stability analyses

Load case	Description	Seismic Coefficient	Groundwater	Target Factor of Safety (FoS)
LC1	Static	-	-	1.5
LC2	Seismic – SLS	0.11	-	1.2
LC3	Seismic - ULS	0.43	-	Displacement less than 100mm

An additional case was run for Section C where the sand/silt layer is temporarily saturated and there is a decrease in effective strength. If this occurs it will be a transient situation because the perched water will drain rapidly from the material, therefore a FoS >1 was adopted as acceptable.

3.3.4 Stability Analysis Results and Discussion

The results of slope stability analysis are summarised in Table 3.3 below. Examples of SlopeW output for each of the cross sections are presented in Appendix B.

Table 3.3: Load Cases for Slope Stability Analyses

Section	Model	Static FoS results	Seismic FoS results
C	Gravel with upper sand/silt lens. Behind Snake building. 1.5(H):1(V)	1.85, dry 1.08, wet sand	1.56, SLS 1.03, ULS
D	Gravel with upper fill layer. Behind Snake building. 1.5(H):1(V)	1.67, fill only 1.77, whole slope	1.40, SLS 0.92, ULS (10mm displacement)
E	Maximum height gravel slope. Behind Snake building. 1.5(H):1(V)	1.56	1.36, SLS 0.94, ULS (10mm displacement)
F	High Gravel cut below accessway 1. Cut to fill profile (see Figure 6). 1:1 and 1.5(H):1(V)	1.54	1.31, SLS 0.88, ULS (30mm displacement)
G	High fill slope over quarry cut slope. 2(H):1(V)	1.77	1.45, SLS 0.90, ULS (10mm displacement)

The proposed 1.5(H):1(V) cut slopes in gravel, sand/silt and fill all have design FoS greater than the acceptance criteria outlined in Table 3.2. General fill slopes proposed at 2.0(H):1.0(V), as represented by section G also have design FoS greater than the acceptance criteria.

The high and steep gravel cut, as modelled on section F is recommended to be modified to a cut to fill slope with 1.0:1.0 upper cut and 1.5(H):1.0(V) lower fill batter (Figure 6). In this configuration the slope design FoS is greater than the acceptance criteria.

All the analysed sections have acceptable design earthquake performance.

In modelling fill beneath the building we have used fill thickness indicated on the cross sections supplied to us. This corresponds to a maximum fill thickness of 6.5 metres in Section D. Additional thicknesses of fill beneath the proposed structures will require further analysis at building design stage, as it may decrease the factor of safety below acceptable levels. We recommend that only select sandy fine to coarse GRAVEL be used as structural fill below the building footprint.

Areas of minor surface erosion were noted on bare ground, generally limited to steep unfinished cut and fill slopes and areas adjacent to water courses which had little or no vegetative cover. The potential for erosion of the site materials is assessed to have no material affect on stability of the proposed finished slopes.

The level of erosion as observed can be controlled by the construction of engineered storm water drains and by the planting of appropriate vegetative cover. The proposed plans indicate the area will be extensively landscaped and re-vegetated.

3.4 Ground Shaking

Ground shaking hazards associated with the stability of the existing quarry slopes and proposed batter slopes are addressed as part of the cut and fill slope stability assessment in Section 3.3 above.

For the design of structures in accordance with the recommendations of NZS 1170.5:2004, Class C ground conditions (shallow soil site) should be assumed to exist.

3.5 Liquefaction

Liquefaction is a potential hazard under strong earthquake shaking in areas of loose, sandy soils and a shallow groundwater table. The bases for assessing liquefaction potential at this site include:

- Susceptibility based on visual grading of on-site materials.
- Observed distribution and expected occurrence of soil units based on the geological model for the site.
- Depth to groundwater, and,
- Depth of the non-liquefiable surface layer over any potentially liquefied layer.

The geology of the site has been interpreted as outwash alluvium, associated with the lateral margins of the retreating Wakatipu glacier. The predominantly gravel and cobble deposits contain lenses of silt and sand associated with features such as small temporary lakes, input from side streams off the Remarkables, and ponded overbank flood waters.

The geological model suggests that lenses of sand and silt can occur at any location within the outwash deposits, while observation of the exposed lenses show individual units of 0.5 to 2 metres thickness with grading and density susceptible to liquefaction. The groundwater table is expected to be about 15 to 20m or greater below ground surface across the site.

Based on the above interpretation of the geology it is considered very unlikely that wide spread liquefaction will occur on the site. Even if there are some restricted lenses of silt and sand beneath the quarry floor and below the groundwater table capable of liquefying there would be no deformation observed at the ground surface due to the thickness of the overlying non-liquefiable layer.

Boreholes BH01 and BH02 were drilled to test the nature of the materials underlying the quarry floor, but more importantly the depth to groundwater, as all materials above the groundwater table are, by definition, non-liquefiable. The depth of the boreholes was based on the potential thickness of non-liquefiable layer required to prevent surface manifestation of deformation. In this case the empirical relationships developed by Ishihara in Kramer[3] indicate a surface non-liquefiable layer of about 5 to 8 metres is required for a liquefying layer about 2 to 4 metres thick under the site ULS seismic event (0.43g).

The boreholes did not encounter any sand or silt lenses, and show groundwater levels are >12 metres below the base of the quarry, confirming the lack of any wide spread sand/silt layer below the site, and a non-liquefiable surface layer exists on site which is at least 12 metres thick.

Based on the above information we conclude that liquefaction does not pose a significant hazard to the proposed development and does not require further engineering consideration.

3.6 Flooding

3.6.1 General

Stoney Creek provides a potential flooding hazard to the proposed development due to the steep, high energy flow path, and 'flash flood' nature of the catchment on the side of step mountain range. The hazard is exacerbated by the routing of the main channel of the creek through the development with 2 changes of direction while upslope of the main accessway and development areas.

The unmitigated flooding risk is considered relatively high relative to the risk of other natural hazards identified for the site due to the relatively significant consequences of large volumes of fast flowing (high energy) water impacting onto structures and dwellings if flows overtop the channel. Structures could be severely damaged and there is an element of risk to life. Therefore the nature and scale of the hazard requires careful consideration, along with robust mitigation measures that provide some level of redundancy in routing design flood flows.

3.6.2 Catchment Characteristics

The Stoney Creek Catchment is located on the western face of the Remarkables mountain range, just south of Kelvin Peninsula and beside Lake Wakatipu. The 147 ha catchment is narrow and steep, with an average slope greater than 10%, and is potentially prone to flash floods due to the relatively short time for water to travel from the catchment into Stoney Creek. The elevation of the catchment varies from RL380 mASL at the Oasis development site to RL1780 mASL at the ridgeline of the Remarkables; an elevation difference of 1400 m.

[3] Kramer., Steven, L. (1996) Geotechnical Earthquake Engineering, pp. 654, Prentice Hall, New Jersey

The catchment has been characterised by three main sections; the Upper, Middle and Lower, all of approximately equal area (i.e. 49 ha each).

- The Upper section is very steep with an average slope greater than 50%, and is Schist bedrock with a light covering of scrub.
- The Middle section is steep with an average slope between 20 and 50%, and has Upland Orthic Brown soil with moderate drainage and an average of 10% gravels. The Middle section is covered by a mixture of pasture, scrub and weed.
- The Lower section is of moderate slope (on average 8 to 15%), with shallow (20 to 45 cm deep) fine sandy loam Pigburn soils, and a cover of pasture, scrub and weed.

Rainfall data was obtained from HIRDS Version 2. This data may not accurately reflect the significant change in rainfall with elevation (the Upper section is likely to receive greater rainfall than the Lower section due to orographic effects), but is considered adequate for this assessment of the magnitude of flooding hazard and feasibility of mitigation measures.

Time of concentration for the catchment is estimated as 20 to 30 minutes. The 30 minute duration rainfall from HIRDS Version 2 was used to calculate the peak flow.

Table 3.4 contains the design flood peak flows for relevant Annual Return Interval (ARI) storms as determined from NIWA's HIRDS Version 2 data, and catchment properties as discussed previously.

Table 3.4: Design Flood Peak Flows

Annual Return Interval (ARI)	*years*	10	20	50	100	150	500
Design flood peak flow – SCS Unit Hydrograph method	*m^3/sec*	5	6	10	15	19	- (1)
Design flood peak flow - Rational Method	*m^3/sec*	5	6	8	11	13	- (1)

(1) Due to the Stoney Creek catchment properties, and lack of data, a 500 year ARI flood peak could not be determined

Based on industry practices and considering the unique development situation and potential impacts of flooding, we consider the 20 year ARI to be suitable for primary flood path design, and the 100 year ARI suitable for secondary flow path analysis. We have also considered the larger 150 year ARI flood for comparison with the design for the 100 year ARI flood.

Site photos were used to estimate the likely hydraulic roughness of the channel. Mannings n values of 0.045 and 0.060 were adopted for the channel base and flood bank areas respectively.

3.6.3 Hydraulic Analysis and Assessment

Using the creek bed cross-sections (see Figure 7) surveyed by CFD at locations requested by T&T, a preliminary HEC-RAS hydraulic model has been created for the reach of Stoney Creek that runs through the proposed Oasis development (see Appendix C).

Key findings from analysis of the HEC-RAS model (see Appendix C) include:

- The 15 cumecs maximum design flow will generally flow within the primary channel.
- The natural channel will flow less than the 20 year ARI design flow of 6 cumecs in the vicinity of surveyed section 6. This is the location where natural flood flows would have split into the main channel, 2 flood channels and overland flow to the PGf fan south of the site (See Figure 5), prior to modification by the quarry and accessways.
- A nominal 1-metre high bund or stop bank located along the true left bank of the channel (Figure 7 and section 6, Appendix C) is sufficient to confine the design peak flows within the channel.
- The proposed location of accessway 1 across the main channel (see Figure 3) is potentially problematic in terms of passing design peak flows by the primary channel and/or secondary flow paths. The proposed location and vertical alignment of the accessway make it difficult to pass all design flows under the road, and when there is overflow it is difficult to keep that flow from spilling into Lots 2 to 5 via accessway 2. This is unacceptable due to the significant consequences for property damage and potential risk to life under uncontrolled, high volume, high energy flows.
- Several alternatives have been explored for accessway 1. The proposed realignment as shown on Figure 7, and as the culvert sections in Appendix C is an acceptable solution. The proposed 2.1m 'helcor' culvert can accept a design flow of flow approximately 10.5 cumecs at the point of overtopping the accessway pavement at 268.4mRL. The realignment places the accessway further into the incised creek channel and therefore any overtopping flow can be accommodated within the channel, rather than spilling to accessway 2.
- Flow has been modelled for a completely blocked culvert on the proposed realignment of accessway 1. The maximum 100 year ARI design flow of 15 cumecs results in a flow depth of 400mm over the accessway pavement. The ability to take large flows without the culvert operating is considered to provide a suitable degree of redundancy for the 'flash flood' type characteristics of the Stoney Creek catchment.
- Modelling has indicated high channel velocities (>3 m/sec) in the creek bed, and given the typically narrow and incised flow channel profile, significant channel erosion is likely to occur under design peak flood flows. This erosion is expected to be highest in the steeper reaches of the channel. Provisions for erosion (such as channel armouring with suitably sized stone) will be required in critical sections of the channel such as constructed bunds to prevent excessive erosion damage.

The recommended mitigation measures to contain 100 year ARI peak flood flows within the main channel of Stoney Creek are shown on Figure 7.

The proposed bund between sections 7 and 4 provides 'training' of flood waters around the bend in the channel where historically the flood flows would have diverged into several flow paths. The realignment of accessway 1 will allow design flows to pass through the culvert with minimal (<300mm) overtopping of the accessway. Detailed design is required at both locations to finalise levels, start and finish locations of the bund and the extent/type of erosion protection required.

Additional work to reform the original channel section is recommended (see Figure 7) between sections 3 and 4, and sections 11 to 13, where existing access tracks constrain the original channel profile.

Provided the above flood control measures are undertaken we consider that the flood hazard to the proposed development is mitigated to a standard acceptable under current interpretation of the New Zealand codes and regulations applicable to subdivision and building development.

3.7 Debris Flows

On first assessment the Stoney Creek catchment has the potential to generate debris flows that could affect the proposed Oasis development as follows:

- A source area where the existing bedrock landslide features can provide debris to potentially block the channel.
- A steep slope (>10%) with erodible gravel bed and banks.
- Landslide debris mobilised by flood water can be added to by channel erosion in the mid reaches.
- 'Broad fan' areas on the lower slopes provide locations for debris deposition.

Closer investigation of the geomorphology of the area indicates that the evidence for debris flow activity is relatively limited, especially in terms of depositional fans. The 'broad fan' areas are a combination of erosion modified glacial moraines, outwash alluvial surfaces and alluvial (debris) fans. Figures 4 and 5 show some key features related to the extent of past debris flows, including:

- Active lobes of the bedrock landslide (Figure 4) have the potential to deposit debris into the deeply incised Stoney Creek channel. The landslide toe slope does not show evidence for relatively large scale rapid movements (evacuated scarps would be expected). More likely are episodic (inferred return periods of 10 to 100 years) creep movements that deposit 10's to 100's of m^3 into the channel at any one time.
- The area between Stoney Creek and the major creek to the south is not a large alluvial fan. It is the eroded surface of a series of lateral moraines.
- The middle reaches of Stoney Creek are moderately incised into the moraine materials with 1 or 2 degradational terraces combining to give a flood plain ranging from about 15 to 50 metres wide. There is poor/indeterminate evidence for recent debris deposition onto the terraces and main channel.
- The Oasis development site is located on outwash alluvium and 2 relatively small fan deposits, now mostly removed by quarrying.
- The small fan deposits are interpreted as mostly deposited between 25,000 and 10,000 years ago (Q2). The incision of channels across the Q2a surface and the Q2f fans suggests that the northern fan has not been active for some time. The interpreted limits of more recent fan activity (approx 10,000 years to present) are indicated in red on Figure 5.

In assessing the potential for future debris flow activity to affect the proposed development we have commenced by assessing the potential flow path and deposition

zone, and consequences for the development assuming that a debris flow will occur. We have not attempted to assess qualitative or quantitative risk at this stage due the difficulty of deriving sensible and testable estimates for debris flow size and recurrence.
Two methods of estimating debris flow run out distance have been utilised, Hunter & Fell (2000)[4] and Fannin & Bowman (2007)[5]. Figure 5 indicates an assumed starting volume of 1400m^3 (conservatively greater than our assessment of landslide activity) and shows approximate 600m, 1200m and 1400m distances from the upstream debris start point.
The Hunter & Fell estimates are based on empirical relationships derived from the study of landslides in Hong Kong, Canada, and the UK. For debris under confined run out conditions on Stoney Creek the travel distance is estimated as 1400 to 2400m, effectively traversing the proposed development site and across SH6.
The Fannin & Bowman paper refers to an empirical based computer program on the University of British Columbia web site called 'UBC D flow'. It is based on studies of catchments in forest logging areas in BC, not dissimilar in profile, length and gravel materials to Stoney Creek. The program allows entry of information for different reaches of the stream, being length, width, slope angle and azimuth.
Stoney Creek has been divided into 6 reaches for assessment of alternative cases in UBC D flow. In the upper reach from 0 to 600m erosion occurs and the debris volume becomes greater. The middle reach from 600 to 1200m is a transition flow between erosion and deposition, which is sensitive to the width of the channel (degree of confinement). Deposition is indicated for lower reaches below 1200m. Alternative cases have been assessed as follows.

Table 3.5: Results of 'UBC D flow' assessments of debris flow travel distance

Case	Reach (m)	Width of channel (m)	Debris Travel Distance (m)
Moderately confined middle reach	600 to 1200 1200 to 1400	15 50	1400
Flow spread out on middle reach	600 to 1200 1200 to 1400	30 50	1200

The results, predicting maximum travel distance from about 1200 to 1400m (Figure 5) correlate closely with the observations and interpretation of past activity on the mapped Q2f + PGf fan (Figure 4 and 5).

The model debris flow, based on mapping interpretation of past activity and the predictions of 'UBC D flow', would be about 1000 to 2000m^3 of gravel, sand and silt, suspended in flood water, travelling about 1000m down Stoney Creek before starting to slow and the deposit onto the creek bed and fan areas. All coarse debris will have dropped out by the maximum travel distance.

[4] Hunter, G. & Fell, R, 2000. Estimation of Travel Distance For Landslides in Soil Slopes. In AGS Vol 37 No2 May 2002.
[5] Fannin, J. & Bowman, E, 2007. Debris Flows – Entrainment, Deposition and Travel Distance. Geotechnical News December 2007, pp 43 – 46.

For cases where debris extends to 1400m, and possibly beyond, there is a potential for direct impact on the proposed development. In these cases it will be necessary to keep the remaining debris and flood water within the defined channel so it does not spill out into the development.

The proposed flood mitigation measures described in Section 3.6 and shown on Figure 7 are considered sufficiently robust to cope with the model debris flow. The proposed bund running from about 1350m to 1450m debris distance (as defined on Figure 5), which results in a channel capable of flowing >19 cumecs of flood water, would also be capable of accepting the distal portion of the model debris flow, where debris would be about 0.5m deep. Channel capacity would be reduced by debris deposition and would require periodic excavation to maintain future flood capacity. The realigned accessway 1 and culvert (Figure 7) is designed to withstand overtopping of the road by flood waters. In the unlikely event that the 2.1m diameter culvert was completely blocked by debris there is sufficient freeboard to take design flood flows of at least 19 cumecs over accessway 1 without spilling into other areas of the proposed development.

In summary, our assessment is that there is the potential for a debris flow to occur. Although the likelihood/risk of a debris flow has not been calculated, the proposed flood mitigation measures (Figure 7) are considered suitably robust to control the path and deposition of a model debris flow which is of similar, or larger magnitude to probable past events. Therefore we consider the debris flow hazard to be mitigated to at least a similar standard to the flood hazard.

4 Conclusions and Recommendations

The proposed Oasis development, which incorporates the hazard mitigation measures recommended in this report, is considered technically feasible from a natural hazard and geotechnical perspective, provided it is properly designed and constructed in accordance with the appropriate New Zealand Codes and Standards.

Investigation and analysis has shown that several natural hazards pose a nil to negligible risk to the proposed development, including:

- Landslide movements on the steep bedrock slopes of the Remarkables, and on the natural slopes in glacial deposits in the immediate vicinity of the development.
- Rock falls, and,
- Liquefaction.

Analysis by limit equilibrium methods has indicated the stability of the proposed cut and fill slopes within the development area is acceptable for the proposed 1.5(H):1.0(V) and 2.0(H):1.0(V) slopes. The exception to this is the steep cut slope in the vicinity of section F (Figure 3), where a cut to fill slope is recommended (Figure 6) to provide adequate design stability. It is also recommended that a fill buttress be constructed at the toe of the 1.5(H):1.0(V) slope at section D (Figure 3), and this fill comprise select sandy Gravel from the quarry borrow area.

The flooding hazard from Stoney Creek has been assessed from the results of a HEC-RAS model developed for the channel which passes upstream of, and through the site. Flood mitigation measures as shown on Figure 7 are required to train the design flood peak flows down the main channel. These flood mitigation measures include:

- A channel training bund nominally 1m high (plus freeboard and erosion protection to be determined) in the area upstream of the site. This location is where natural flood flows would have spread out into channels that have been cut off by the quarry development.
- A realignment of accessway 1 to lower the vertical alignment into the existing main channel, allowing flows up to about 10.5 cumecs to pass through a 2.1m diameter culvert, with overflow passing over the accessway pavement and remaining in the main channel. Detail of the culvert and pavement levels and extent of erosion protection are to be determined during detailed design for building consent.
- The original channel section should be reformed where it is constrained by quarry access and ROW crossings at locations upstream (channel section 3 to 4) and downstream (Channel sections 11 to 13) of the site.

The hazard of channelized debris flow on Stoney Creek has been assessed qualitatively from geomorphic evidence, with potential deposition and travel distance analysed by the University of British Columbia program 'UBC D flow'. The modelled design debris flow, which is based on the probable size of past events that have built up the observed fan deposits, stops in the area immediately upstream of the site. The proposed flood mitigation measures will also work in training the distal portion of the design debris flow deposits and associated flood waters, resulting in insignificant consequences and therefore acceptable risk to the proposed development.

The development design plans which have been provided to us do not include details of structural foundations or retaining walls. Detailed design of these components should be completed by a suitably qualified and experienced engineer.

- Design of all foundations which are to be constructed in the vicinity of a cut or fill slope will require specific consideration of the foundation and slope interaction.
- All retaining walls which are to be constructed as part of the proposed development should be designed by and constructed under the supervision of a suitably qualified and experienced engineer.
- For structural design purposes the magnitude of seismic acceleration should be estimated in accordance with the recommendations of NZS 1170.5:2004 assuming Class C ground conditions (Shallow soil site) exist beneath the proposed buildings.
- All fill required to support engineered structures, such as roads, residential buildings, and any other structures and services should be placed and compacted in accordance with NZS 4431:1989 and certified in accordance with QLDC standards.

5 Applicability

This report has been prepared for the benefit of Scope Resources Limited with respect to the particular brief given to us and it may not be relied upon in any other context or for any other purpose without our prior review and written agreement.

TONKIN & TAYLOR LTD

Environmental and Engineering Consultants

Report prepared by:	Report reviewed by:
....	....
Shamus Wallace	Barry McDowell
Engineering Geologist	Senior Engineering Geologist

Authorised for Tonkin & Taylor by:

....

Anthony Fairclough

Senior Geotechnical Engineer

scww

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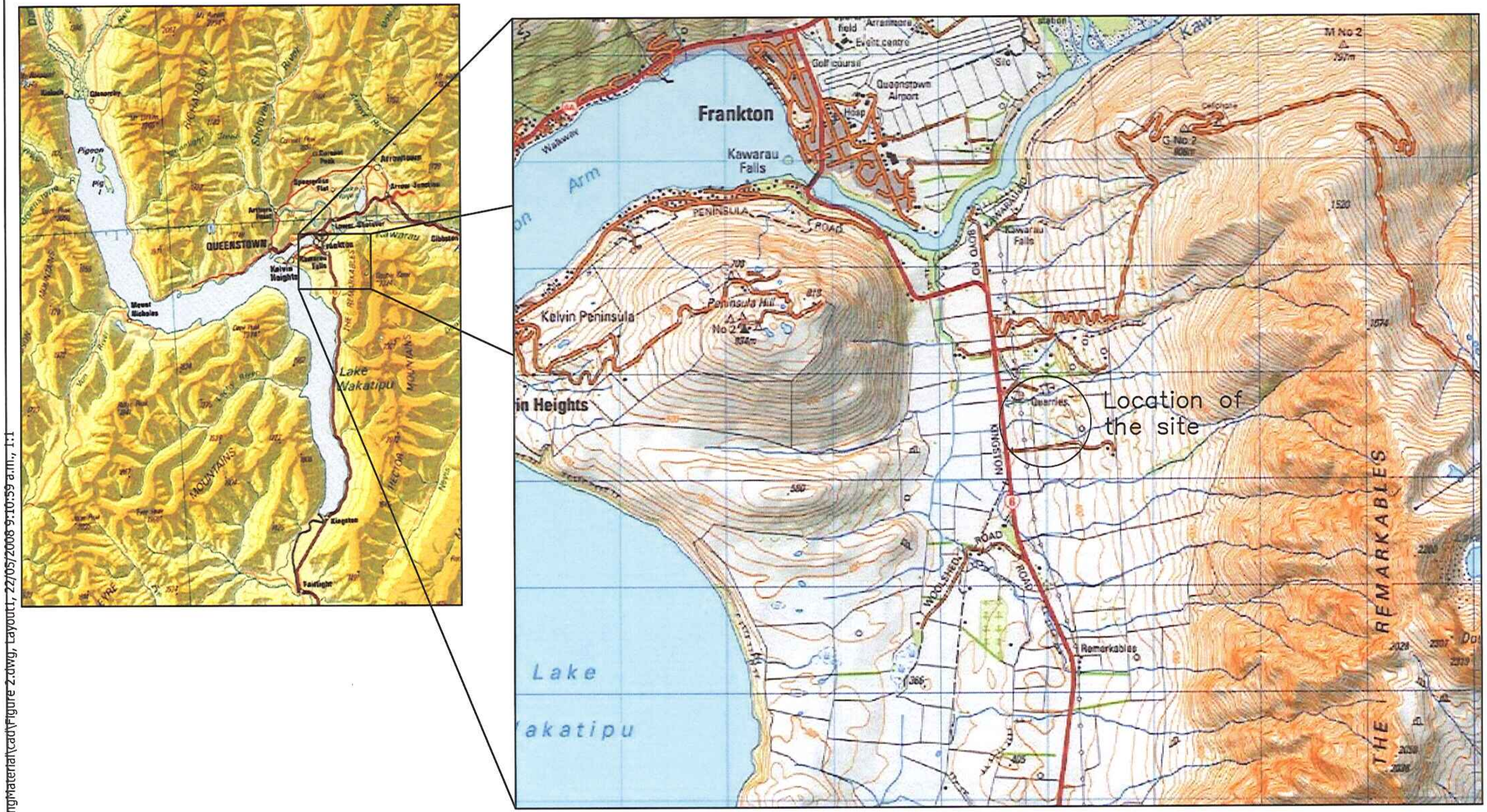
Appendix A: Figures

- Figure 1 – Site Location
- Figure 2 – Stoney Creek Catchment
- Figure 3 –Site Plan and Development
- Figure 4 – Engineering Geology Map
- Figure 5 – Flood & Debris Flow Hazard
- Figure 6 - Steep Slope Design Section F
- Figure 7 – Stoney Creek Flood Mitigation Concepts



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THE OASIS DEVELOPMENT
STONEY CREEK, FRANKTON
Site location plan

FIG. No. Figure 1 REV. 0

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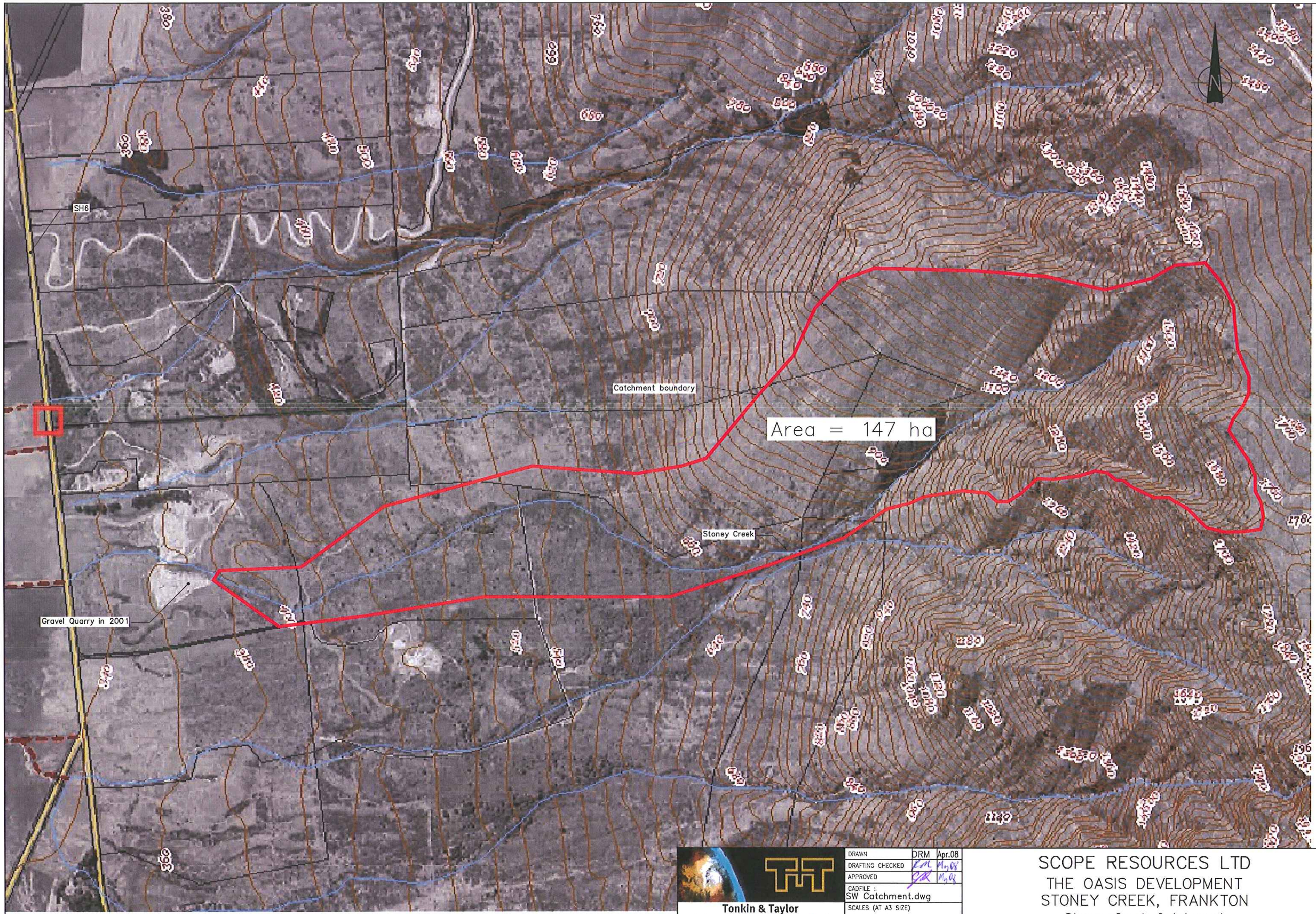

SCALE 1: 10,000
0 100 200 300 400 500 (m)

Image, contours, streams, roads, boundaries from Terraview 2008

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THE OASIS DEVELOPMENT
STONEY CREEK, FRANKTON
Stoney Creek Catchment

FIG. No. Figure 2

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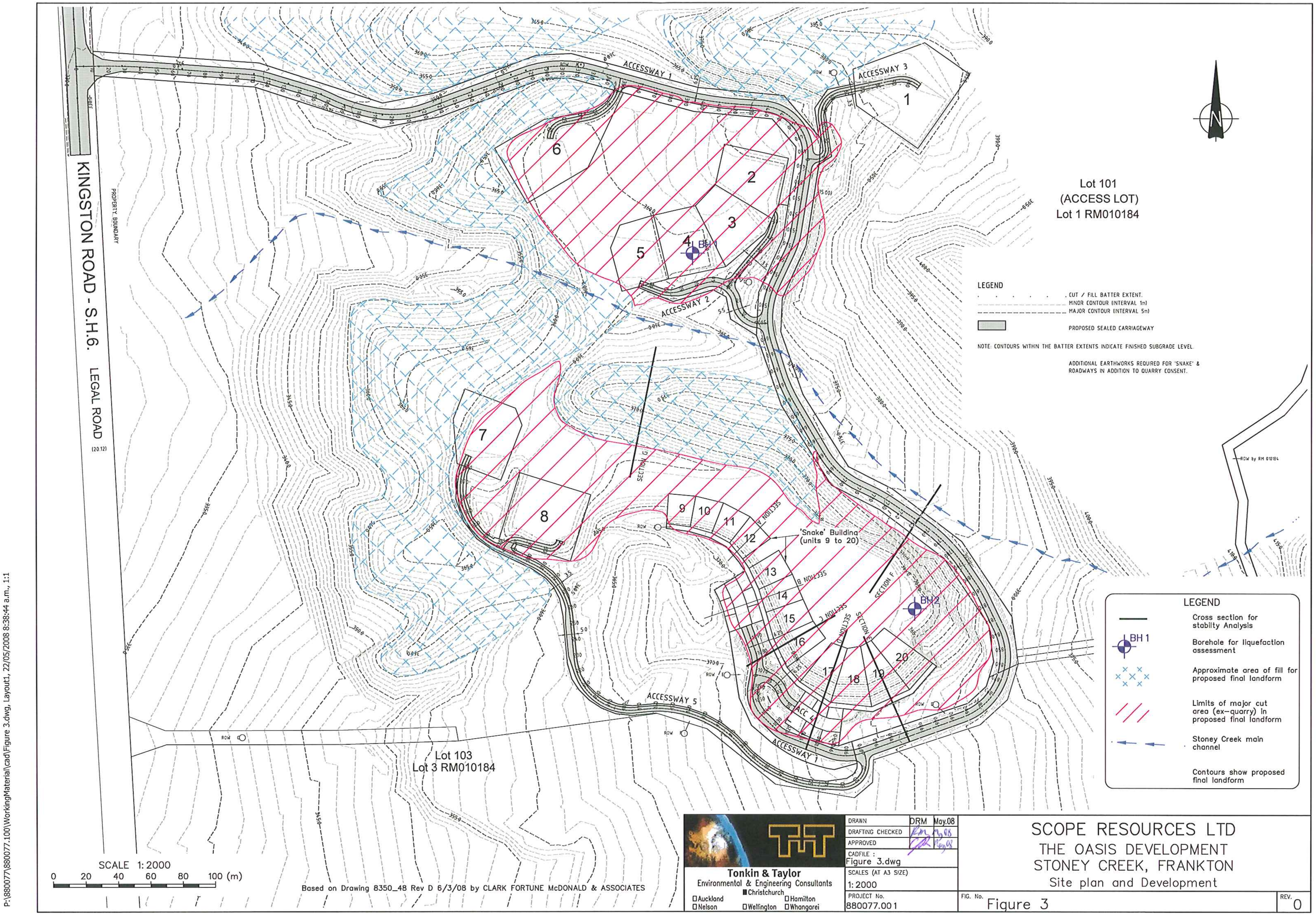

KINGSTON ROAD - S.H.6.
LEGAL ROAD
(20.12)
PROPERTY BOUNDARY
ACCESSWAY 1
ACCESSWAY 2
ACCESSWAY 3
ACCESSWAY 5
ACC 4
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
BH 1
BH 2
'Snake' Building (units 9 to 20)
SECTION A
SECTION B
SECTION C
SECTION D
SECTION E
SECTION F
SECTION G
ROW
Lot 101 (ACCESS LOT) Lot 1 RM010184
Lot 103 Lot 3 RM010184
ROW by RM 010184
LEGEND
CUT / FILL BATTER EXTENT.
MINOR CONTOUR (INTERVAL 1m)
MAJOR CONTOUR (INTERVAL 5m)
PROPOSED SEALED CARRIAGEWAY
NOTE: CONTOURS WITHIN THE BATTER EXTENTS INDICATE FINISHED SUBGRADE LEVEL.
ADDITIONAL EARTHWORKS REQUIRED FOR 'SNAKE' & ROADWAYS IN ADDITION TO QUARRY CONSENT.
LEGEND
Cross section for stability Analysis
Borehole for liquefaction assessment
Approximate area of fill for proposed final landform
Limits of major cut area (ex-quarry) in proposed final landform
Stoney Creek main channel
Contours show proposed final landform
SCALE 1: 2000
0 20 40 60 80 100 (m)
Based on Drawing 8350_48 Rev D 6/3/08 by CLARK FORTUNE McDONALD & ASSOCIATES
Tonkin & Taylor
Environmental & Engineering Consultants
☐Auckland ☐Nelson ■Christchurch ☐Wellington ☐Hamilton ☐Whangarei
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APPROVED
CADFILE : Figure 3.dwg
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PROJECT No. 880077.001
SCOPE RESOURCES LTD
THE OASIS DEVELOPMENT
STONEY CREEK, FRANKTON
Site plan and Development
FIG. No. Figure 3
REV. 0
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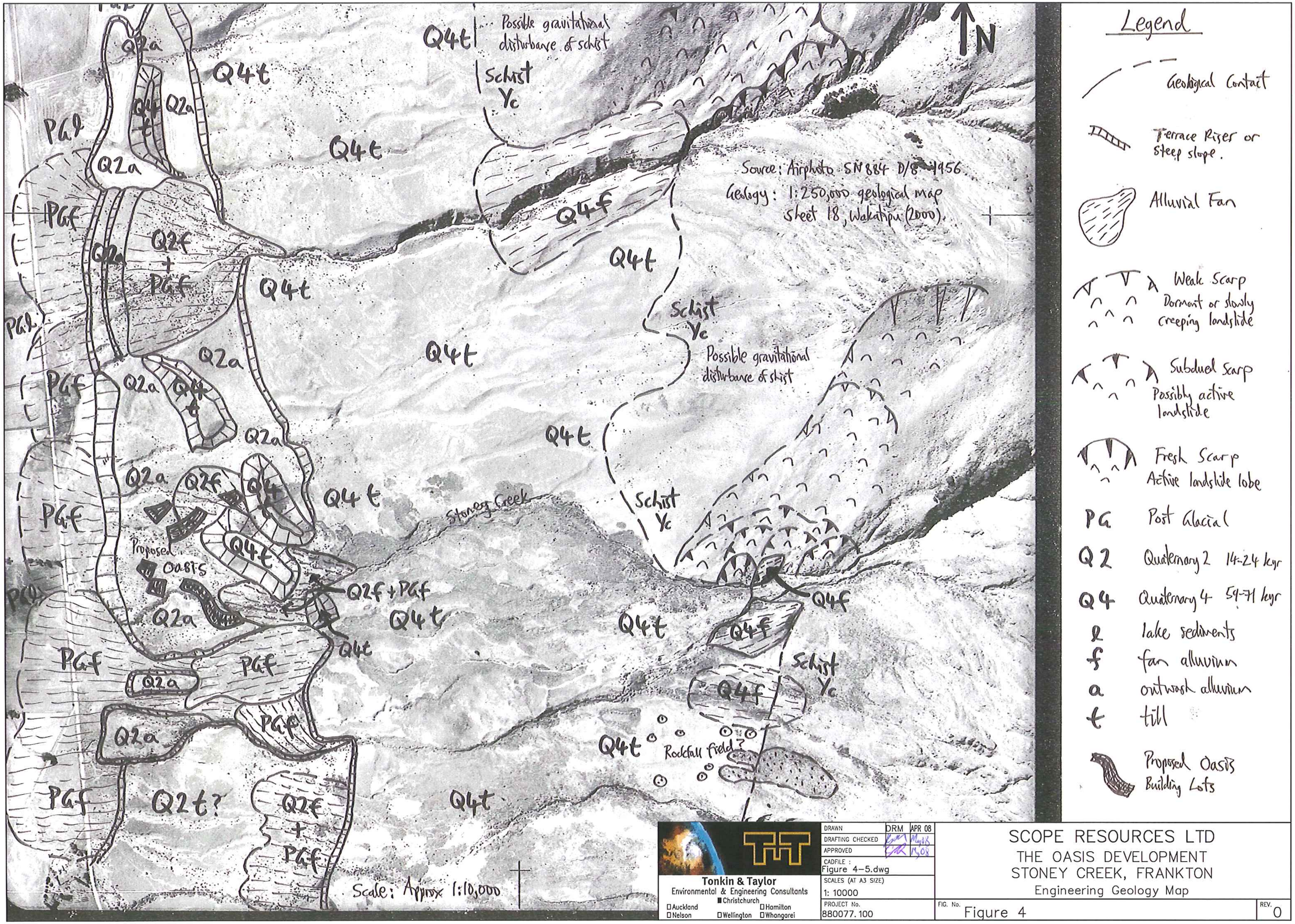

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THE OASIS DEVELOPMENT
STONEY CREEK, FRANKTON
Engineering Geology Map

FIG. No. Figure 4

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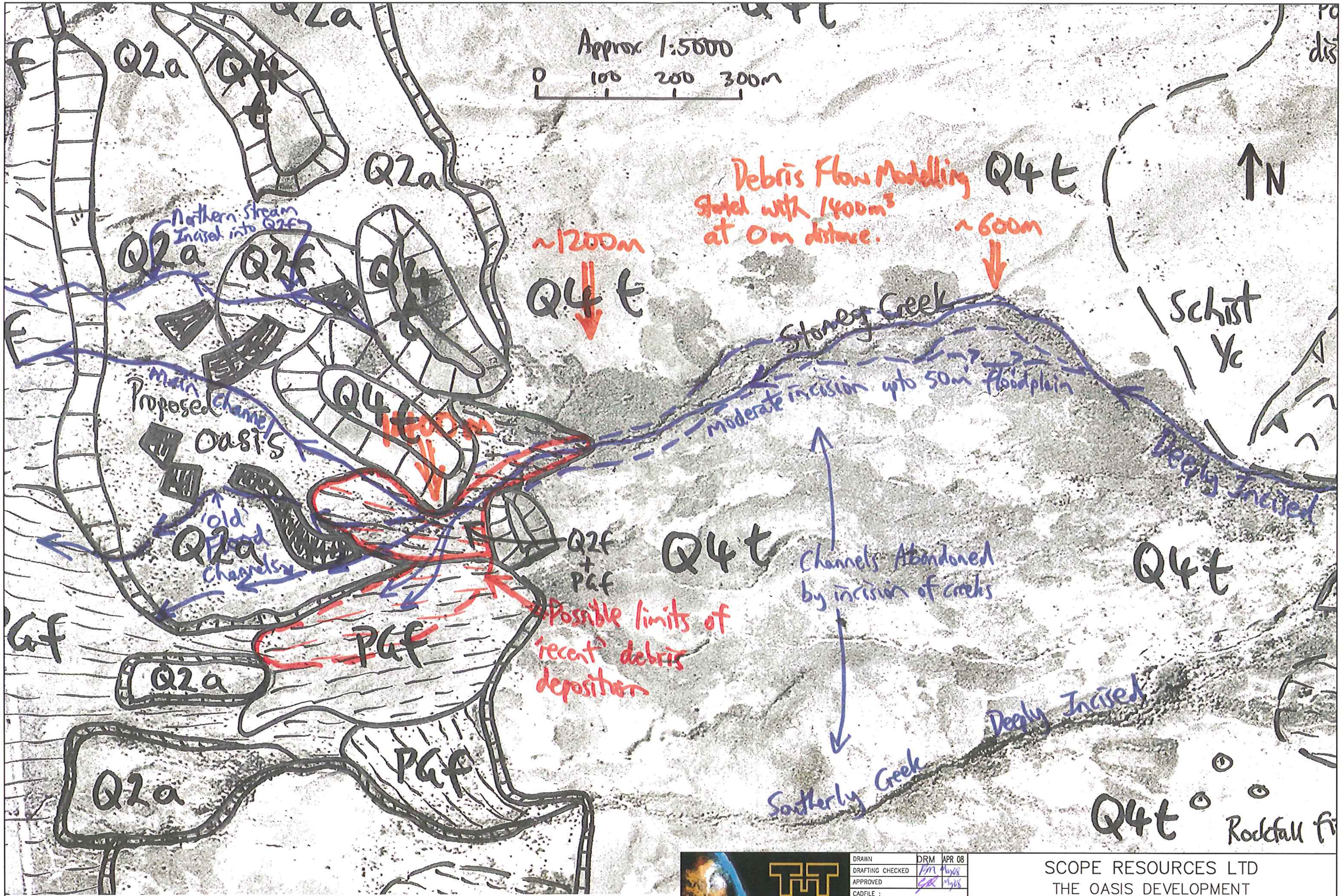

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Christchurch Auckland Nelson Wellington Hamilton Whangarei

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THE OASIS DEVELOPMENT
STONEY CREEK, FRANKTON
Flood & Debris Flow Hazard

FIG. No. Figure 5
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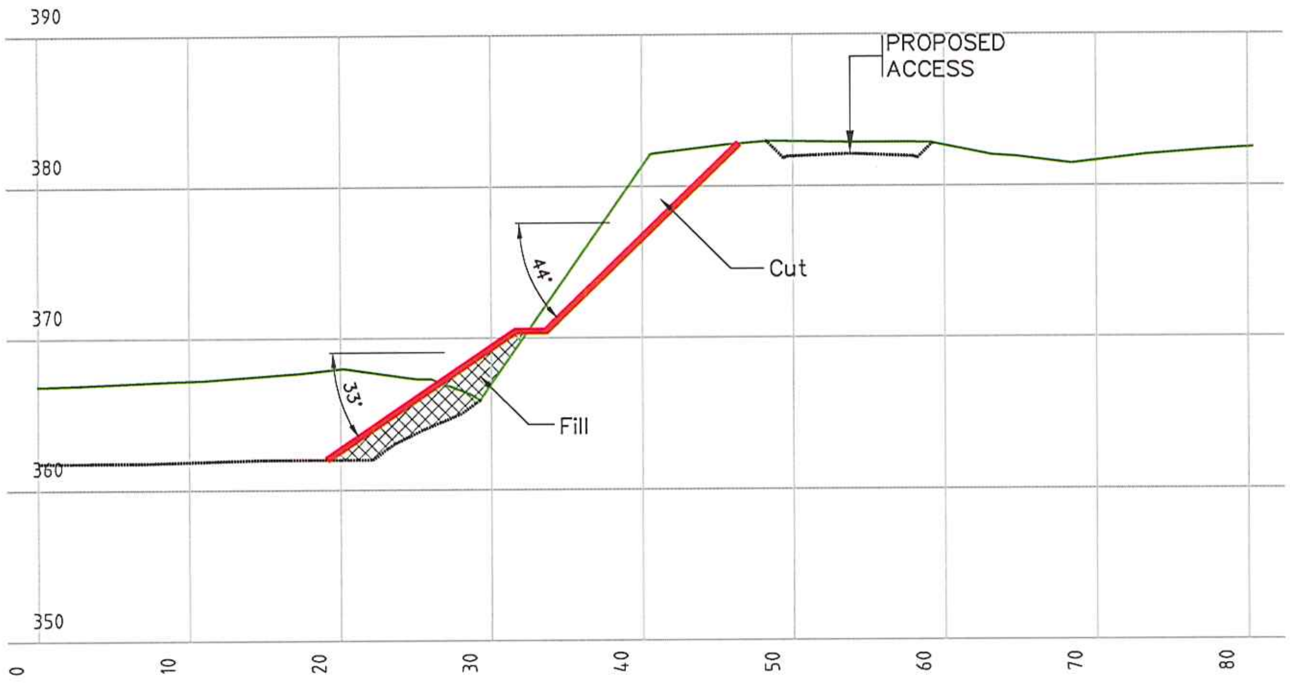

SECTION F

LEGEND

GROUND LEVELS AS AT DECEMBER 2005

EXCAVATION LINE IN ACCORDANCE WITH QUARRY CONSENT

PROPOSED CUT & FILL LINE BASED OF SLOPE STABILITY ANALYSIS

SCALE 1: 500

0 5 10 15 20 25 (m)

P:\880077\880077.100\WorkingMaterial\cad\Figure 6.dwg, Layout1, 22/05/2008 9:14:25 a.m., 1:1

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THE OASIS DEVELOPMENT
STONEY CREEK, FRANKTON
Steep Slope Design Section F

FIG. No. Figure 6

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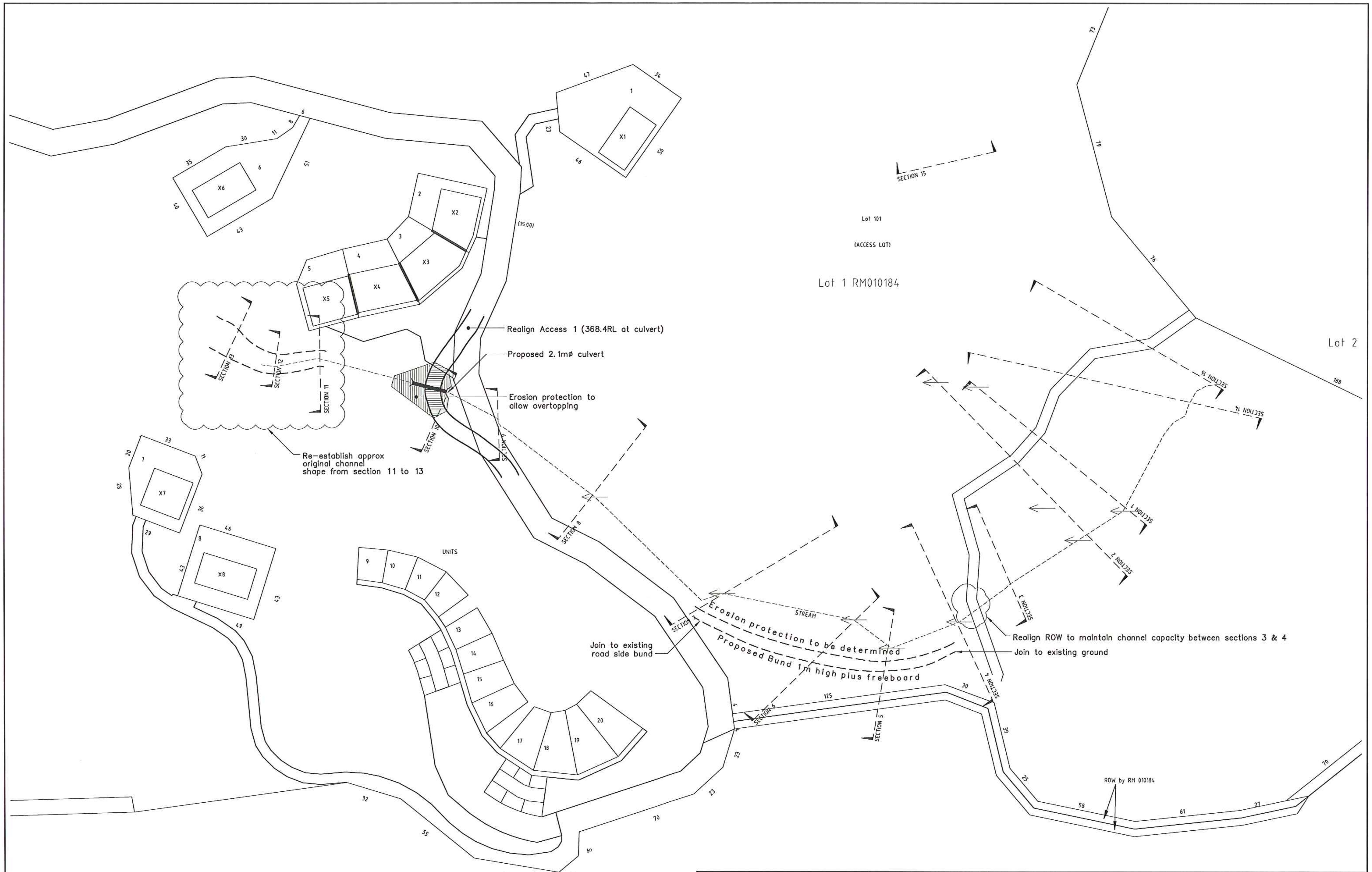

Drawing supplied by
CLARK FORTUNE McDONALD
& ASSOCIATES (dwg 8350_59, 27/02/08)

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APPROVED	[signature]	May 08
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THE OASIS DEVELOPMENT
STONEY CREEK, FRANKTON
Stoney Creek Flood Mitigation Concepts

FIG. No. Figure 7

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Appendix B: Investigation and Slope Stability

- Borehole Logs BH01 and BH02 (2 pages)
- Figure B1 – Rock Fall Analysis
- SlopeW example outputs (11 pages)

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BOREHOLE LOG

BOREHOLE No: BH01
Hole Location:
SHEET 1 OF 1

PROJECT: CFM Stoney Oasis	LOCATION: Stoney Creek, Frankton		JOB No: 880077.100
CO-ORDINATES mN mE	DRILL TYPE: UDR650	HOLE STARTED: 20/2/08	
R.L. m	DRILL METHOD: TUBEX	HOLE FINISHED: 20/2/08	
		DRILLED BY: McNEIL	
DATUM	DRILL FLUID:	LOGGED BY: SCWW	CHECKED:

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
Glacial outwash gravels		Dry	N/A	TBX					0–10.5			DRY	MD - D				Coarse Silty Gravels
									10.5								End of borehole - 10.5 m

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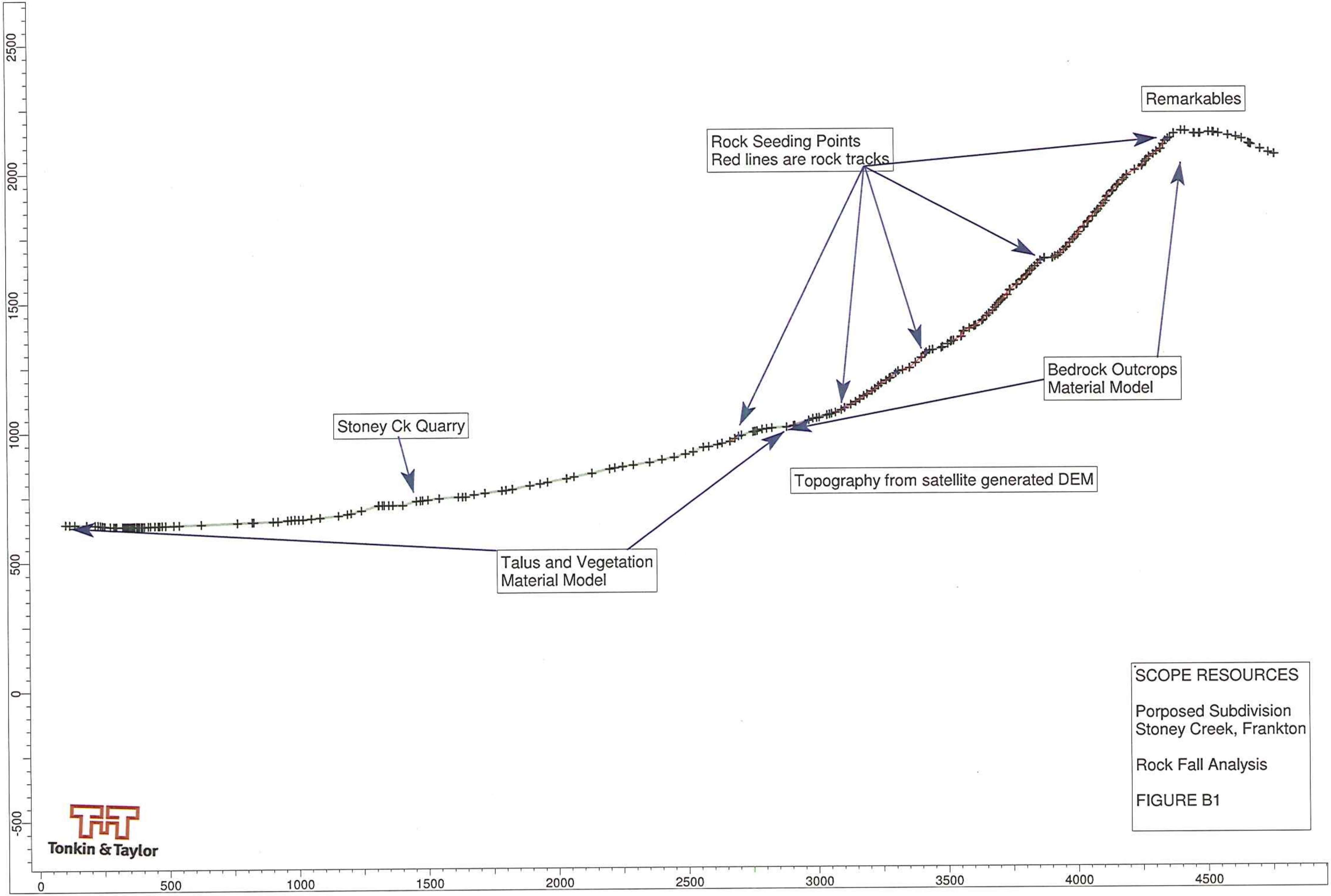
BOREHOLE LOG

BOREHOLE No: BH02
Hole Location:
SHEET 1 OF 1

PROJECT: CFM Stoney Oasis	LOCATION: Stoney Creek, Frankton	JOB No: 880077.100	
CO-ORDINATES mN mE	DRILL TYPE: UDR650	HOLE STARTED: 20/2/08	
R.L. m	DRILL METHOD: TUBEX	HOLE FINISHED: 20/2/08	
DATUM	DRILL FLUID:	DRILLED BY: McNEIL	
		LOGGED BY: SCWW	CHECKED:

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
Glacial outwash gravels		DRY	N/A	TBX					0–6.1			DRY	MD - D				Coarse Silty Gravels
Boulder									6.1–6.4								Boulder
Glacial outwash gravels									6.4–12								Coarse Silty Gravels
									12								End of borehole - 12 m

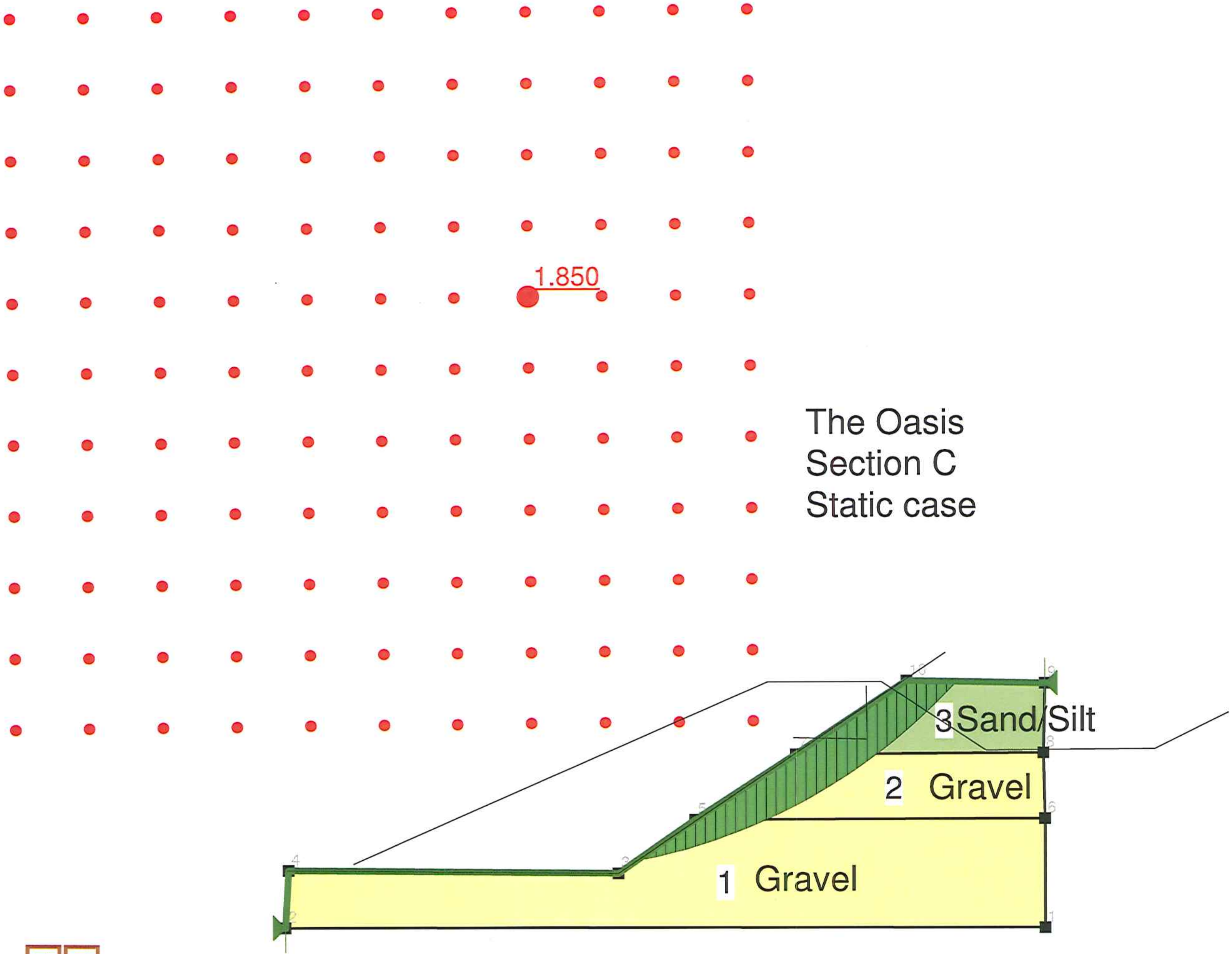


SCOPE RESOURCES

Porposed Subdivision
Stoney Creek, Frankton

Rock Fall Analysis

FIGURE B1



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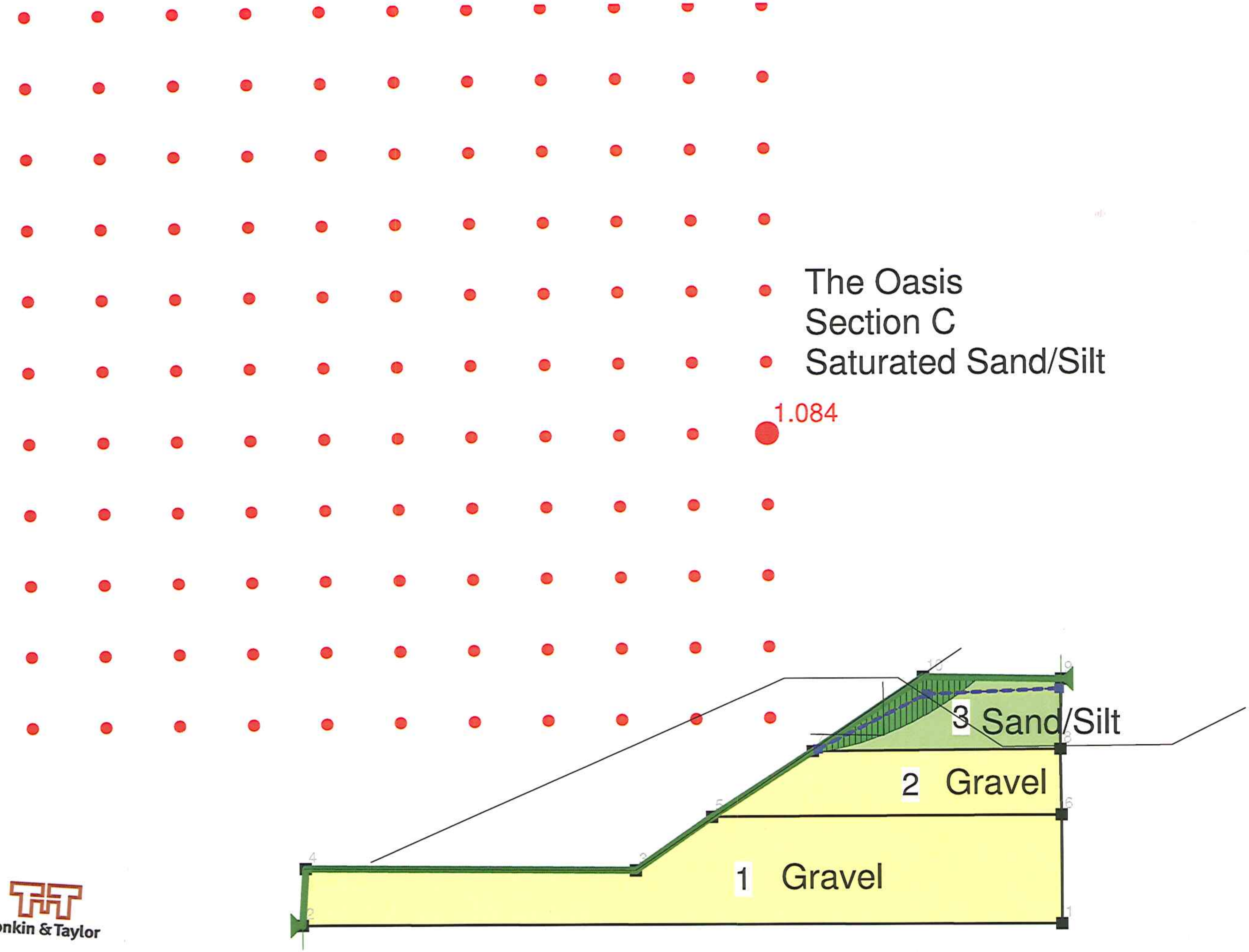

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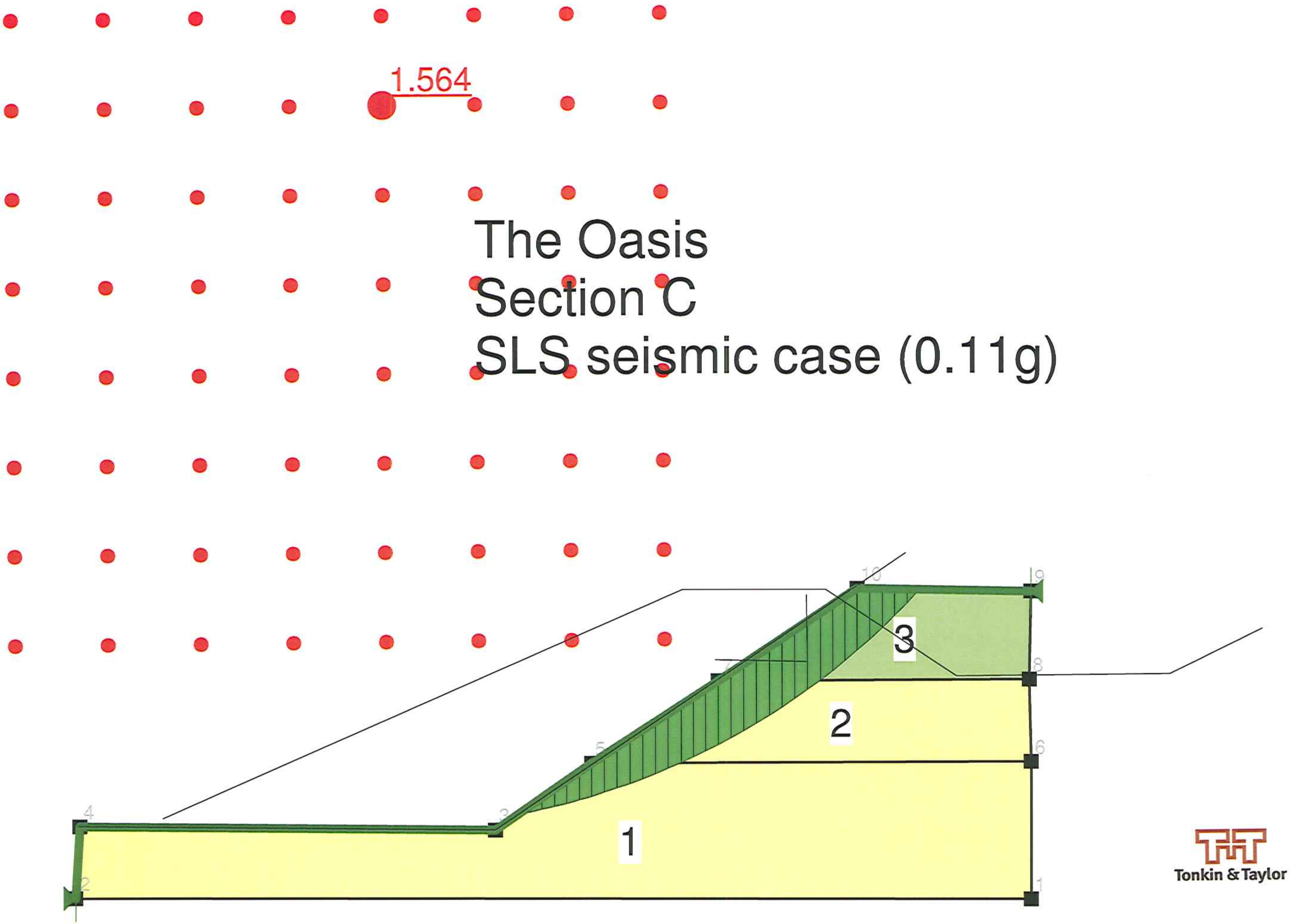
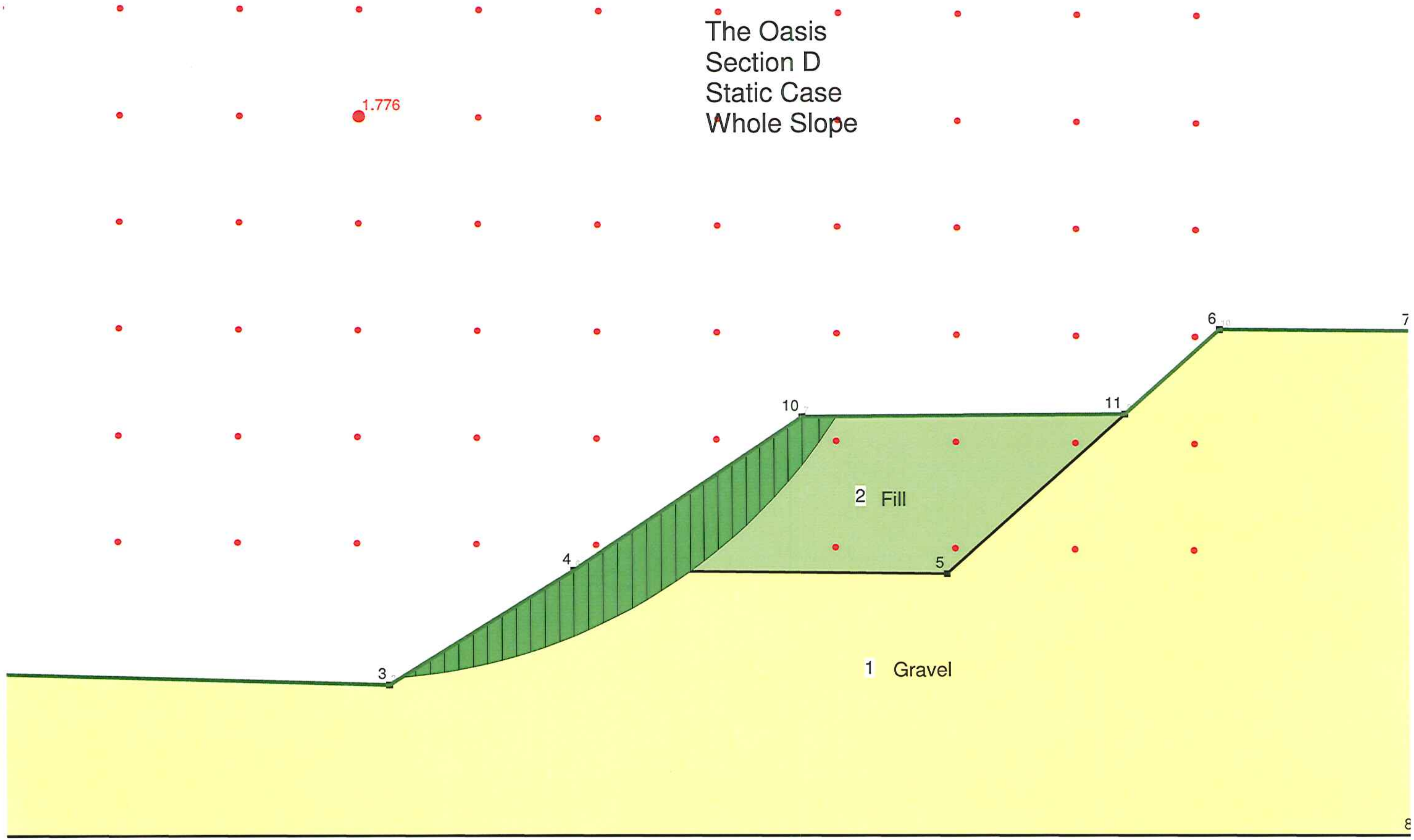

1.564
The Oasis
Section C
SLS seismic case (0.11g)
1
2
3
Tonkin & Taylor



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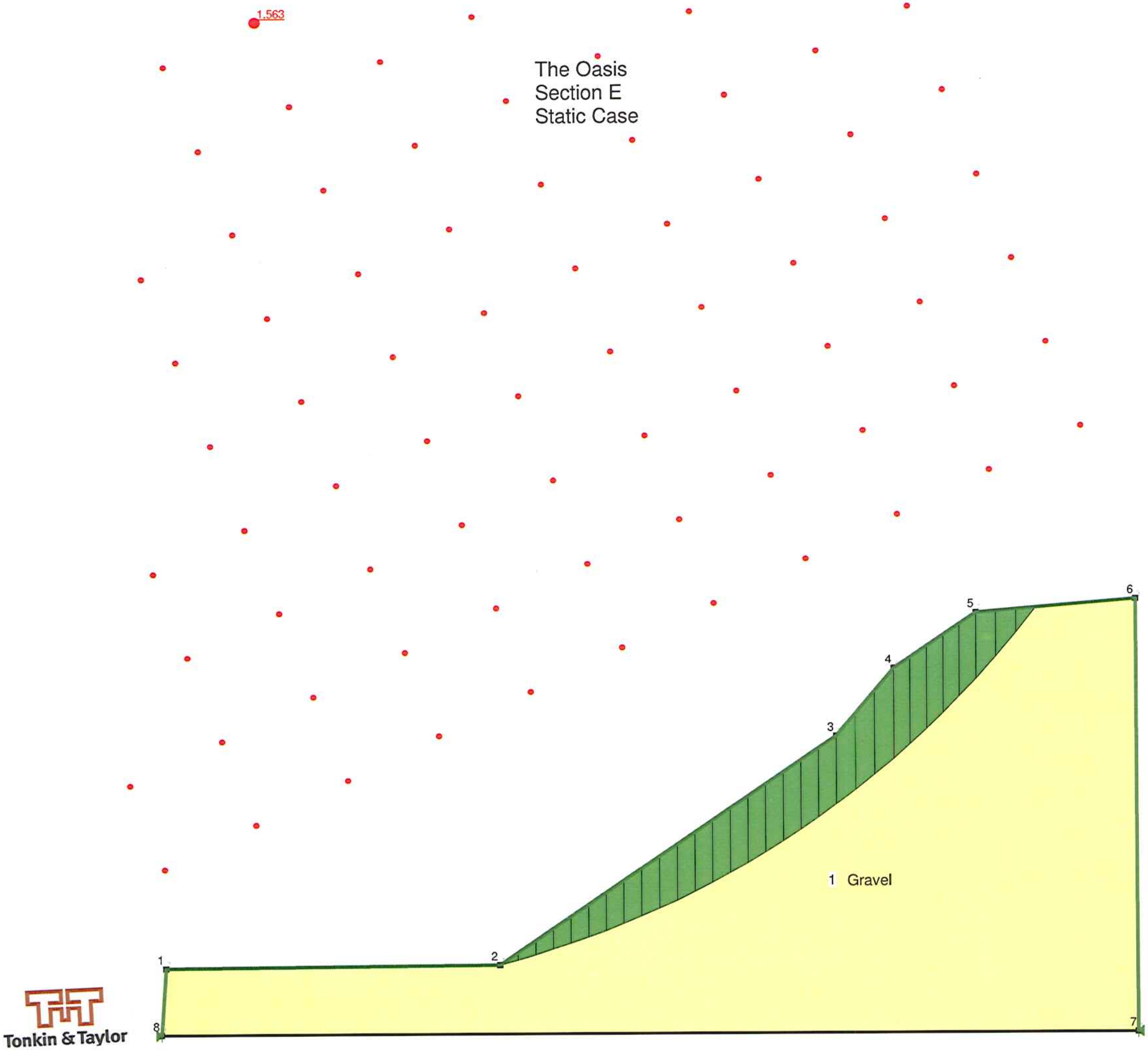
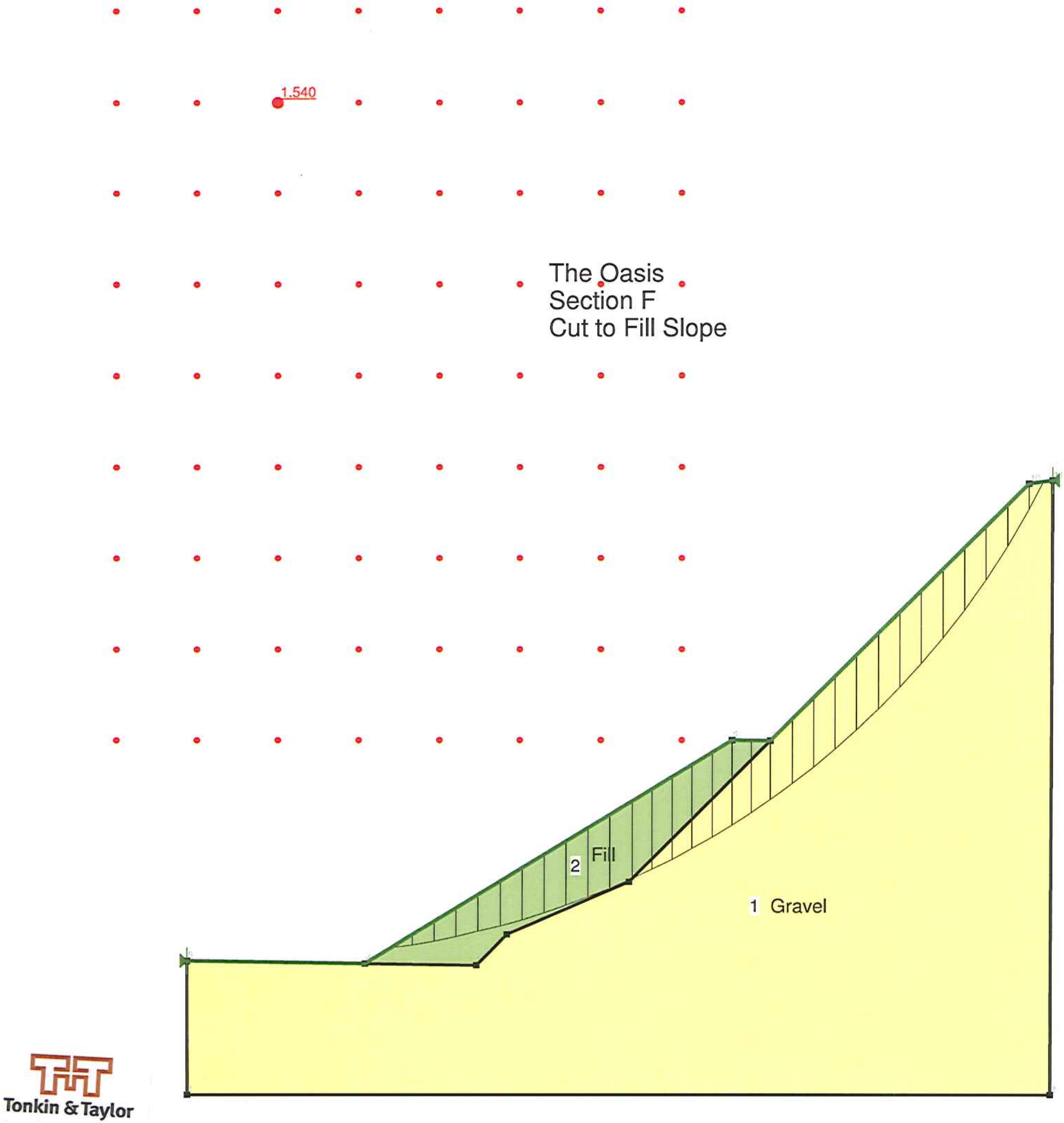

1.563
The Oasis
Section E
Static Case
1
2
3
4
5
6
7
8
1 Gravel
Tonkin & Taylor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The Oasis
Section F
Cut to Fill Slope
2 Fill
1 Gravel
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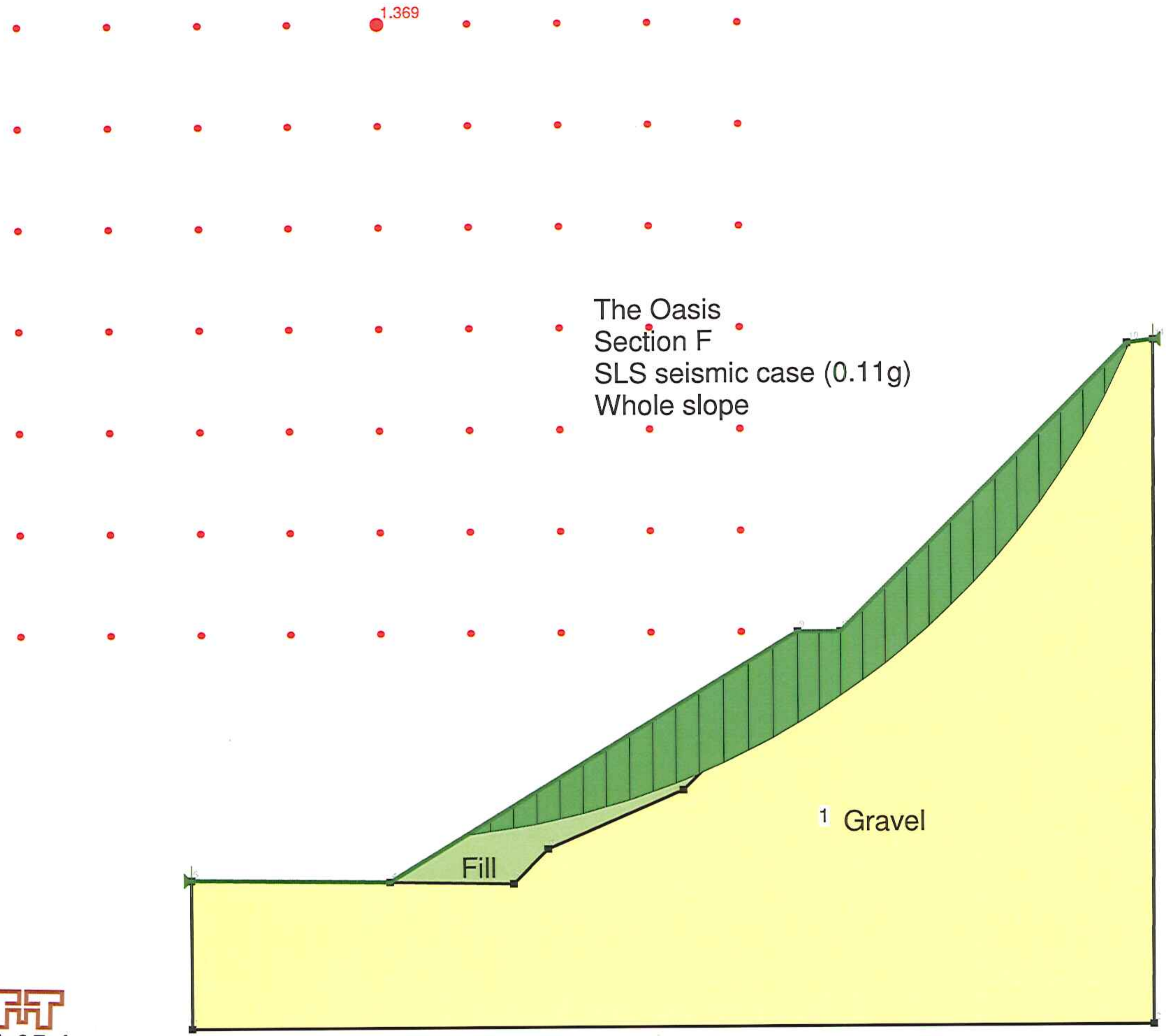

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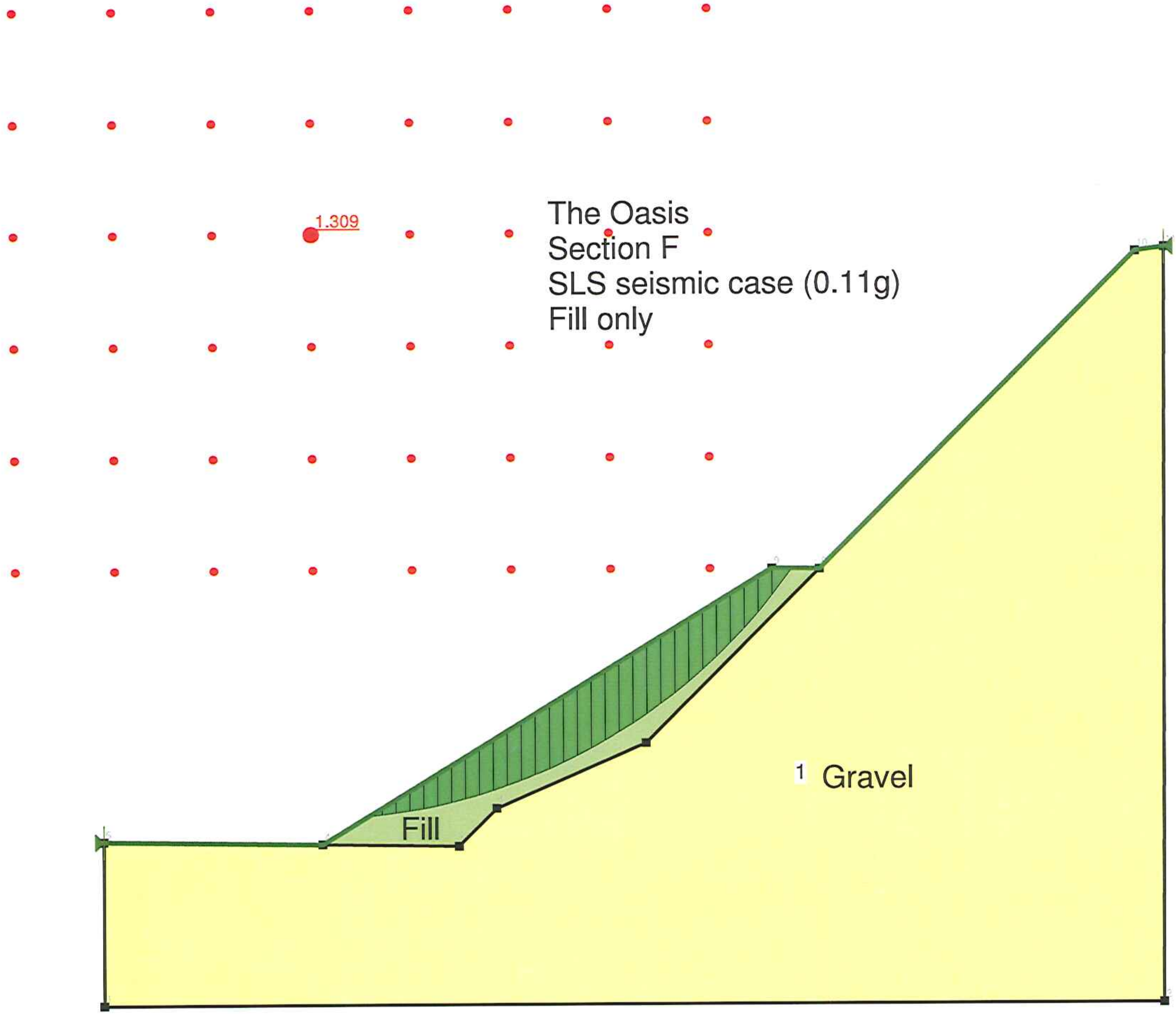

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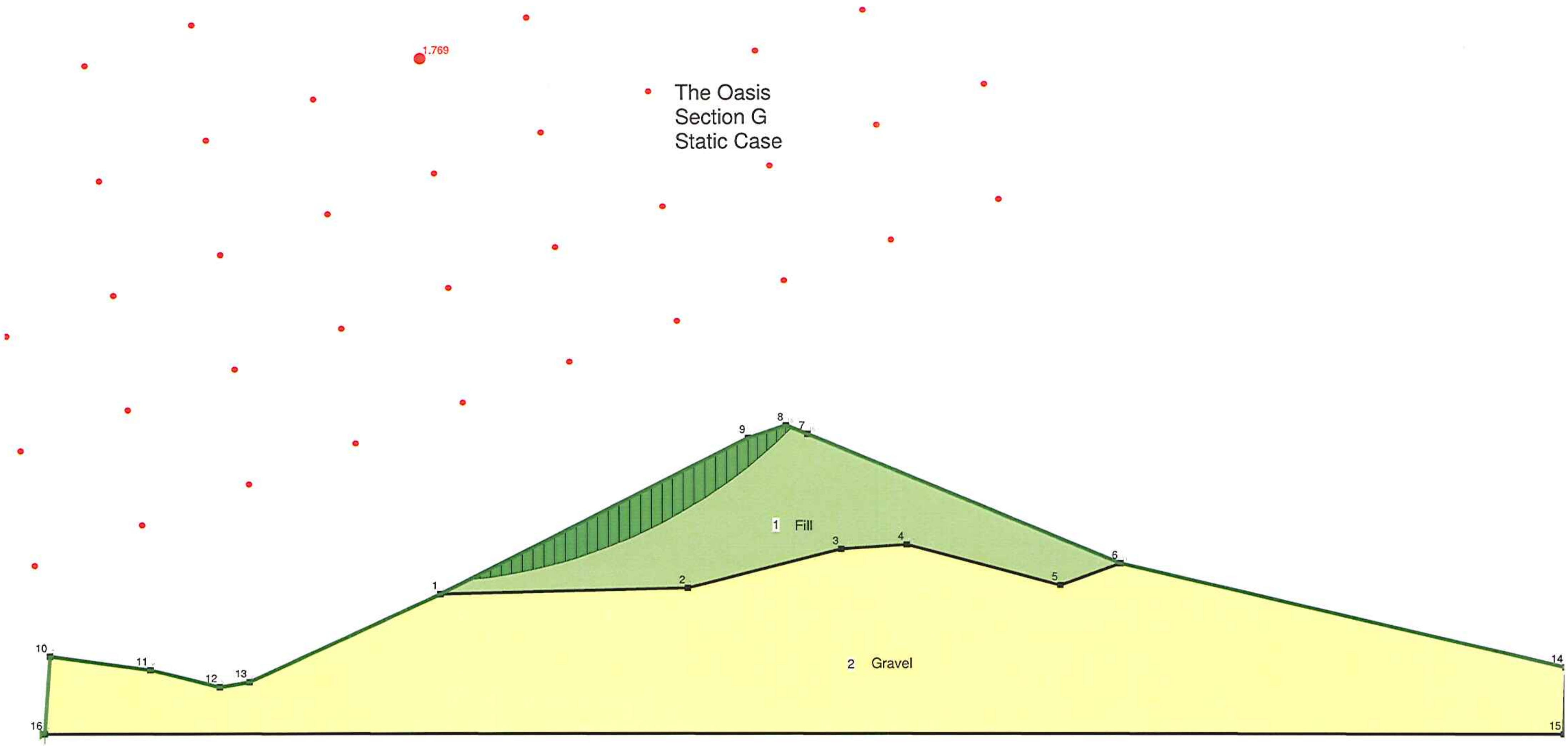

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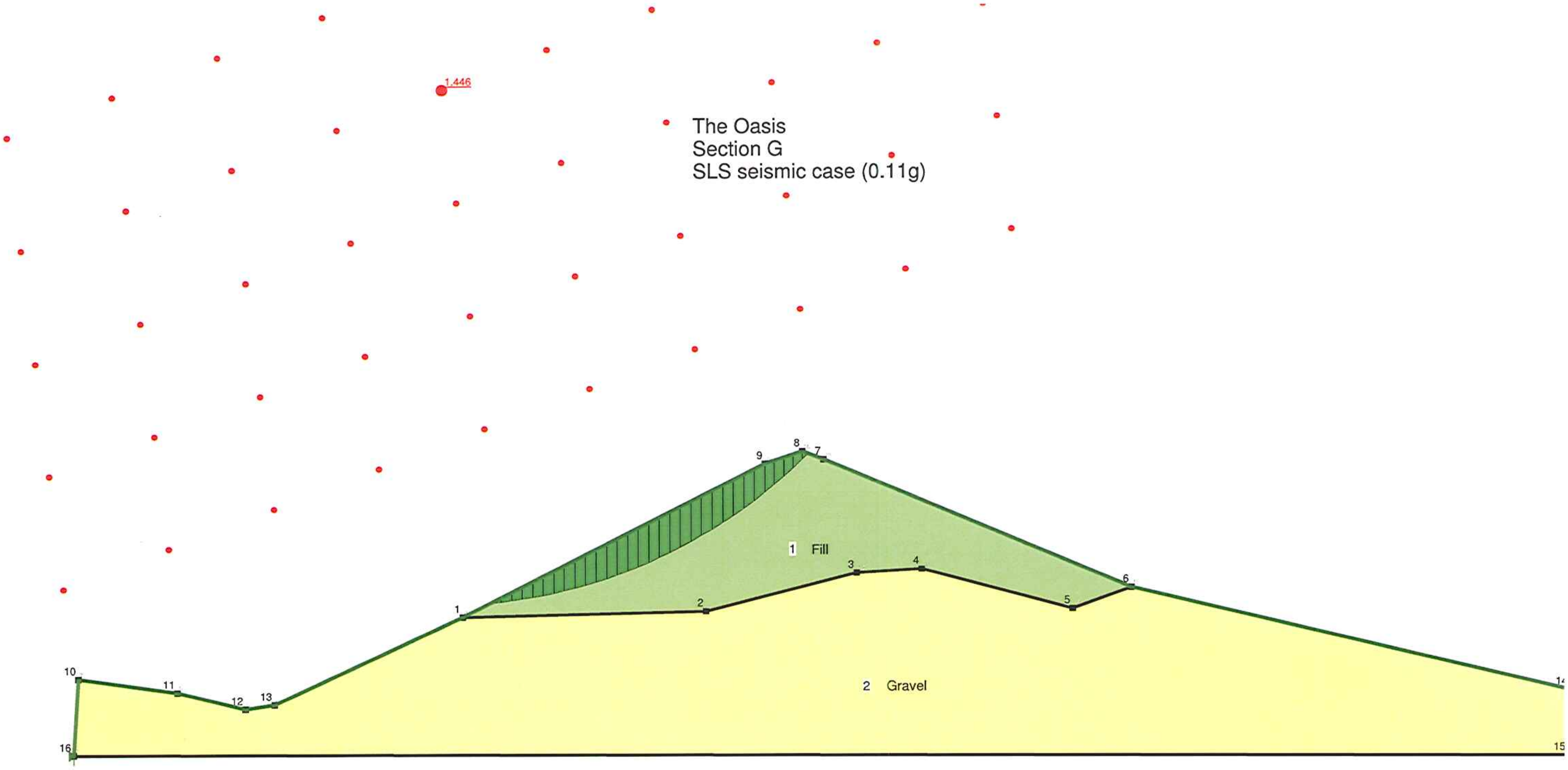

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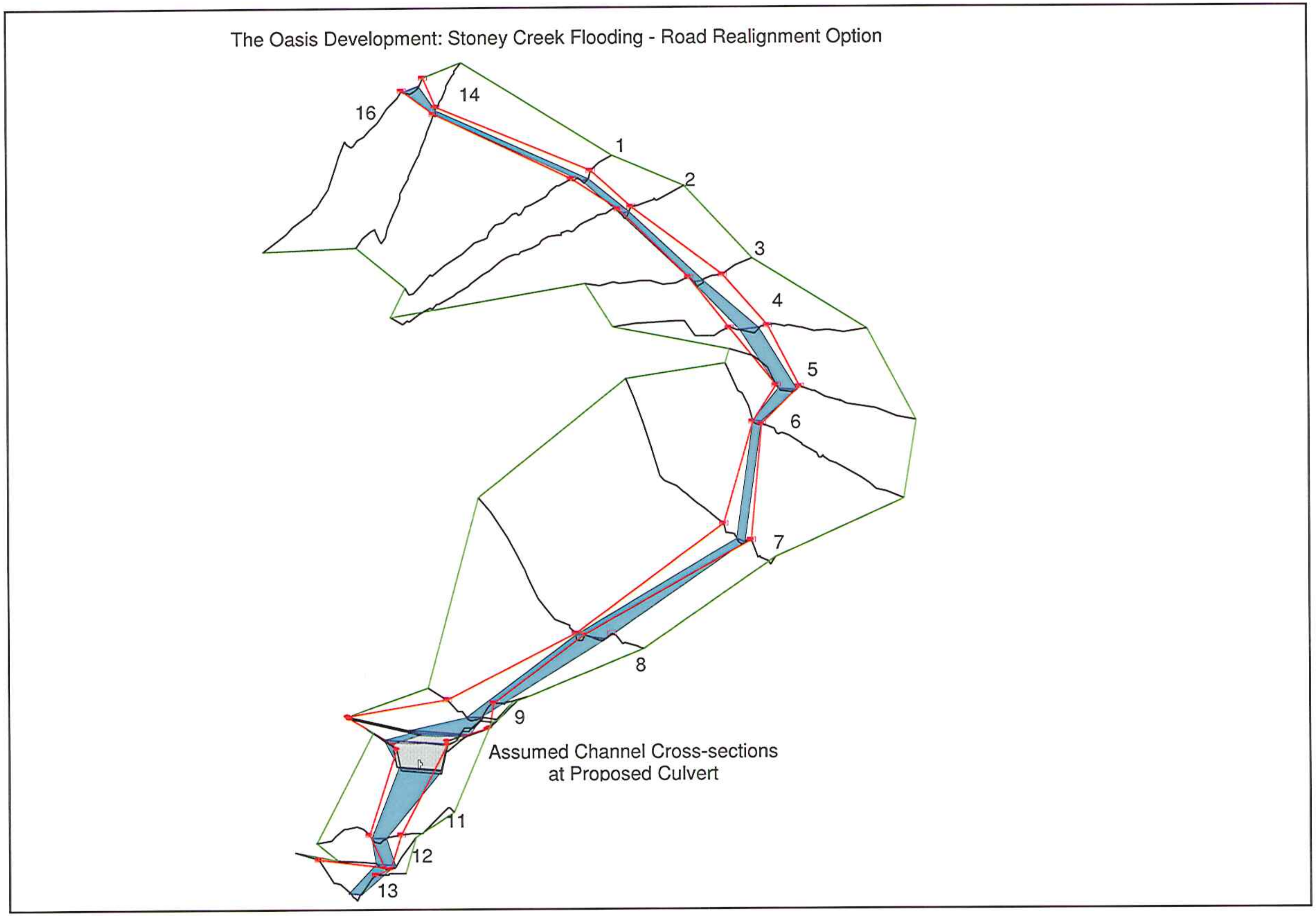
Appendix C: Flooding: Stoney Creek HEC-RAS model cross sections (12 pages)

Figure 1: 3 Dimensional schematic of HEC-RAS Model of Stoney Creek with 15 m^3/sec flood flow. Job Ref: 880077.100



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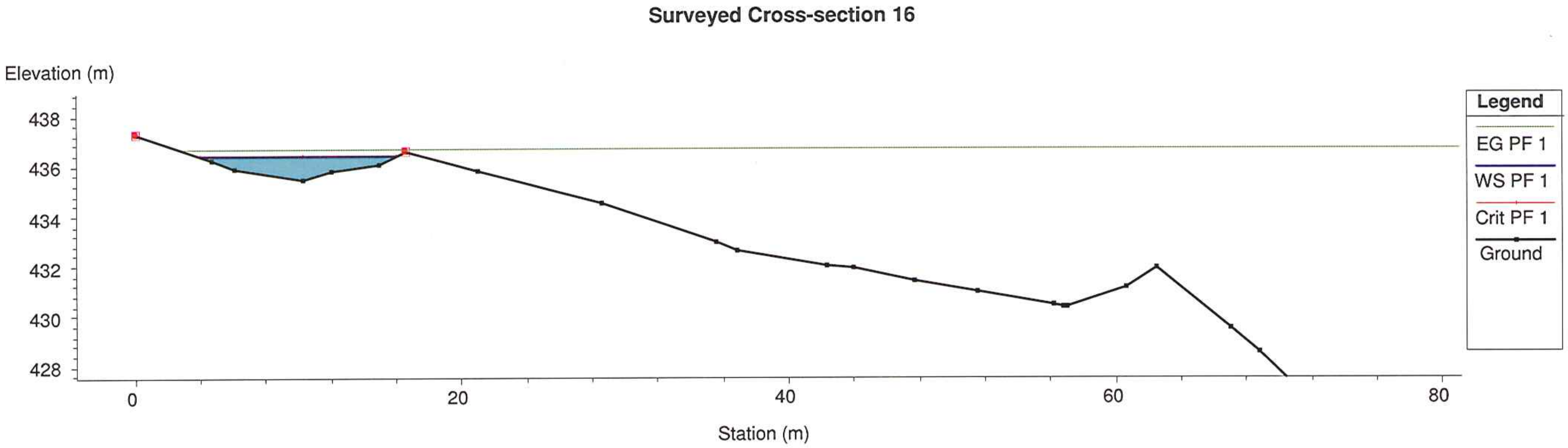
1/05/2008

Figure 2: Stoney Creek Surveyed Cross-sections – Water Level during 15 m^3/sec flood event



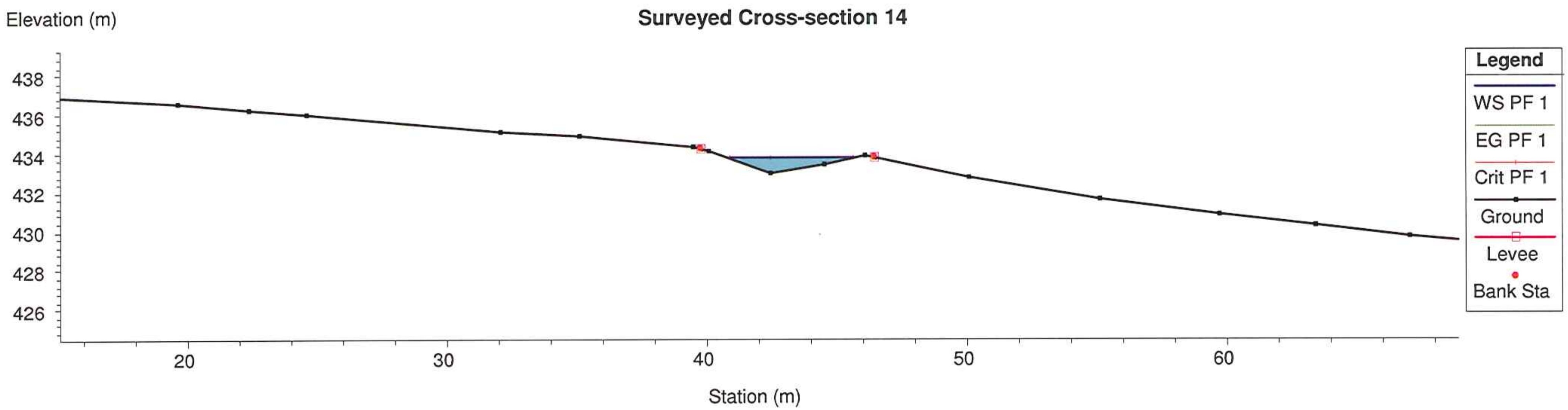
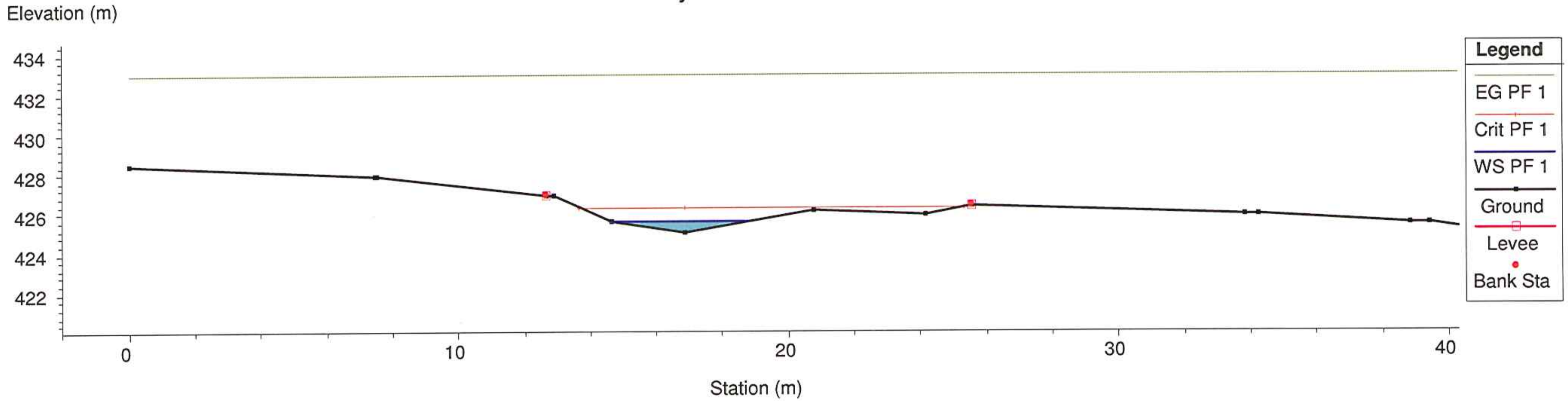


Figure 2: Stoney Creek Surveyed Cross-sections – Water Level during 15 m^3/sec flood event

Surveyed Cross-section 1



Surveyed Cross-section 2

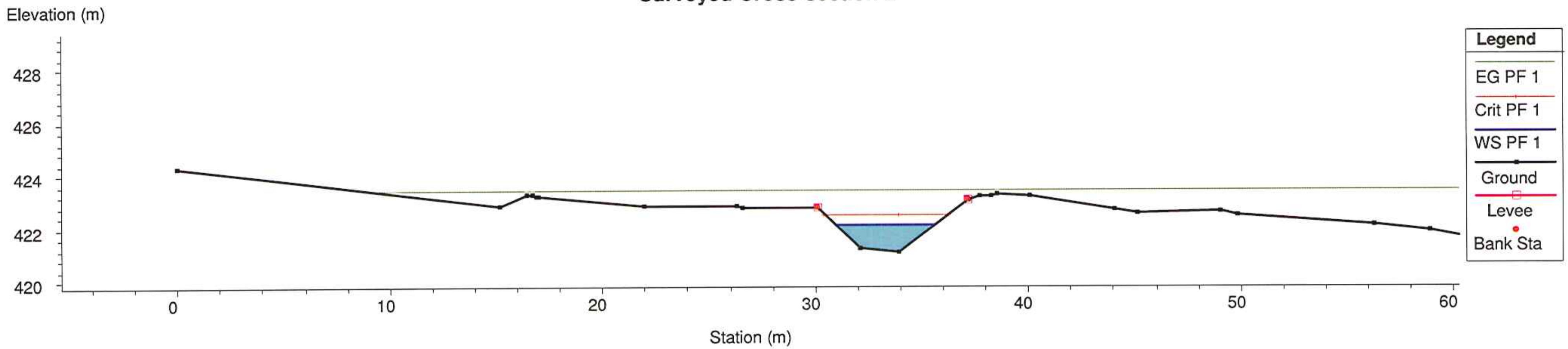
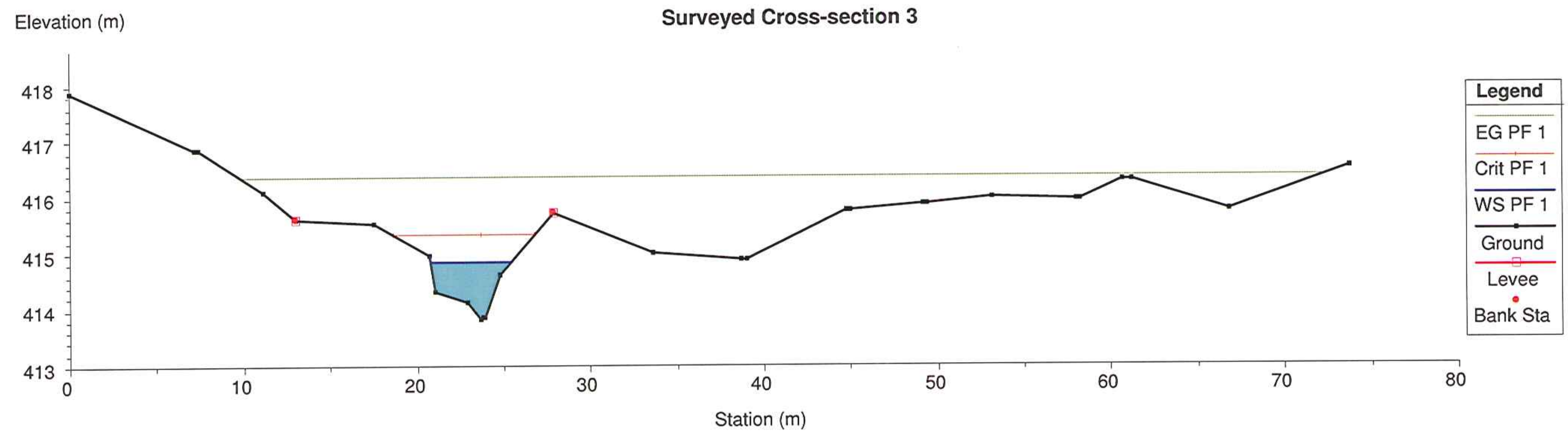


Figure 2: Stoney Creek Surveyed Cross-sections – Water Level during 15 m^3/sec flood event



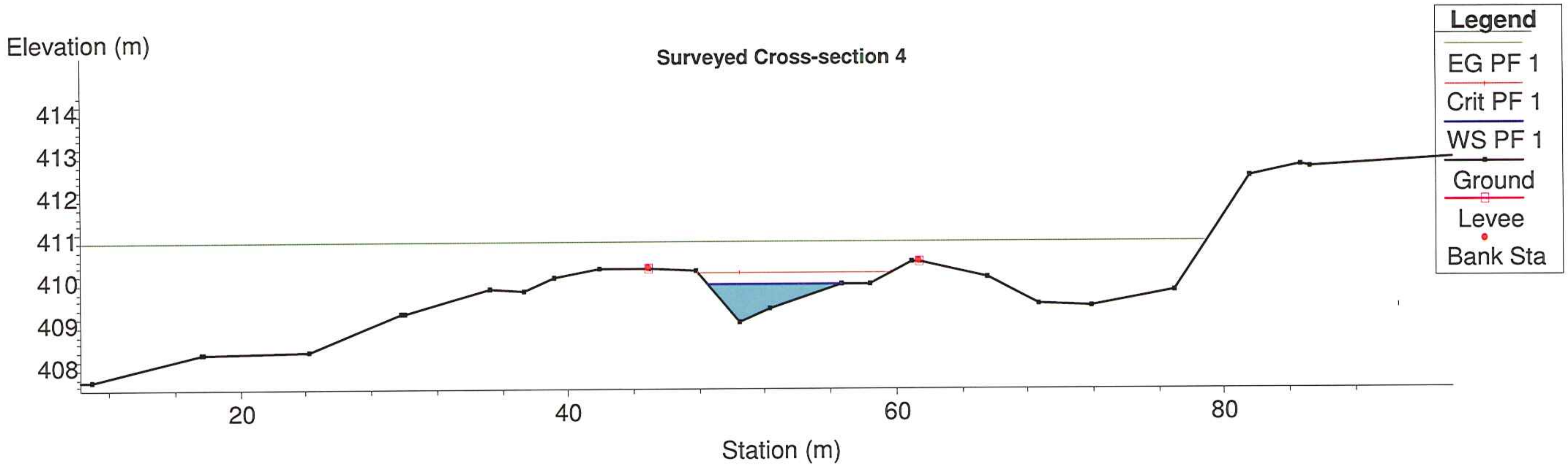
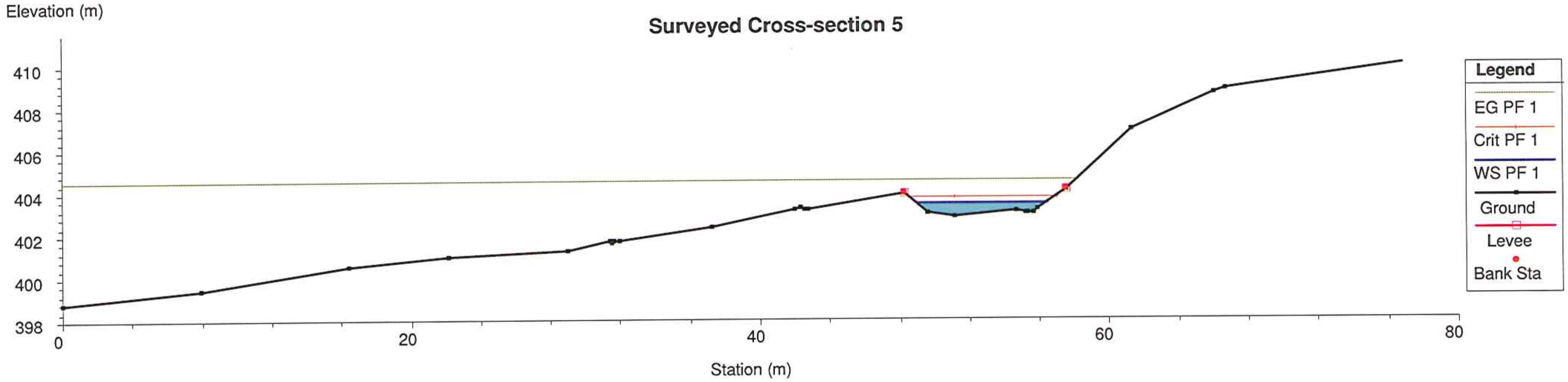


Figure 2: Stoney Creek Surveyed Cross-sections – Water Level during 15 m³/sec flood event



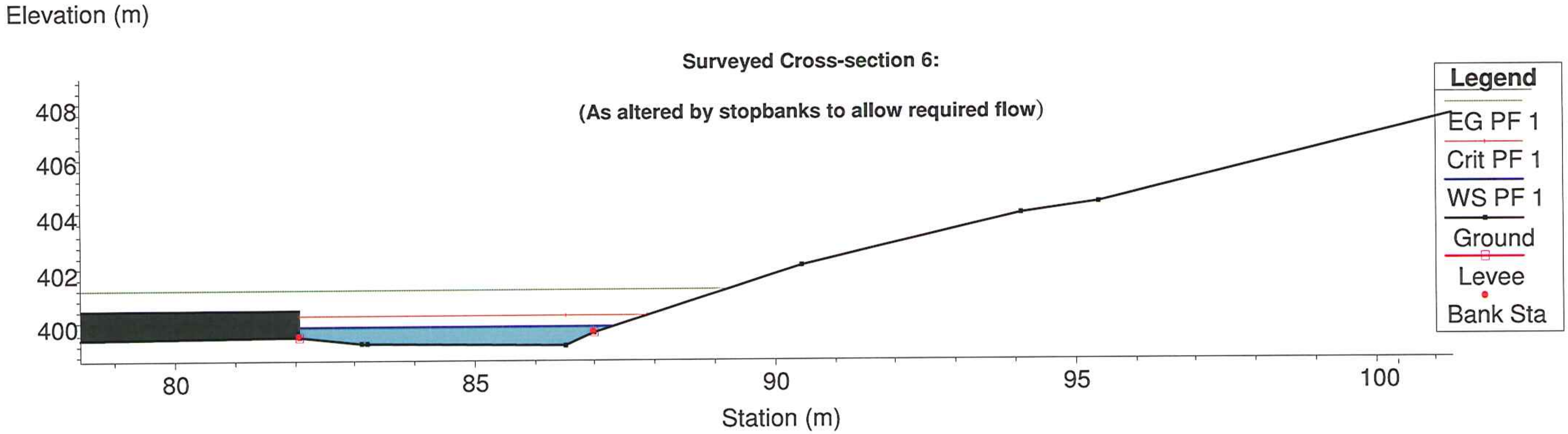
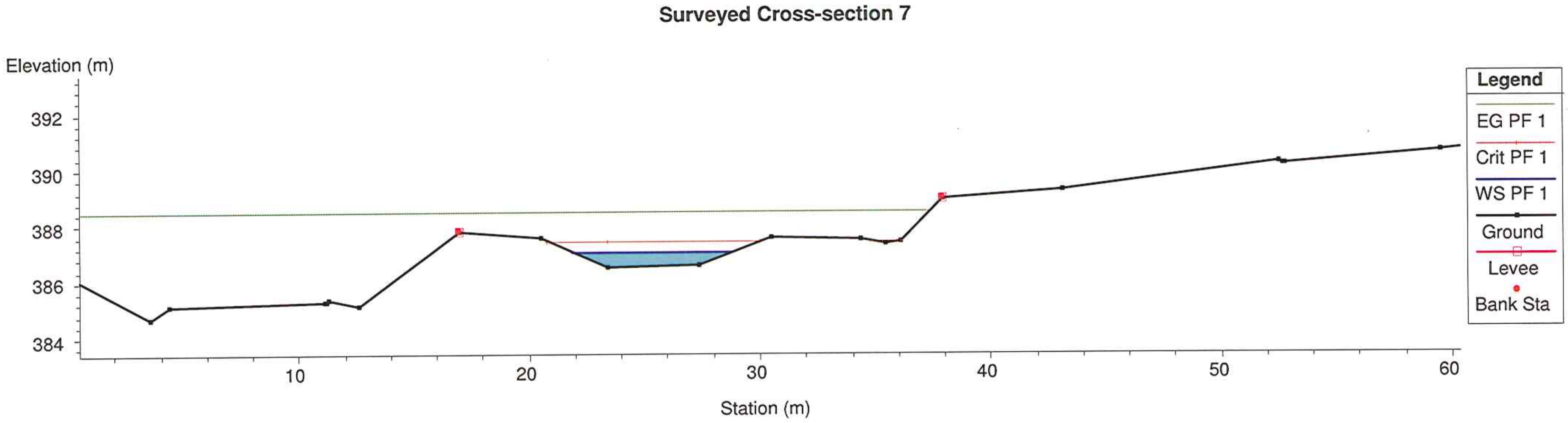


Figure 2: Stoney Creek Surveyed Cross-sections – Water Level during 15 m^3/sec flood event



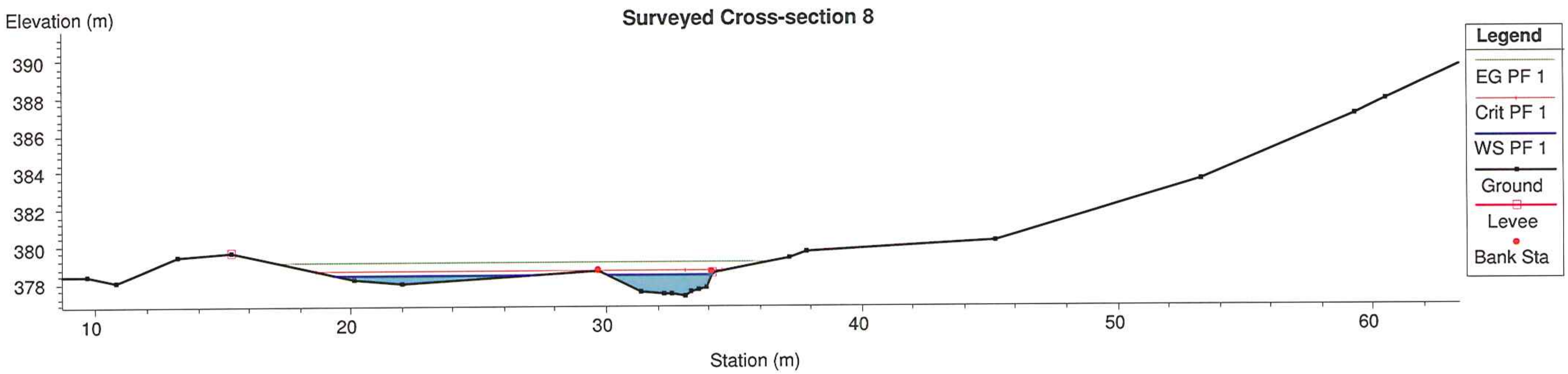
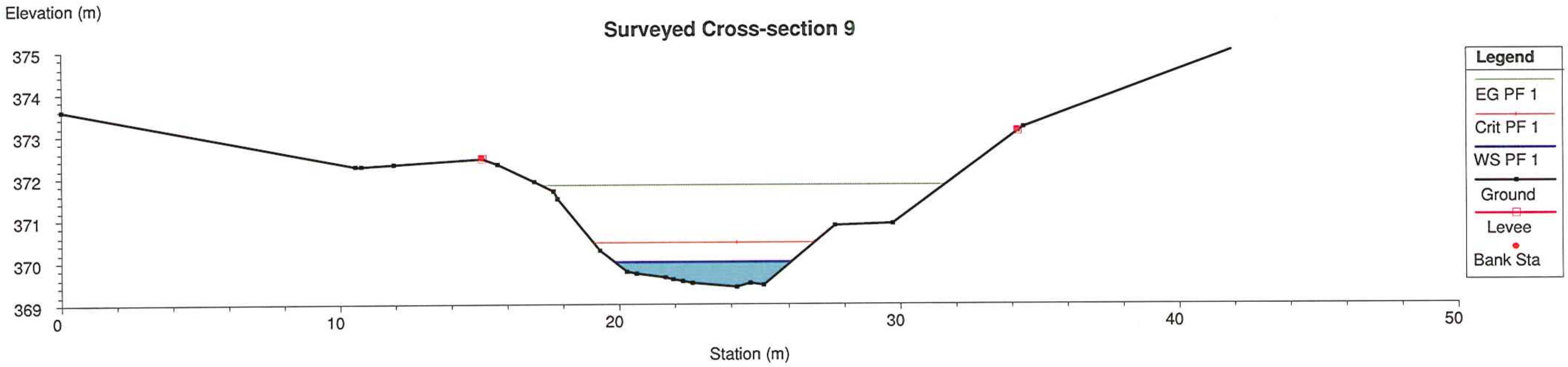


Figure 2: Stoney Creek Surveyed Cross-sections – Water Level during 15 m^3/sec flood event



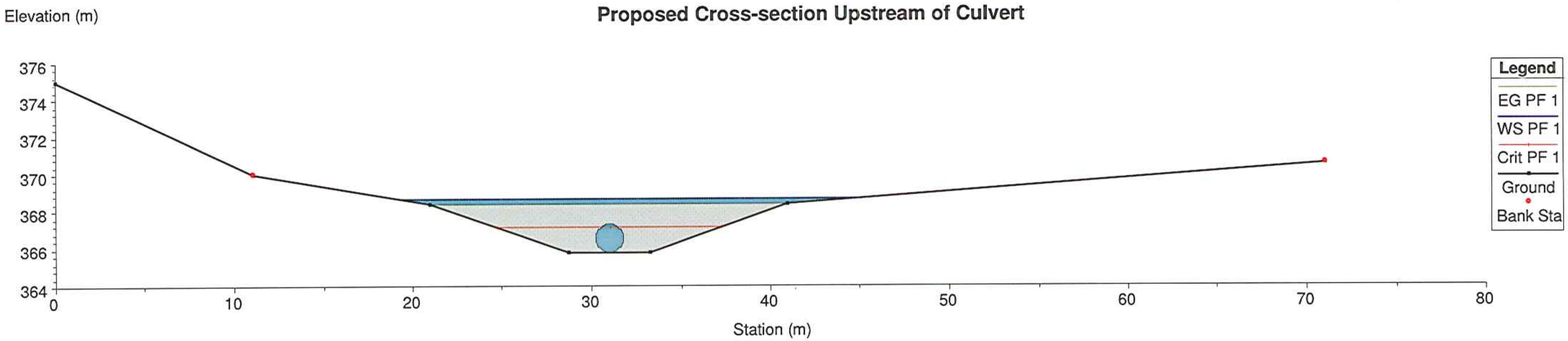
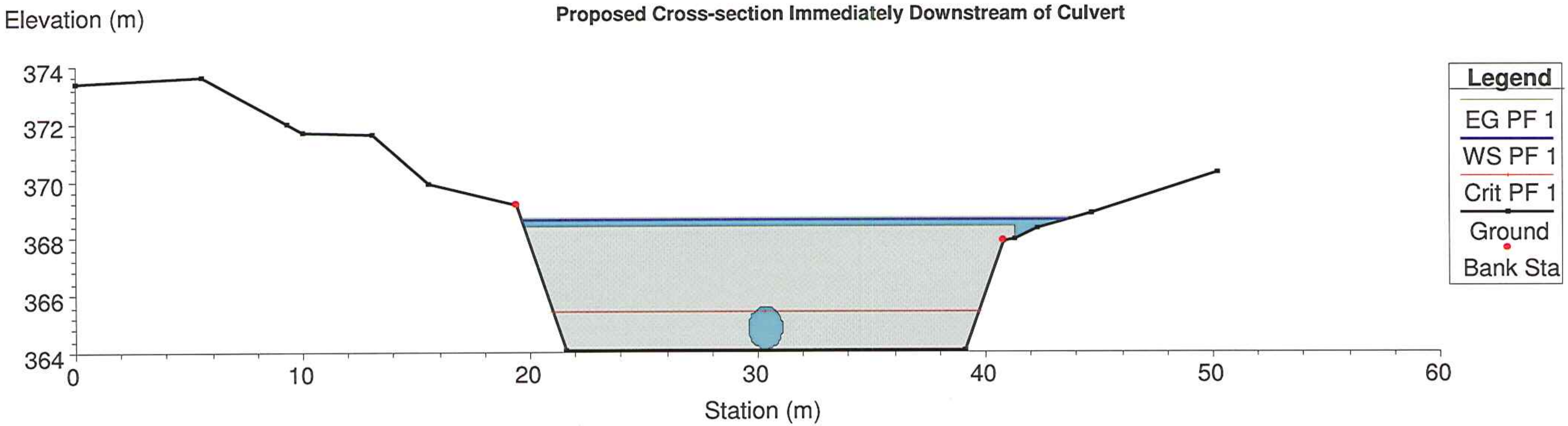
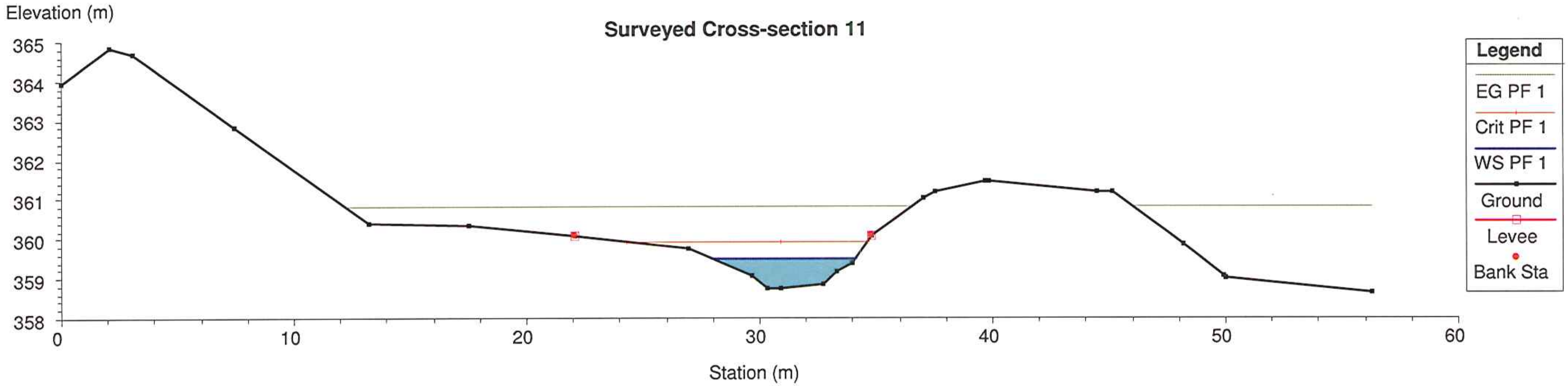
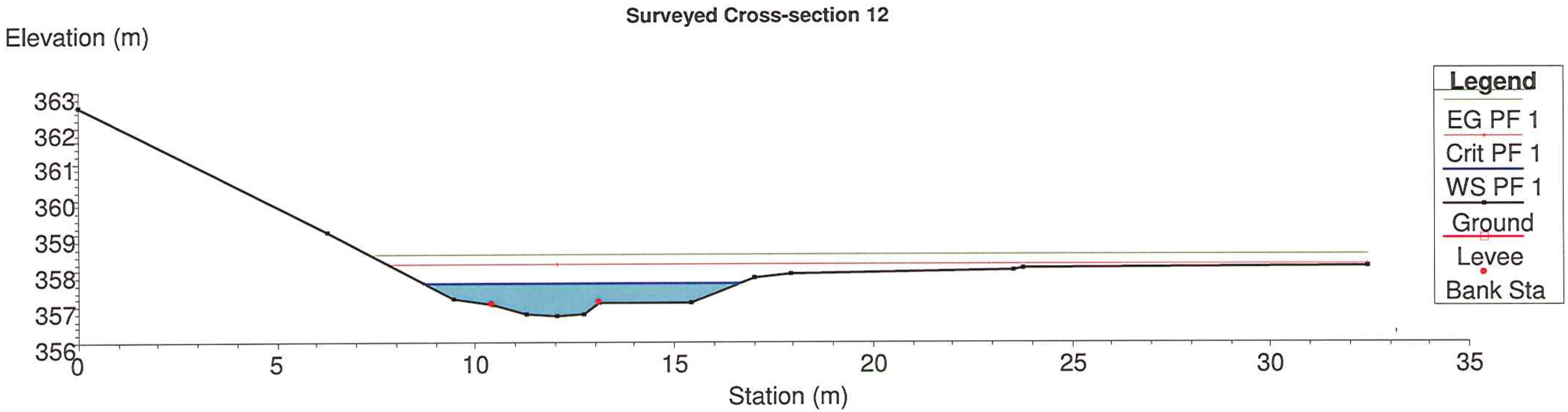


Figure 2: Stoney Creek Surveyed Cross-sections – Water Level during 15 m^3/sec flood event






Surveyed Cross-section 12
Elevation (m)
363
362
361
360
359
358
357
356
0
5
10
15
20
25
30
35
Station (m)
Legend
EG PF 1
Crit PF 1
WS PF 1
Ground
Levee
Bank Sta

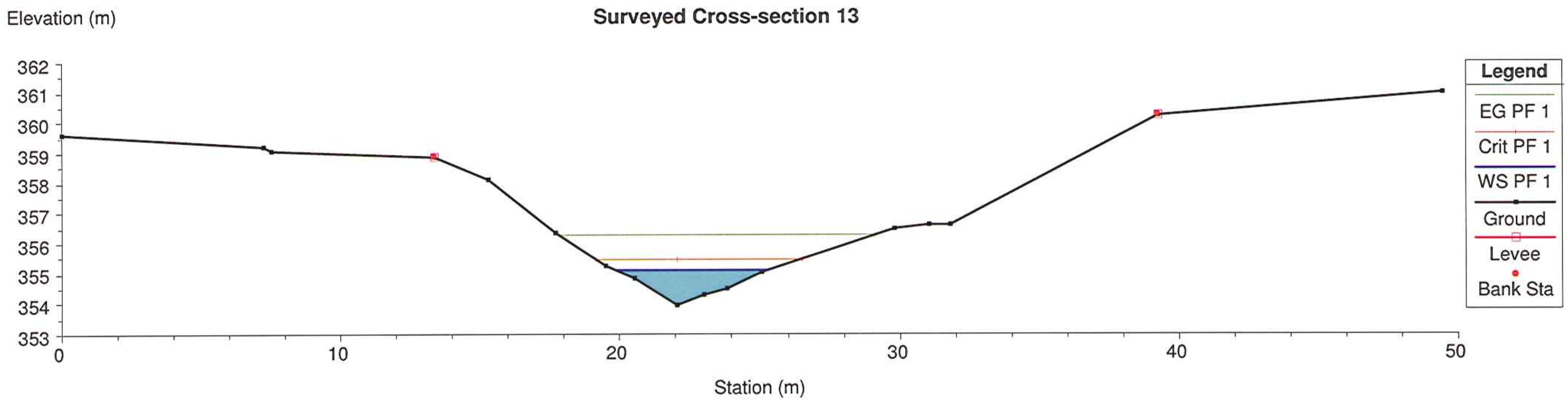
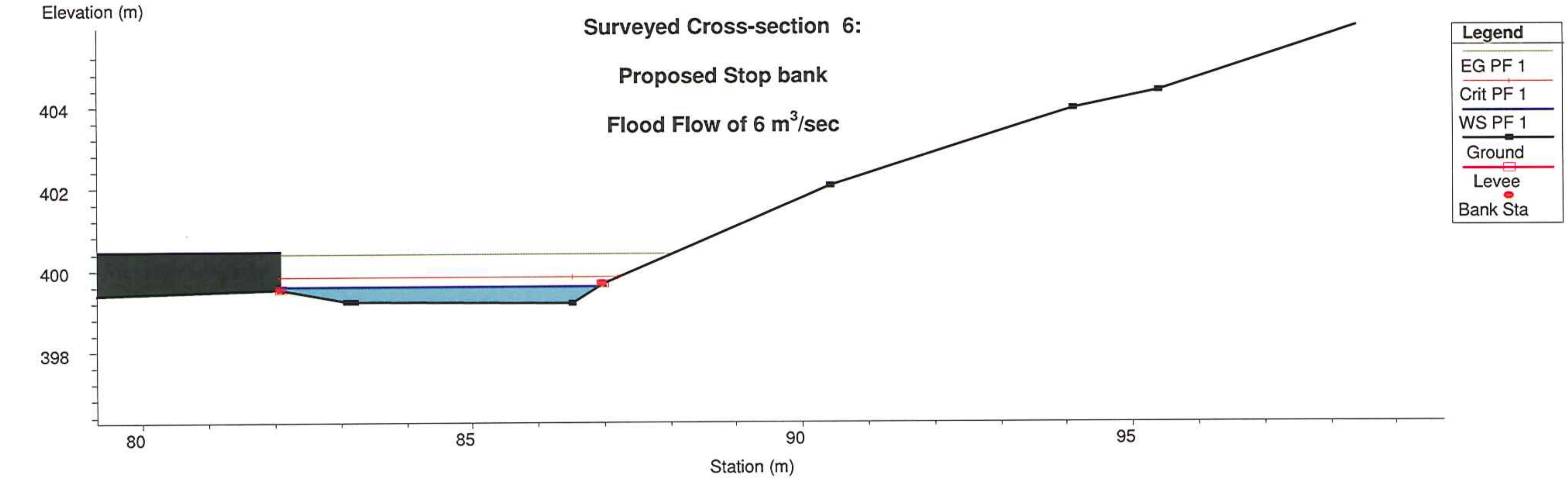

Surveyed Cross-section 13
Elevation (m)
362
361
360
359
358
357
356
355
354
353
0
10
20
30
40
50
Station (m)
Legend
EG PF 1
Crit PF 1
WS PF 1
Ground
Levee
Bank Sta

Figure 3: Water level at proposed Stopbanks – 6 m^3/sec and 19 m^3/sec flood events



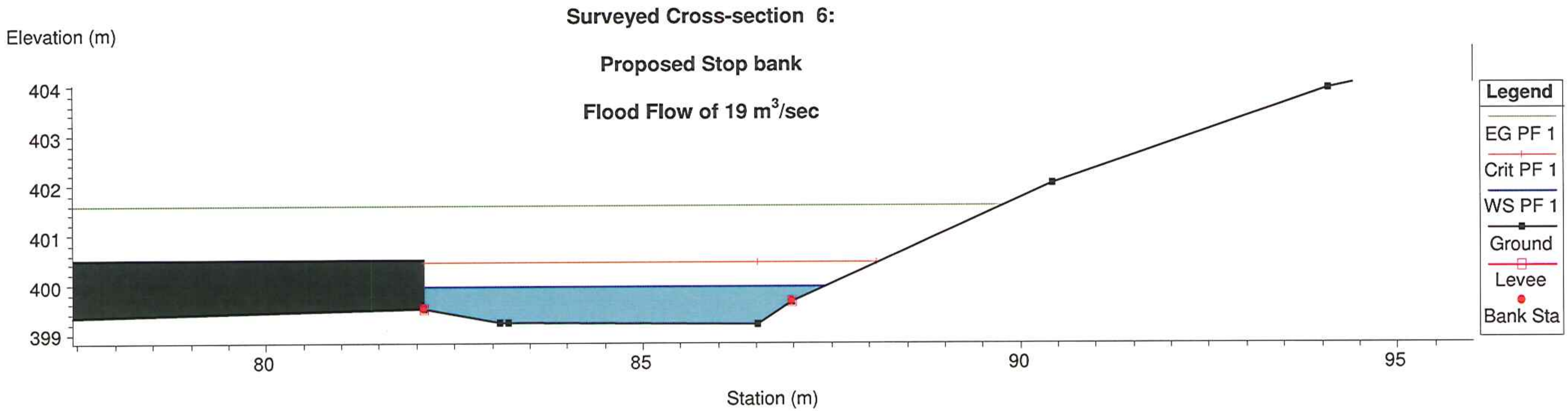
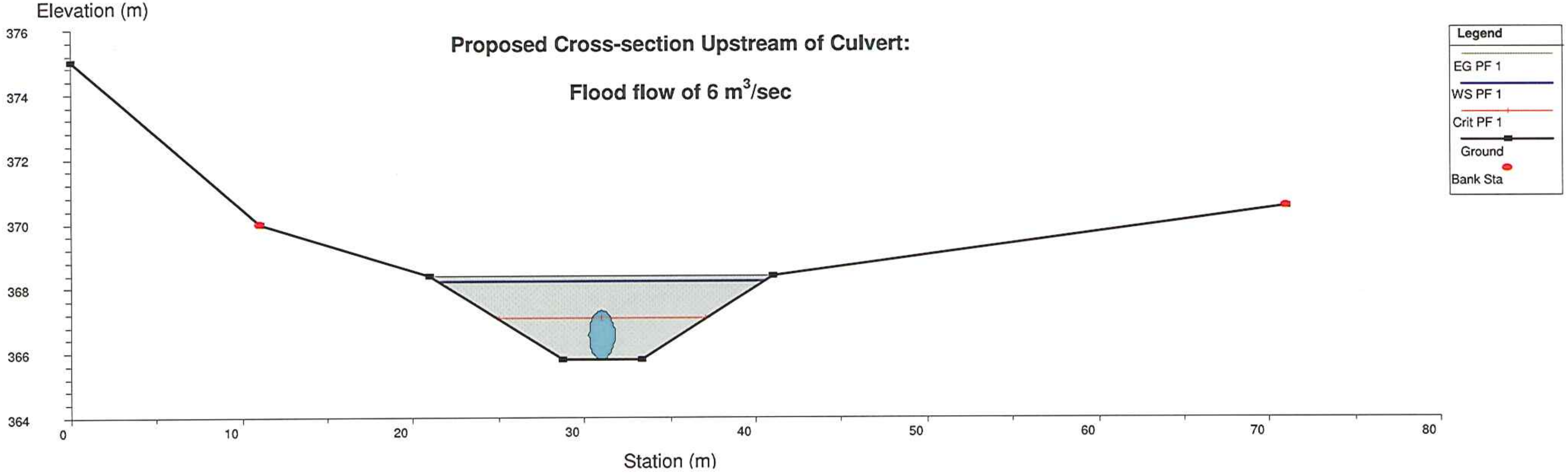


Figure 4: Water level at Proposed Road and Culvert – 6 m^3/sec and 19 m^3/sec flood events



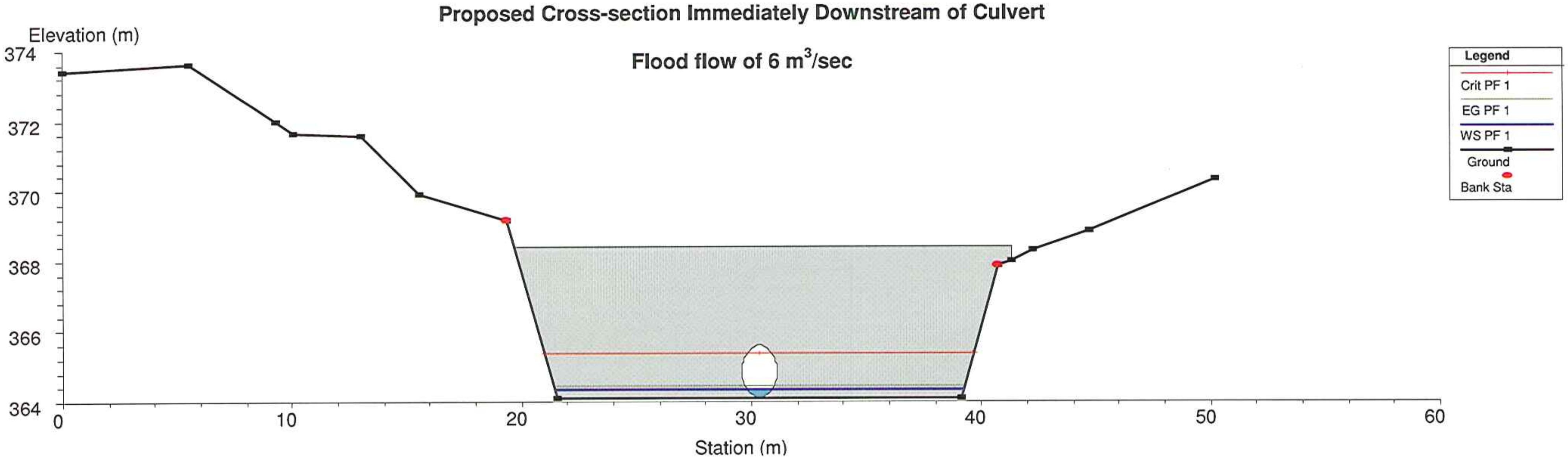
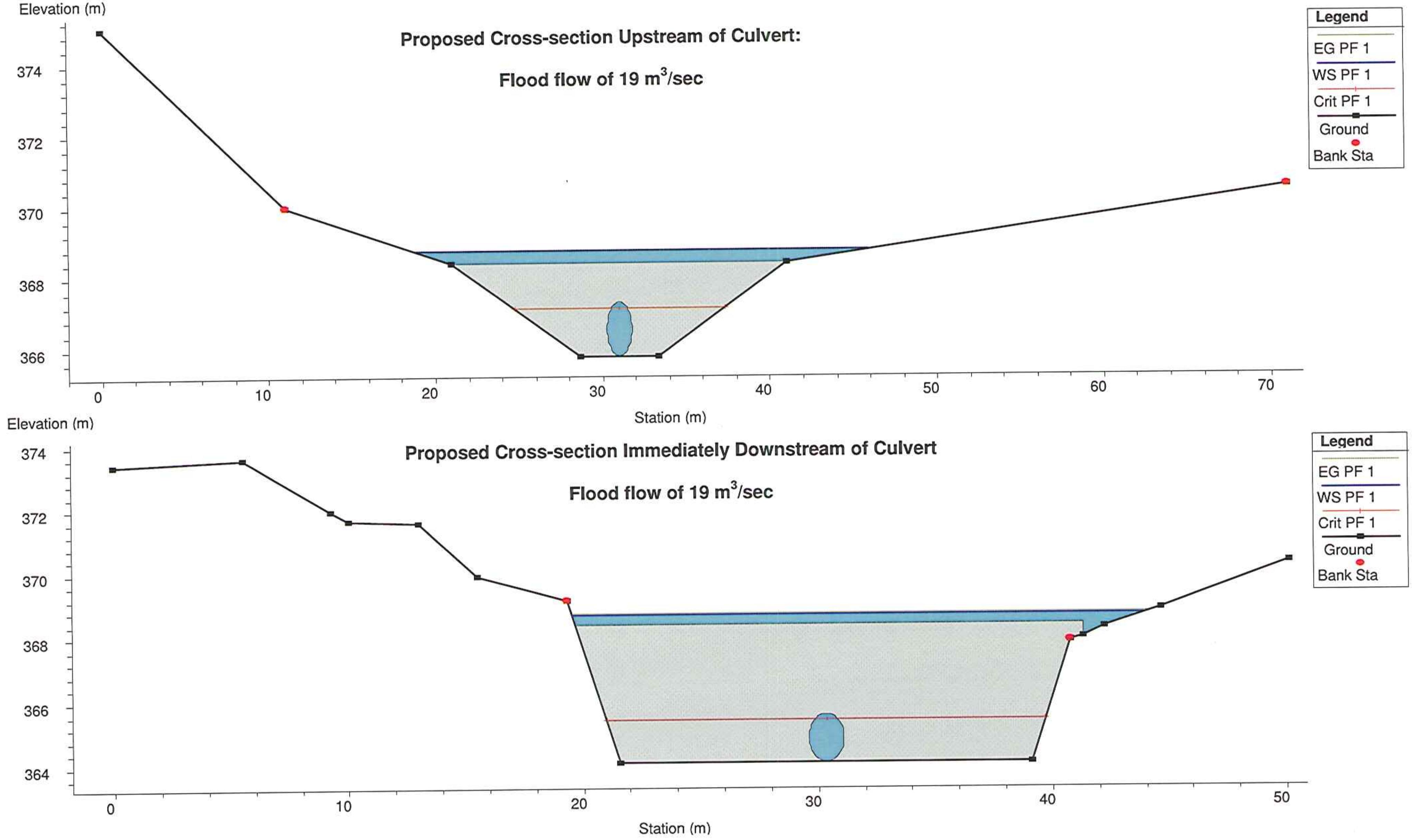
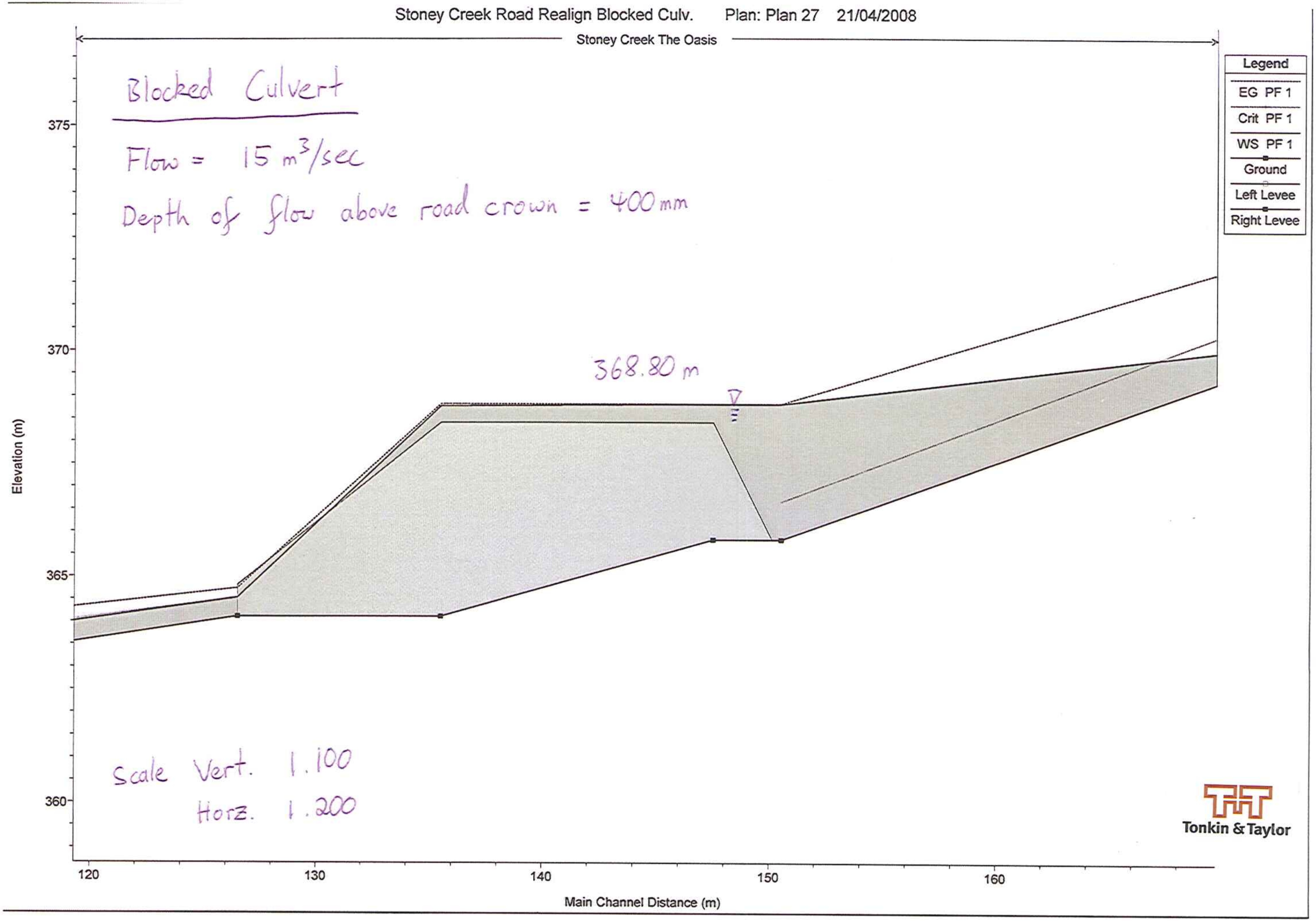


Figure 4: Water level at Proposed Road and Culvert – 6 m³/sec and 19 m³/sec flood events





Stoney Creek Road Realign Blocked Culv. Plan: Plan 27 21/04/2008
Stoney Creek The Oasis
Legend
EG PF 1
Crit PF 1
WS PF 1
Ground
Left Levee
Right Levee
Blocked Culvert
Flow = 15 m3/sec
Depth of flow above road crown = 400mm
368.80 m
Scale Vert. 1.100
Horz. 1.200
375
370
365
360
Elevation (m)
120
130
140
150
160
Main Channel Distance (m)
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