

memorandum

August 30, 2012

To: MTO Central Region, MTO Northeastern Region, Geotechnical and Operations

From: David F. Wood. P.Eng., David F. Wood Consulting Ltd.

Re: Rockfall, Hwy 403, Ancaster, 13 March 2012

Background:

Background information to this event was provided by MTO. A very detailed, nine-page, post-rockfall site visit 'photo report' was prepared by Steve Senior. No attempt has been made to duplicate this effort in the present report. About 3:30pm, Tuesday March 13th 2012, a piece of rock approximately 5 cubic metres fell from the face of the Niagara Escarpment. The rock fell into the rockfall catchment fence which prevented it from falling onto the highway below. The location of the fall is alongside the eastbound lanes of Highway 403 between the Lincoln Alexander Parkway and Aberdeen Ave.

The rock damaged the rockfall catchment fence; however the AMC responded and made some temporary repairs. The OPP, who also attended, requested that MTO staff review the fence and rock face. Lanes of traffic were temporarily impacted and closed by the OPP to allow a front end loader to move the rock from the fence. MTO's Steve Ferretti, who is familiar with the area and fence, attended the scene. The area was cleaned and temporary repairs were made to the fence, all lanes were opened by 6pm.

On a seasonal basis, rocks of various sizes fall from the face of the escarpment. The rockfall catchment fence is intended to protect the travelling public, while signs warning motorists of the potential for rockfall hazard are posted on the highway in this area. MTO staff and the AMC inspect the fence and the rock face regularly, cleaning up the area and removing rocks as required.

The following are some details about the existing rockfall catchment fence;

- the rock fence was constructed in 1999 and 2000 under MTO Contract 98-76, at an estimated cost of \$1.5M
- it is approximately 2.5m high and 1km in length,
- it was designed by the late Dr. John A. Franklin of Franklin Geotechnical Ltd. and manufactured by Brugg Wire Rope Technology, now Geobrugg
- the rock fence is designed to restrain large rocks that fall from the escarpment and reach the highway ditch thereby improving safety and reducing the risk of rock from entering onto the highway,
- when the fence was installed, limited machine scaling was carried out on adjacent areas of the face of the escarpment to clean off weathered and loose rock.

MTO operations staff with the assistance of MTO HQ and Regional Geotechnical Staff will review the fence for permanent repairs and the rock face to determine if any further cleaning of aging/loose rock is required.

Contractual Arrangements:

MTO NER arranged for David F. Wood Consulting Ltd. (Wood) to carry out a site visit and provide detailed design rockfall hazard mitigation recommendations for the Hwy 403 rockfall site referenced below under their existing Rockfall Hazard Retainer.

The scope of work is briefly described below. This assignment includes the emergency post rockfall incident review for the Niagara Escarpment on the south side of Highway 403 eastbound lanes. The location of the fall is along Highway 403 between Aberdeen Avenue and the Lincoln Alexander Parkway at LHR 48315/2.5 in the City of Hamilton within MTO Central Region. Photographs of the site were provided by the Ministry.

A large rockfall incident (totalling about 9 m³) occurred at this site on March 13, 2012, and a second smaller rockfall event occurred a few hundred metres to the east on March 21, 2012. There is a Geobruigg high-energy rockfall catchment barrier fence at this location (2 sections, ~1km length total) which prevented the rockfall material from impacting the travelled portion of the highway. Although contained by the fence, the fence was damaged and additional unstable rock was observed at the site that requires a detailed review over the 1km length of rockfall catchment fence.

The scope for services to be provided for this assignment is outlined within the terms of reference for this agreement. "The Service Provider shall provide detailed recommendations for mitigation of the rockfall hazards at the site, including item quantities, special provisions and marked-up photographs delineating work areas. These recommendations will be incorporated into a Contract Package by others. Note, marked-up photographs shall also be provided in a separate stand alone document for contract purposes."

Thursday 29 March 2012, joint inspection DFWCL and MTO:

During the 29 March 2012 joint inspection of the rockfall activity alongside the eastbound lanes of Hwy 403, Steve Senior (MTO) and Wood traversed the complete upper slope above the more eastern rockfall catchment fence installed in 1998. At the location of the 21 March 2012, the remnant material that fell from the face and remains on the upper slope is well in excess of the largest block that reached the highway in the 13 March 2012 event. There is one block wedged into the upper talus that is approximately 6 to 7 cubic metres in size. There are numerous locations along the bluff where relatively recent rockfall events have occurred, although the majority of these do not involve such large blocks of rock as the two most recent events. It is inevitable that there will continue to be rockfall events from this bluff, and "removing" the hazard may not be practicable.

However, the rockfall catchment fence at highway level "did its job" and prevented approximately 70 metric tonnes of dolostone from reaching the highway and creating a hazard to the travelling public. Wood's initial recommendation was to reinstate the existing fence as best as possible in the short term and carry out a more detailed rockfall evaluation as part of a longer term strategy that might involve replacing some of the fence with a more modern design, with a higher capacity and probably taller posts (two such fences have been installed in recent years at locations in Northwestern Region in which Wood has been involved as designer.) It would be important to generate some sort of Digital Terrain Model to cut sections and carry out some computer simulation analyses to confirm or refute the adequacy of the existing design. From our full traverse, we could not identify any specific blocks that are likely to fall and overpower the existing

fence, even though there are many places where cracked blocks and undercut overhangs, etc. are visible.

After the joint site inspection today, Wood returned to the site to carry out a more detailed evaluation of the Geobrugg fence. Wood started at the upper (west) end of the lower (east) fence and worked downhill, towards the east. While carrying out this review, the TWD maintenance crew stopped by to tighten the come-along connecting two posts at the location of the 13 March 2012 fall.

There are 56 posts in this section of the fence that are nominally spaced 7.6 to 7.7 metres apart. This would most likely correspond to an Imperial design of 25 feet (although this dimension was not apparent on the drawings provided.) At each post location, Wood measured the distance to the next post, checked to see if the back anchor was properly fixed, checked the tension of the back cable (taut, slack, very slack or very, very slack), measured the angle from HI standing at the base of the post to the crest of the slope, noted where there were lateral anchors, commented on the amount of rocks in the ditch to the next post, identified locations where rocks had struck either the post or the fence, observed the limits of the overhead power lines, noted where braking elements appeared to have been compromised, and estimated the total volume of material involved in the two most recent rockfall events.

The attached Excel file is an "inventory" of the lower fence and may assist in identifying locations of future rockfall events. It is suggested that some metal plates be made up with identification numbers that can be permanently fixed to the galvanized posts so that maintenance workers can easily locate themselves along the fence line. I would also strongly recommend that "rockfall incident reports" be generated not just for the recent falls, but for others that have occurred in the past for which there is still local knowledge regarding location, volume, etc.

It is the professional opinion of Wood that the rockfall catchment system in place along this stretch of highway will provide continued service in restraining rockfall activity and thereby reducing the rockfall hazard to the public.

Thursday 12 April 2012, joint inspection DFWCL, Geobrugg and MTO:

A second meeting was held on site with Wood, MTO and Mr. Joseph Bigger, Geobrugg, to review the earlier findings and to gain insight from the manufacturer of the rockfall catchment fence which was installed in Contract 98-76, WP 166-88-00. There are a number of phases for remedial work that are required to provide continued rockfall protection and diligent security to the travelling public. The work program discussed involved Phase 1 – Repair the existing fence, Phase 2 – Reinstall the existing fence, and Phase 3 – Confirm the appropriateness of the design of the existing fence. Phase 1 is detailed below; Phases 2 and 3 are included in the Options presented below.

PHASE 1. Repair the existing fence. The AMC needs to remove the Come-Alongs being used to hold the top rope in place now that the upper braking elements have been activated. They should be replaced with a new length of approximately 15 metres of 19mm top rope with a braking element installed. Two replacement upslope retaining ropes with braking elements are also required (these can be used in the short term from the extreme east end of the existing fence where they have been disconnected for access – they should be replaced eventually.) Further supplies include about 20 metres of 8 mm lacing cable to attach the fence mesh and chain link mesh to the top rope. The new top rope will be spliced to the old rope using the method shown in the Contract Dwg's supplied by Geobrugg (Cont No 98-76, WP 166-88-00, Sheet 26, "Splicing wire rope detail" with eight (8) wire rope clips each end). Geobrugg will need to prepare a Method Statement to remove and replace the components noted above. Some rock will need to be removed from the lower part of the fence. It is noted that the replacement upslope retaining ropes can be installed over top of the large rock blocks currently lying within the catchment area.

Thursday 28 June 2012, joint inspection DFWCL, TWD and MTO:

The TWD representative, André, noted that all Phase 1 and parts of Phase 2 work had been carried out:

- Two anchor cables and braking elements from “The Cascades” area at the extreme east end of the Geobruigg fence were used to repair the fence where damaged by the 13 March 2012 rockfall event.
- One rockfall catchment panel and two panels of chain link mesh were also replaced; this is considered part of Phase 2.
- Geobruigg supplied additional braking elements and also hog rings to attach the system.

It was determined that additional work would be required at the 7th and 8th posts from the north end (#50 and 51 in the table at the end of the text), as follows:

- Pole #7 needs the braking element replaced and the pole needs to be re-anchored,
- Pole #8 needs to have the rear cable re-attached, and
- Two large rocks need to be pushed back into the ditch away from the fence.

This remedial work will complete the minimum requirement to allow the fence to operate basically as designed.

Rockfall Hazard Reduction Options

With most inspections following rockfall events, the site is relatively limited in size and the rockfall is commonly a result of a gravity driven failure of a mass of rock bounded by well defined discontinuity planes. Under these circumstances, remedial work is relatively easily defined, item quantities can be estimated with a fair degree of certainty, special provisions can be prepared with minor revisions to existing specifications, and the areas for work can be clearly marked on site photos.

It appears likely, however, that letting a contract to mitigate rockfall hazards at this site will not be a straightforward activity. Rather than attempting to provide the specific deliverables that would be very difficult to administer, I am proposing a range of engineering options for this area that can be discussed and reviewed by all concerned.

Option 1 – Do Nothing

Under this option, it would be assumed that the high energy rockfall catchment fence installed in the late 1990s is still functioning as designed and protecting the travelling public from rockfall hazards. This is, indeed, what occurred this spring. The costs associated with this option relate to maintaining the existing fence, purchasing spare parts as required, attending to repairs of the fence as needed, and providing appropriate traffic control when work is being planned. It should be remembered that working below the fence is considered working in a known rockfall hazard area and suitable protocols should be observed.

Normally, the “Do Nothing” option has a residual risk, commonly quite profound, that needs to be accepted. The only risk I see at the present time for this site is if the fence is “over-powered” by a rockfall event of a larger size than the fence is designed for.

Option 2 – Carry out detailed rockfall hazard reduction measures

In order to reduce the current hazard (it should be noted that the Ministry currently expresses ‘hazard’ as a high probability of rockfall material landing on the shoulder and travelled portion of the highway, which is not necessarily the case when a catchment fence is installed) then some removal of loose rock near the crest of the slope should be carried out. As noted above, this will

probably require coordination with the Niagara Escarpment Commission, understood to have some restrictions and/or controls on physical work carried out on the rock face.

It is estimated that a rock scaling program would require a crew of 4 scalers and a foreman about three weeks of work at 10 hours per day to scale rock from the source areas of the two rockfall events and locally elsewhere along the crest between these two occurrences, see images at end of memorandum. Although there were a few small rocks in the ditch between Pole #1 and Pole #20, the crest in this area did not appear to be in a critical condition. The site geometry includes a sub-vertical crest face (the source of the rockfalls) with a talus and overburden slope below that extends to the back of the ditch at highway level. The angle of this slope allows some material to roll and bounce towards the highway, while retaining other material on the slope. A complete scaling exercise of the complete crest area and 'chasing' the scaled rock right to the highway level would take months to complete and the whole point of the rockfall catchment fence is to preclude the need for such extensive programs by protecting the public at the toe of the slope. Instead of this, the estimated 750 man hours of work would concentrate at the source areas of the two 2012 rockfall events and small areas in between as shown in the images at the end of this memo.

Estimating crew time for scaling is by no means a rigorous process. Sometimes a block of rock of many cubic metres in size will be dislodged with very limited effort, whereas at other times, a small block needs to be worked at for a considerable period by two scalers to eventually be brought down. It is also challenging to estimate volume quantities of rock to be scaled. Commonly rocks behind the loose surface material may also be somewhat loosened, but may not need to be scaled.

Images 1 through 6 show the 13 Mar 2012 event (Poles # 20 to 22 on the catchment fence) and the area at the crest as well as the slope and the ditch area. Image 3, for example, shows where an air bag would likely be used. A total of about 15 cubic metres of rock could be removed from this area. Images 7 through 12 show the 20 Mar 2012 event (Poles #48 to 50) immediately south of "The Cascades" (about Pole #53). A further 5 to 10 cubic metres could be removed from this area, including the large rock block 'stuck' on the slope shown in Image 9. Images 13 through 17 show crest conditions between Pole #50 and 20, and represent small areas where local manual scaling and air bag removal would be considered appropriate. An estimated 4 to 6 cubic metres of rock could be removed at each such location. Image 18 shows voids immediately to the south of the 13 Mar 2012 event which could be addressed with air bag technology, while Image 19 shows the damaged slope where one of the larger rocks rolled and tumbled to the ditch. This block moved with its long axis parallel to the slope and each time it rolled over, the edge marked the damp ground.

This estimate would not include traffic control, removal of scaled rock or other debris from the ditch, or incidental repairs to the fence. It is noted that the initial recommendation was to carry out slope work before repairing the fence, since some 'collateral' damage should be anticipated. Together with normal scaling equipment, it is recommended that the scaling contractor arrive on site prepared to use "air bag" technology to bring down large masses of rock.

The cost for this type of scaling exercise, including mobilization and demobilization is estimated to be in the order of \$87,500. It is anticipated that "others" would be in charge of traffic control, any ditch clean out deemed necessary, fence reinstatement, etc. The costs for this part of the program are not known.

Option 3 – Carry out complete reinstatement of Existing Fence and Confirm Design

This option should be carried out in tandem with other proposed work at the site. Option 3 is made up of Phases 2 and 3 of the discussions held on Tuesday 12th April 2012.

Option 3a, PHASE 2. Reinstall the existing fence. At some point in the near future (not under "Emergency" conditions) two of the Geobruigg fence panels and chain link mesh will need

to be replaced. This will require new top and bottom ropes with braking elements as originally designed (estimated to be 30 metres long). One post and its foundation will also need to be replaced. This is for the first rockfall event area. It appears that reinstating the fence at the location of the second rockfall event will only require one upslope retaining rope with braking element (also available from the extreme east end of the fence), one wire rope clip and one shackle. The fence itself and posts have not been damaged too badly.

This work will also require moving some of the rock debris currently 'behind' the fence. It would be highly prudent to sub-contract slope work to one of the rope-access companies that we have been dealing with over the last few years (Pacific Blasting, BAT Construction, or Janod) to have them spend some time along the crest of the slope carrying out hand scaling of the escarpment and preparing for air bag removal (or similar) of the large mass of rock just to the west of the source area of the first rockfall event this spring. It would be unwise to fully reinstate the fence prior to carrying out rock removal, since there is a very good chance that the fence would be further damaged during scaling. The basic premise would be that the maintenance contractor would be preparing to carry out the complete removal of at least two panels of fence at the highway level while the scaling contractor was working along the crest from the east end.

It is likely that the largest mass of rock to be removed will be at the west end of the first rockfall event, and it appears that there could well be a further 15 cubic metres (40 tonnes) of rock that could be brought down. This will require a full closure of Hwy 403 – in both directions.

Preparations for this will take some time as the site is readied for the air bag work. Once the major mass has been removed and any rock cleared from the highway, the traffic can be allowed to pass and a careful review of the upper slope will be carried out to determine whether any further rock needs to be removed. It is strongly recommended that Ministry personnel discuss this project at great length with the Niagara Escarpment Commission to ensure that we are conforming to their regulations.

Once the rock has been brought down to highway level, it is recommended that the catchment area 'behind' the fence be completely cleaned out as the fence is being reinstated. If the maintenance contractor were to work from the west towards the east, once the west area was cleared out, the first part of the fence reinstatement can be undertaken, and once the complete catchment is cleaned, the second part of the fence reinstatement can be completed. However, it is also recognized that attempting to remove all rock from behind the fence could lead to further damage to the fence infrastructure. Some removal using a 'clam shell' bucket and crane over the top of the fence may work, but there is also some benefit to be gained by leaving rockfall material behind the fence as an additional barrier or berm.

Option 3B, PHASE 3. It is strongly recommended that the Ministry obtain detailed high definition photography, thermal imagery and LiDAR coverage of the area to permit a new rockfall hazard evaluation to be carried out to ensure that the 500 kJ fence is appropriate for the current hazard. I include communications from Dr. Dave Gauthier, post-doctoral fellow at Queen's University on this issue (see Appendix). Once we have some accurate topographic and rock mass information, it would be possible to carry out some computer rockfall simulations using back analysis of the recent events to provide accurate and realistic input parameters for a modern review of the catchment fence design.

Option 4 – Excavate to Full Clear Zone Width

This is commonly an option for rockfall hazard remediation on projects where the rock face is immediately adjacent to the highway. By definition, full clear zone width ditches will retain all rockfall material and prevent any material from spilling across the shoulder onto the travelled lanes. In the situation on Highway 403, there is very little chance that any additional excavation near to the highway could ever be contemplated, and this option is not considered worth developing.

Discussion, Conclusions and Recommendations:

Once the minor work mentioned in the sections above is completed, the rockfall catchment fence alongside Hwy 403 in this area will continue to function basically as designed. It is recommended that a full rockfall catchment fence design be carried out using current, state-of-practice design methods, once a detailed topographic model has been generated. It may end up that the current fence is adequate and the hazard is controlled by the presence of the catchment fence.

However, no specific work has yet been carried out to reduce or mitigate the rockfall potential. Work on the escarpment face above the highway would include removal of brush and vegetation, manual scaling (with ropes and bars, air bags, etc.); it is unlikely that trim blasting or rock bolting would be effective in reducing the rockfall hazard. Regardless, consultation with the Niagara Escarpment Commission will be required to determine if removal of the rockfall hazard could be considered the most appropriate solution to the ongoing situation.

As has been noted in past rockfall event reviews that the solutions available to mitigate the hazard usually fall into four categories: remove, reinforce, provide catchment, and warn. Removing the problem rock is commonly the first category selected. For most Ontario highway rock cuts machine scaling, either by hoe ram or backhoe excavator, is commonly the preferred alternative. Far less commonly, but more effectively for high rock faces set back from the highway platform, manual scaling using crews with 5-point fall arrest harnesses and ropes may be used. At the present time, Occupational Health and Safety Regulations require "a two-rope system" for manual scaling, and there are limited contractors set up for this work.

During the Thursday 29 March 2012, joint inspection by Wood and MTO's Senior, it was noted that inevitably there will continue to be rockfall events from this bluff, and "removing" the hazard may not be logical, practical or plausible. Not only would it be very challenging to start at the extreme crest and work down the slope in panels with crews working from ropes (the only realistic way to scale the bluff), but the end result would likely be unacceptable to the Niagara Escarpment Commission since the slope would be essentially denuded of all vegetation and the overall slope would end up having a very different appearance from its current condition. A limited and focussed program as outlined above, however, may be appropriate to reduce the existing rockfall potential, without necessarily changing the hazard.

Since reinforcing the hazard using rock bolts, cables, straps, or other restraints would also be complicated for this site, the notion of providing adequate catchment for potential future rockfall events appears to be the most appropriate long-term solution to the rockfall hazard. If this is the direction that the Ministry would like to follow, then a detailed rockfall simulation process would need to be undertaken.

It is also noted that at the present time, none of the rockfall material that has accumulated behind the fence has been removed. Until such time as a complete scaling review has been carried out along the Escarpment, which would require the approval of the Escarpment Commission, and all previous rockfall material disposed of, it will be impossible to state that the rockfall hazard *per se* has been reduced.

Appendix 1 to this memo shows some comments regarding one method of assessing the ground conditions remotely. Appendix 2 gives two Non Standard Special Provisions that might assist in administering a contract.

Currently, the accumulated piles of rockfall material can act as barriers or part of a berm to restrict other falling rock from reaching the highway and potentially damaging the fence. We need to enter into negotiations with the Niagara Escarpment Commission to determine how best to proceed with further remedial work. The specific restrictions to scaling work along the escarpment, or limitations regarding timing of work, or working limits, etc. need to be determined

before detailed plans can be made to carry out further rock removal along the crest area, if so allowed.

Respectfully submitted:
David F. Wood Consulting Ltd.

David Wood, P.Eng.
President

Post #	Distance to next	Back anchor		Angle to crest*	Rocks in ditch	Shape	Lateral anchor	Power lines
		Fixing	Tension					
1	7.7	OK	slack	29.5	0			
2	7.6	OK	taut	30.1	0			
3	7.5	OK	slack	28.6	0		1	
4	7.5	OK	slack	28.6	0	Km 66.4	2	
5	7.7	OK	v. slack	29.7	0		1	
6	7.7	OK	v. slack	29.8	0			
7	7.5	OK	taut	29.9	1x20cm	block		
8	7.6	OK	taut	29.7	0		1	
9	7.6	OK	taut	30.7	0		2	
10	7.6	OK	taut	30.7	1x20cm	block	1	
11	7.7	OK	taut	31.0	0			
12	7.6	OK	taut	30.9	0			
13	7.6	OK	taut	31.6	1x20cm	block	1	
14	7.6	OK	v. slack	32.8	1x20cm + 1x40cm	block	2	
15	7.6	OK	v. slack	30.9	0		1	
16	7.6	OK	slack	34.2	0			
17	7.6	OK	v. slack	34.2	0			
18	7.7	OK	v. slack	33.8	2x40cm	slab	1	
19	7.8	OK	v. slack	34.6	0		2	
20	7.6	OK	v. slack	34.1	A+B 13Mar12	block	1	
21	8.1	OK	brake	34.3	C 13Mar12 ++	block		
22	7.1	OK	brake	34.1	D 13Mar12 ++	block		
23	7.7	OK	v. slack	34.7	0		1	
24	7.7	OK	v. slack	32.7	0		2	√
25	7.7	OK	slack	33.9	0		1	√
26	7.6	OK	slack	34.2	.25m ³ in 5 pieces	slab		√
27	7.7	OK	taut	32.3	0			√
28	7.6	OK	v. slack	32.7	0		1	√
29	7.7	OK	v. slack	32.7	0		2	√
30	2.5	OK	v.v. slack	31.7	0		1	√
31	7.7	OK	v.v. slack	31.5	.25m ³ in 5 pieces	block		√
32	5.2	OK	slack	28.9	.1m ³ in 3 pieces	block		√
33	7.7	OK	slack	33.2	.1m ³ in 4 pieces	block		√
34	7.7	OK	v.v. slack	34.2	.5m ³ in 5 pieces	block	1	√
35	7.5	shackle?	v. slack	34.1	1x50cm + small	block	2	√
36	7.6	shackle?	v. slack	31.7	0		1	√
37	7.7	OK	v. slack	34.6	.1m ³ in 12 pieces	slab		√
38	7.5	OK	v. slack	35.3	.25m ³ in 12 pieces	block		√
39	7.5	OK	v.v. slack	37.5	.25m ³ in 7 pieces	block		√

41	7.6	OK	slack	37.8	.1m ³ in 6 pieces	block	2	
42	7.5	OK	slack	37.8	.01m ³ in many bits	block	1	
43	7.6	OK	slack	36.0	few pieces	slab		
44	7.6	OK	v. slack	36.3	1x20cm	block		
Post #	Distance to next	Back anchor		Angle to crest*	Rocks in ditch	Shape	Lateral anchor	Power lines
		Fixing	Tension					
45	7.7	OK	v. slack	35.8	1x30cm	block	1	
46	7.5	OK	slack	35.7	0		2	
47	7.7	OK	slack	34.6	0		1	
48	7.5	OK	v. slack	35.3	W block 21Mar12	block		
49	7.6	not attached		34.7	E Block 21Mar12 +	block		
50	7.5	OK	brake	34.6	2x30cm	block	1	
51	7.7	OK	slack	34.2	0		2	
52	7.7	OK	brake	34.0	0		1	
53	7.7	not attached		29.8	0			
54	7.9	not attached		32.6	0			
55	7.8	not attached		32.0	0			
56		not attached		31.6			1	

* Crest angle from HI (1.73m) at base of fence, approx 2.8 m above ditch at 4.2 m offset

post struck by falling rock, or fence has strike mark from rockfall activity

Block A	~1m ³	2.7 tonnes	13-Mar-12
Block B	~4.5m ³	12.15 tonnes	13-Mar-12
Block C	~5m ³	13.5 tonnes	13-Mar-12
Block D	~4m ³	10.8 tonnes	13-Mar-12
W block	~4.5m ³	12.15 tonnes	21-Mar-12
E block	~3.5m ³	9.45 tonnes	21-Mar-12

Total volume ~26m³, amounting to ~70.2 tonnes of blocky rock



Image 1. View of source of 13 Mar 2012 rockfall event from below crest of Niagara Escarpment. (Image date – 29 March 2012)



Image 2. Close up image of source area. Rockfall came predominantly from intact band of rock in lower middle of image. Piles of rock above do not appear to have been involved. (Image date – 29 March 2012)



Image 3. Void to right of source area in Image 2, isolates approximately 7 cubic metres of loose rock. Approximate total rock to be removed in this area is 15 cubic metres.



Image 4. View towards highway from source of main rockfall event 13 March 2012.
(Image date – 29 March 2012)



Image 5. Appearance of slope in late June, in full vegetation. (Image date – 28 June 2012)



Image 6. Accumulated rockfall material from main event, 13 March 2012. (Image date – 29 March 2012)



Image 7. Overview of second rockfall event, 20 March 2012 to just west of “The Cascades”. (Image date – 29 March 2012)



Image 8. Looking upslope from highway ditch to second rockfall source. (Image date – 29 March 2012)



Image 9. Close-up of second source area, note failed material still on slope. (Image date – 29 March 2012)



Image 10. View of highway from source of second rockfall event, 20 March 2012. (Image date – 29 March 2012)



Image 11. Close-up of crest of failed area, upper left in Image 9. (Image date – 29 March 2012)



Image 12. Typical crest conditions in rock formation that failed, adjacent to second event. (Image date – 29 March 2012)



Image 13. Similar cracking seen to west of second failure area. Same geological formation. (Image date – 29 March 2012)



Image 14. Friable inter-bed allows more competent overlying rock mass to fail. (Image date – 29 March 2012)



Image 15. Same geological sequence to west with similar failure style to Image 13. (Image date – 29 March 2012)



Image 16. Displaced block near crest that appears to be relatively stable! (Image date – 29 March 2012)



Image 17. Fresh looking talus pile below failed rock just to east of power lines. (Image date – 29 March 2012)



Image 18. Voids in rock mass immediately adjacent to first rockfall event. (Image date – 29 March 2012)



Image 19. Strike mark on slope below main failure, indicating that the long axis of the block was parallel to the slope and that the slope materials were saturated at the time of failure. (Image date – 29 March 2012)

Appendix 1 Remote data collection:

Seehawk Inc. operates an unmanned aerial vehicle (UAV), which flies autonomously and collects imagery and other data using on-board sensors. The UAV itself is very small and light (2m wingspan), has no red-tape associated with its deployment, and performs very short take-offs and landings. It is launched by hand, and lands in any small clear area.

Digital Imagery: The main sensor is a high resolution digital camera for aerial photography. Pixel size is as small as 3mm from typical flight altitudes (100m), which is more than adequate for rock hazard work in most cases. The photos are geotagged with a high-precision gps unit, and can be stitched to form seamless coverage. The application to the 403 rock fall area would be to collect detailed images of the crest area and upper face, to enable us to characterize the rock mass and identify any tension cracks or other signs of imminent failure from the most useful vantage point. Helicopter would be the only other way to capture these images; this would be difficult given the proximity of the site to the highway and to the HV lines, and of course the photos would not be geotagged if we taking them obliquely.

Thermal Imagery: The UAV can also carry a thermal imager for infrared thermography. The images are false-coloured for temperature with very high precision (relative temperature from place to place). These images would be geotagged as per the photographs. There is on-going research at Queen's University in applications of infrared thermography to rock fall problems (e.g. loose block detection, groundwater discharge points, freeze thaw cycling). For the Hwy 403 project I think the loose block detection and identifying seeps would be the primary goals.

LiDAR: Sometime in the coming months the Seehawk UAV will be equipped with a LiDAR sensor, allowing it to collect very high resolution airborne LiDAR data. Compared to helicopter-based systems this will be very inexpensive, very high resolution, and able to collect data in difficult terrain in a very short time. It may also be able to scan faces obliquely in order to reduce the occlusion issues that are common in steep ground scanned from a conventional aircraft.

All of these surveys are completed the same way: they plot a flight path and a set of data collection instructions into the on-board computer, launch the UAV, and it does the rest autonomously. It actually beams the data back to the base station as it's scanning, in near real-time. If it gets in trouble it finds a place to land and sends its coordinates to the base so they can find it.

Seehawk can do the digital photography within about 2 weeks, but they are quite booked for thermography for about the next 6 weeks. The LiDAR will be deployed for its initial flights within about a month. Approximate costs are on the order of \$600/km plus mob to the site for the photography, similar for the other sensors.

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ROCK EXCAVATION (MANUAL SCALING) - Item No.

Non Standard Special Provision

September 2012

Scope

Work under this item is for the complete removal of loose rock material by appropriate manual scaling at locations indicated in the contract and redistribution of the scaled rock material behind the existing Geobrugg rockfall catchment fence.

Construction

The work unit shall consist of the following:

A work crew consisting of at least four scalers completely conversant with scaling at heights using rope access methods in accordance with OHSS regulations.

Tools and material needed for the efficient performance of the work.

Manual scaling shall mean all authorized work by the manual scaling crew including scaling, grubbing, sounding, trimming with hand-tools and hand-held machine tools, as well as minor blasting with a small quantity of explosives. Manual scaling shall also include the use of air bags designed for rock removal work.

Manual scaling shall be undertaken from the top of the rock face down to ensure that at no time the scaling crew is working beneath loosened or undercut sections of the rock face.

The scaling crew shall be in full-time radio contact with the foreman to permit direct and immediate control.

The rock face shall be inspected by the scaling crew at the start of each working day to identify rock that requires immediate removal so as not to endanger the workers.

The rock face shall be inspected by the scaling crew to ensure that loose rock that may endanger the travelling public has been removed prior to shutdown.

All material resulting from the operation shall be re-distributed within the area near to the existing rockfall catchment fence to act as a barrier against future rockfall events without compromising the drainage capacity of the ditch.

All costs associated with the management of materials are deemed to be included in the contract unit price.

Measurement for Payment

The measurement for payment shall be by the hour and only for the time in which a minimum of four scalers are in effective operation.

Time for the management and disposal of materials shall not be considered as effective operation.

Basis of Payment

Payment at the contract price for this item shall be full compensation for all labour, equipment and material required to do the work.

WARRANT: Always with this tender item.

ROCK EXCAVATION (AIR BAG) - Item No.

Non Standard Special Provision

June 2010

Scope

Work under this item is for the removal of loose rock material from the rock face using appropriate airbag technology at locations indicated in the contract, and disposal of the rock material.

Construction

Lifting Equipment shall consist of the following:

A two person man-lift, crane, or other suitable equipment, capable of accessing existing rock faces up to 15 metres in height.

Airbag rock removal shall utilize small air bags that can be placed within cracks in the rock mass that are between 25 and 50 mm aperture. Once the airbag is securely located within the crack, the bag is connected to a compressed air supply providing an air pressure of at least 500 kPa (70 psi). The pressure shall be maintained to fill the airbag and then provide a relatively uniform force to push the rock apart at the crack. Removal of loosened rock shall be carried out in such a manner to minimize disturbance to any surrounding rock beyond the planned limits.

All material resulting from the operation shall be managed in accordance with OPSS 180.

Measurement for Payment

The measurement for payment shall be by Plan Quantity, as may be revised by Adjusted Plan Quantity of the number of man hours required to remove rock using the airbag technology.

Basis of Payment

Payment at the contract price for this item shall be full compensation for all labour, equipment, and material required to do the work.