1. BOREHOLE LOGS
2. Guard rails.
3. Digital files — auto cad ....
4. Asphalt thickness low. 70 mm

REPORT

**December 2013**

## OPG NIAGARA PLANT GROUP

# Glen Access Road/North SAB1 Tailrace Road - Investigation and Recommendations for Road Upgrade

TO FIND :
1. CITY STANDARD
2.

**Submitted to:**
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12:20 - 2:30 next Wednesday.



# 1.0 BACKGROUND

In response to a request by Ontario Power Generation (OPG), Golder Associates Ltd. (Golder) prepared a proposal to provide engineering services for a long term slope maintenance program for various sites within the Niagara Plant Group (NPG), including Area 1 (Glen Access Road), Area 2 (between Sir Adam Beck 1 (SAB 1) and SAB 2), Area 3 (North of SAB 1), and Area 4 (DeCew). In particular, two work packages, in Areas 1 and 3 (see Figure 1, following the text of this report), were to include the following:

- Area 1, WP 1D, Glen Access Road Upgrade;
  - a drilling investigation to determine the road bed material;
  - a GPS survey of the Glen Access Road (centreline and road edges);
  - a site visit and recommendations for gravel road upgrade; and
  - recommendations for road pavement design (pavement thickness design, recommendations on pavement material and drainage, and construction recommendations).
- Area 3, WP 3, SAB 1 Tailrace Road Upgrade;
  - a GPS survey of the SAB 1 Tailrace Road (centreline and road edges);
  - a site visit and recommendations for road upgrade;
  - preparation of a topographic map of the SAB 1 Tailrace Road;
  - preparation of a plan view of the road showing layout of security fences; and
  - preparation of a plan view and cross sections of the upgraded road surface, alignment and drainage

Permission to proceed with the work was provided with Purchase Order # 4400035894, dated February 27, 2012.

This report gives the results of the related investigation for WP 1D and WP 3. In broad terms, the geometric design and pavement design, together with a discussion of drainage, is given for both the Glen Access Road and the SAB 1 Tailrace Road. The investigation results for the remaining work packages are provided in a separate Golder report.

This report should be read in conjunction with "Important Information and Limitations of This Report" included in Appendix A. The reader's attention is drawn specifically to this information as it is essential for the proper use and interpretation of this report.

# 2.0 GLEN ACCESS ROAD

The Glen Access Road begins at its intersection with the Niagara Parkway at approximately 657855 m E, 4777186 m N, then runs northward in a sidehill cut through a gate (Gate 14) at approximately 658138 m E, 4777542 m N, to a chain link fence and gate (Gate 13) at the tailrace of SAB 2 at approximately 659101 m E,

4778559 m N. To the west of the road lies the Niagara River cliff face up to the Niagara Parkway; to the east of the road is the continuation of the cliff down to the Niagara River. Over a length of approximately 2.0 km (6600 ft), the road drops steadily through approximately 115 m (380 ft) in elevation, at an average gradient of 4%, and a maximum gradient of 8%. It has a crushed rock surface, and although narrow, carries two-way traffic. The road has one significant horizontal curve, and a few other more gentle curves. Reference markers showing chainage in feet have been installed along the road from station 0+00 ft at the intersection of Glen Access Road with the Niagara Parkway to station 65+00 ft at the bottom of the road at Gate 13.

## 2.1 Site Visit

A site visit was carried out by a Golder engineer on July 13, 2012. Beyond the observations given above, the following were noted:

- to the left of the road (west, looking down chainage) a ditch of varying width and depth ran between the toe of the cliff and the new rock-fall fence
- to the right of the road (east) is the steep slope down to the Niagara River – a galvanized steel guide rail was provided at the edge of the road – the slope started immediately beside that in many locations
- the road was surfaced with competent crushed rock
- due to the required deflection zone of the rock-fall fence the road was inconveniently narrow in some places, down to a single wide lane
- drainage appeared to be a problem, with water coming down from the Niagara Parkway pavement above, and off the cliff face on the left side, overwhelming culverts placed under the road, and flowing down the gravel surface of Glen Access Road

Based on the site visit, the following needs were identified:

- a program of shallow boreholes through the road structure to determine the pavement materials and layer thicknesses. The information would be an input to an assessment of the strength and adequacy of the road structure
  - this work was performed, and is reported below
- provision of recommendations for an asphalt pavement design
  - this work was performed, and is reported below.

## 2.2 Geometric Design

Geometric design work was undertaken to find where the road was too narrow for two lane traffic. In addition, if widening the road to the east, beyond the current edge of pavement at the guide rail, was to be contemplated, the width of retaining structures could be determined with the geometric design work.

### 2.2.1 Methods of Investigation

The design alignment was modelled with RoadEng 6.0080 software. RoadEng models horizontal alignment elements (tangents, horizontal curves), vertical alignment elements (grades, vertical crest and sag curves), and cross sectional elements (road width, crossfall, ditches, cut and fill volumes). The results of the RoadEng geometric design are shown on Figure 2.

A manual check on the width of the road was performed at the chainage sign posts to confirm the RoadEng results.

### 2.2.2 Geometric Design Modelling

The geometric design started with LiDAR data, provided by OPG, which modelled the terrain in the vicinity of the road. The line of the existing rock fall fence was then superimposed on the plan view of the road together with the line of the guide rail. The fence deflection zone's boundary was found by offsetting a line 2.32 m (7.6 ft) from Fence 1, and 3.15 m (10.3 ft) from Fences 2 and 3, delineating the edge of the rock fence deflection zone.

A new road with the characteristics shown in Table 1 was laid out to fit adjacent to the edge of the rock fence deflection zone. The eastern edge of pavement was compared to the line of the existing guide rail to determine if there was insufficient space for the road between the edge of the rock fence deflection zone and the existing guide rail.

**Table 1: Design road geometry**

| Element | Value adopted | |
|---|---|---|
| lane width | 2 lanes each 2.75 m | 2 lanes each 9 ft |
| road subgrade width | 5.9 m | 19.3 ft |
| gravel layer thickness | 0.2 m | 8 in |
| slope of gravel layer | 1:1 (horizontal:vertical) | |
| cross fall (camber) | 3% | |
| ditch depth | no ditches (ditch to be built inside the rock fence deflection zone boundary on west side, road is in fill above steep slope to Niagara River on east side) | |
| ditch bottom width | | |
| ditch slopes | | |
| final slope beyond ditches | 1:1 (horizontal:vertical) | |

### 2.2.3 Results

The width measurements made on the existing road are shown in Table 2.

**Table 2: Measured width of existing Glen Access Road**

| Chainage marker sign | Approximate metric chainage | Distance from rock fence to guide rail | | Width of rock fence deflection zone | | Width available to road (distance from rock fence to guide rail – rock fence deflection zone width | |
|---|---|---|---|---|---|---|---|
| | | metres | feet | metres | feet | metres | feet |
| 20+00 | 0+610 | 8.80 | 28.9 | 2.32 | 7.6 | 6.5 | 21.3 |
| 24+00 | 0+735 | 7.80 | 25.6 | 2.32 | 7.6 | 5.5 | 18.0 |
| 28+00 | 0+855 | 7.10 | 23.3 | 2.32 | 7.6 | 4.8 | 15.7 |
| 32+00 | 0+975 | 8.00 | 26.2 | 2.32 | 7.6 | 5.7 | 18.6 |
| 36+00 | 1+100 | 9.60 | 31.5 | 2.32 | 7.6 | 7.3 | 23.9 |
| 40+00 | 1+220 | 10.30 | 33.8 | 3.15 | 10.3 | 7.2 | 23.5 |
| 44+00 | 1+340 | 8.10 | 26.6 | 3.15 | 10.3 | 5.0 | 16.3 |
| 48+00 | 1+465 | 7.40 | 24.3 | 3.15 | 10.3 | 4.3 | 14.1 |
| 49+00 | 1+500 | 7.70 | 25.3 | 3.15 | 10.3 | 4.6 | 15.0 |
| 52+00 | 1+585 | 8.90 | 29.2 | 3.15 | 10.3 | 5.8 | 18.9 |
| 56+00 | 1+710 | 10.80 | 35.4 | 3.15 | 10.3 | 7.7 | 25.1 |
| 60+00 | 1+830 | 9.70 | 31.8 | 3.15 | 10.3 | 6.6 | 21.5 |
| 64+00 | 1+950 | 10.70 | 35.1 | 3.15 | 10.3 | 7.6 | 24.8 |

calculated width < 5.5 m (18 ft)

According to Table 2, about 490 m (1600 ft) or 37% of the fenced length of the road had insufficient space for the required rock fence deflection zone and a 5.5 m wide road.

A second approach to determine the length of road with insufficient space was to inspect the plan view of the road produced by RoadEng, Figures 2 (a) to (i). The figures were inspected for the length of road where the right edge of pavement ran outside the guide rail. Table 3 shows the results.

**Table 3: Approximate locations where space was inadequate for rock fence deflection zone and 5.5 m road**

| Metric chainage | | | Imperial chainage | | |
|---|---|---|---|---|---|
| from | to | length (m) | from | to | length (ft) |
| 0+690 | 0+950 | 260 | 22+60 | 31+20 | 860 |
| 1+280 | 1+430 | 150 | 42+00 | 46+90 | 400 |
| 1+460 | 1+530 | 70 | 47+90 | 50+20 | 320 |
| | Total | 480 | | Total | 1580 |

The results of Table 3 indicate that there was insufficient space for the rock fence deflection zone and a 5.5 m wide road over about 480 m (1580 ft) or 36% of the fenced length of the road.

### 2.2.4 Discussion

The geometric design work indicates there is a significant length of the Glen Access Road that is too narrow to accommodate the deflection zone and two-lane traffic. Any solution to the problem should include a physical delineation of the edge of the deflection zone beside the roadway. Solutions include the following:

- tolerating the locally narrow width;
- building the road two full lanes wide for its entire length, even where it encroaches on the rock fence deflection zone, and tolerating the risk of a vehicle being within the deflection zone when a rock happens to hit the fence at the vehicle's location;
- building the road two full lanes wide for its entire length, moving the guide rail towards the east where required and building retaining structures to support the road and guide rail where needed due to the existing topography;
- widening the road to two full lanes wide where currently narrow by moving the guide rail towards the east where the topography can accommodate it without the need for retaining structures, and for the remaining narrow sections, building strategically located short lay-bys on retaining structures, where one vehicle would wait as another passes in the opposite direction; or
- tolerating the locally narrow width and installing a traffic light system to control the uphill and downhill traffic, first giving priority to one, then the other. The system could be demand-based.

The maximum legal width of vehicles[1] in Ontario is 2.6 m, thus the absolute minimum road width to allow two vehicles to pass would be 5.2 m. The vehicles would have to pass at very low speed. According to Table 2, the available road width is less than 5.2 m wide over approximately 360 m (1200 ft) of the road. Given the following circumstances:

- low traffic volume;
- good sight lines;
- a short length of narrow road;
- a small probability that two vehicles would meet within a narrow stretch of the road; and
- a small probability that the two vehicles would both be the maximum legal width,

it might be considered to simply tolerate the narrow stretches. Signage warning vehicle operators of the narrow road would be recommended.

[1] http://www.mto.gov.on.ca/english/trucks/oversize/guide.shtml#weight, visited 2013 09 25

Accepting the chance of a large rock hitting the rock fence and deflecting it far enough to strike the side of a vehicle within the rock fence deflection zone would defeat the purpose of declaring the deflection zone. The probability of such an occurrence would be low, although the consequences would be catastrophic. If on careful consideration the risk is deemed acceptable by OPG, the edge of the rock fence deflection zone should be clearly marked, and signage warning vehicle operators of the nature of the risk would be required.

To accommodate the full-width road outside the limit of the rock fence deflection zone for the full length of the road would require at least 420 m of retaining structures (Table 4), based on a requirement for at least 2 m of flat ground beyond the edge of pavement. The existing ground falls off rapidly, sloping down steeply to the Niagara River on that side of the road (see cross sections in Appendix D). This solution would be a low risk one compared to others, but with the need for sound foundations on steep ground, and a solid edge barrier, it would be an expensive one.

**Table 4: Retaining structures†**

| Approximate start (m) | Approximate end (m) | Length (m) | Approximate start (ft) | Approximate end (ft) | Length (ft) |
|---|---|---|---|---|---|
| 0+700 | 0+900 | 200 | 23+00 | 29+50 | 650 |
| 1+240 | 1+320 | 80 | 40+60 | 43+30 | 270 |
| 1+380 | 1+520 | 140 | 45+30 | 49+90 | 460 |
| | Total | 420 | | Total | 1380 |

† based on the premise that a retaining structure is needed if there is 2 m or less distance between the edge of the road and the crest of the drop-off beyond the edge of the road, determined by inspection of the cross sections, Appendix D

Shorter lengths of retaining structures could be installed at strategic locations, to permit the construction of lay-bys. It is suggested that about 4 lay-bys would be required, at approximately sta 0+900 m, 1+300 m, 1+430 m, and 1+500 m (sta 29+50 ft, 42+65 ft, 46+90 ft, 49+20 ft). The lay-bys should have long site lines, and for the three at the bend at the north end of the road, the next lay-by should be visible from the current one in both directions. Signage explaining the provision of lay-bys, as well as marking their locations, should be provided.

A traffic light system similar to the one provided by the contractor during the construction of the rock fall fence could be installed. It is suggested that it only needs to cover the length of narrow road at the bend, approximately sta 1+250 m to sta 1+600 m (sta 41+00 ft to sta 52+50 ft). Signage would be required, to warn vehicle operators. The narrow stretch at the south end of the road could be tolerated, or a second pair of traffic signals installed, or a single system spanning the length of road from the south end at approximately sta 0+700 m (sta 23+00 ft) to sta 1+600 m (sta 52+50 ft) installed. This solution would not account for vehicles that stop along the road for road work. However, wider areas of the road could be constructed as lay-bys for parking these vehicles. Signage explaining the provision of lay-bys, as well as marking their locations, should be provided.

The final solution adopted will be one of compromise between cost and risk to vehicle operators and vehicles.

## 2.3 Pavement Design

### 2.3.1 Field Work

On August 24, 2013, a total of 10 boreholes were drilled through the gravel pavement of the existing road, at intervals from approximately sta 0+620 m to sta 1+600 m (sta 20+00 ft to sta 52+00 ft). The boreholes were to be advanced to a planned depth of 1.5 m (5 ft) but all met refusal at depths of 0.6 m to 1.3 m. During the earlier rock-fall fence investigation the auger refusal was interpreted to be bedrock or rockfill; however, in most cases it was found to be rockfill. The boreholes were drilled by a specialist drilling contractor using a truck-mounted power auger. A member of Golder's field staff directed the drilling, logged the boreholes, collected representative samples, and located the boreholes using the milepost signs. All of the samples were taken to our Whitby pavement materials laboratory for further examination and classification testing.

It should be noted that the boundaries between strata have been inferred from drilling observations and discontinuous samples. They generally represent transitions from one soil type to another and should not be inferred to represent exact planes of geological change. Further, conditions will vary between and beyond boreholes.

### 2.3.2 Results of Borehole Investigation

The results of the borehole investigation are shown on the Record of Borehole sheet in Appendix B. They indicate that the existing pavement consisted of 600 to 1250 mm of crushed rock on either silty clay or clayey silt, or shattered rock / bedrock. The silty clay, encountered in BHs 5 to 7 and 10 varied in thickness from 430 mm (17 inches) to 600 mm (24 inches). A pocket of clayey silt 650 mm (26 inches) thick was encountered in BH 3.

### 2.3.3 Laboratory Test Results

Grain size distributions for the crushed granular road base material are shown on Figure C1 in Appendix C. The material did not meet the gradation requirements for MTO OPSS 1010 Granular A, being too fine. The natural water contents of samples of the granular road base ranged from 0.9 to 2.1 percent. A standard Proctor laboratory compaction test yielded a maximum dry density of 2.30 $Mg/m^3$ at an optimum water content of 6.2 percent.

Grain size distributions for the silty clay found in BHs 1, 3, 5, 6, 7, and 8 are shown on Figure C2. The natural water content of samples of the soil ranged from 4.5 to 8.2 percent. As shown in Figure C3, two Atterberg tests indicated liquid limits of 29.4 and 22.8, and plasticity indices of 11.9 and 7.2.

### 2.3.4 Pavement Design

Designs for pavement upgrades with additional crushed gravel and with asphalt are provided in the following sections.

#### 2.3.4.1 Traffic

The actual traffic is unknown. Pavement design is driven by the number of passes of heavy trucks; light vehicles such as cars and pickup trucks are assumed not to contribute to the progressive damage of the pavement. It is assumed that five three-axle, heavy trucks per day use the road, and that the heavy trucks impose the equivalent of 2.2 equivalent single axle loads (ESAL) per pass. Because the road is narrow, it will be further assumed that the trucks follow the same wheel path going down the road and returning. On the basis of these assumptions, the design traffic loading is estimated to be 8,030 ESAL per year.

#### 2.3.4.2 Crushed Rock Pavement Design

DARWin 3.1.19.1 software was run to develop the pavement design, using the input data in Table 5.

**Table 5: Crushed rock pavement design input assumptions**

| Design parameter | Value adopted |
|---|---|
| initial serviceability | 4.2 |
| terminal serviceability | 2.0 |
| reliability | 90% |
| overall standard deviation | 0.49 |
| roadbed resilient modulus | 20,000 kPa |
| layer coefficient for existing granular road base material | 0.12 |
| drainage coefficient for existing granular road base material | 0.9 |

Note that a relatively high reliability was chosen, to suit the importance of the road. In addition, a high standard deviation was chosen to account for the relatively low degree of confidence in the traffic assumed.

Typically gravel roads are designed for a design life of approximately five years. After the initial period of five years, additional gravel is added to repair any rutting and to replace gravel scuffed off by traffic or lost during routine grading maintenance. For a five-year design life (40,150 ESAL), using the parameters in Table 5, a minimum thickness of 700 mm was estimated.

The existing granular material on the road is a minimum of 600 mm thick, lying on the silty clay deposit for much of its length. Where the existing thickness of granular base is less than 700 mm, the difference would have to be made up with the addition of crushed rock meeting the specifications for OPSS Granular A. However, the granular base thickness was 700 mm or thicker where encountered in six of the ten boreholes. It is recommended that a survey of the existing thickness of granular base be carried out with shallow test pits more closely spaced than the boreholes, to carefully identify where the existing base is less than 700 mm. Shallow holes could be dug with a tractor-backhoe to reveal the thickness of the base. The data acquired could then be used to delineate those stretches of the road that need additional crushed rock, and how thick the additional material should be. Where the existing base is significantly thicker then needed, the excess crushed rock could

be skimmed off to be used where needed elsewhere on the road, provided the longitudinal profile of the road is kept smooth.

#### 2.3.4.3 *Asphalt Pavement Design*

An asphalt pavement would have higher capital costs but lower maintenance requirement, would be less dusty, and would be less affected by surface water drainage problems. To develop the pavement design, the input data in Table 6 was used in DARWin.

**Table 6. Asphalt pavement design input assumptions**

| Design parameter | Value adopted |
|---|---|
| initial serviceability | 4.2 |
| terminal serviceability | 2.0 |
| reliability | 90% |
| overall standard deviation | 0.49 |
| roadbed resilient modulus | 20,000 kPa |
| layer coefficient for existing granular road base material | 0.12 |
| drainage coefficient for existing granular road base material | 0.9 |
| layer coefficient for new granular road base material | 0.14 |
| drainage coefficient for new granular road base material | 1.0 |
| layer coefficient for new HMA | 0.44 |
| drainage coefficient new HMA | 1.0 |

For a 20-year design life (161,000 ESAL, assuming no growth in traffic), the following pavement layer thicknesses are recommended.

? city standard not maintained.

**Table 7: Recommended asphalt pavement design**

| Layer | Thickness (mm) |
|---|---|
| hot mix asphalt (HMA) | 70 ? so little ? HL3 / or HL8 or others. |
| new OPSS Granular A crushed rock base | 150 |
| existing crushed rock base material | 380 (minimum, after 220 mm removed) |
| Total | 600 minimum |

As shown by the grain size distributions (Figure C1), the existing road base material does not meet the specification limits for OPSS Granular A. As such it will have poor drainage characteristics. The recommended design therefore includes the removal of 150 mm of existing base material to be replaced with 150 mm of new

OPSS Granular A. A further 70 mm of existing base material is to be removed, so that the placement of 70 mm of HMA does not result in a grade raise.

If a grade raise of 220 mm can be accommodated, it would not be necessary to remove the 220 mm of existing base material. This would have the advantage of eliminating the need for disposal of the existing base material off site.

## 2.4 Drainage

It was evident during the site visit that a considerable amount of water is delivered to the road from the cliff to the west. This is currently handled with a discontinuous ditch on the west side of the road, and a number of culverts carrying the water under the road. The condition of the culverts should be surveyed and any required repairs made before any improvements are made to the road.

deepen the ditch

### 2.4.1 Drainage of Crushed Rock Pavement

If the road is upgraded with a crushed rock pavement, it is recommended that the ditch on the west side be deepened and made continuous. Cross drain culverts should be installed at more frequent intervals than exist now along the road. The outlets of these culverts should be provided with rip rap to reduce the amount of erosion that can occur at the downstream ends of the culverts where flow is concentrated.

It is recommended that a surface water hydrologist be engaged to prepare a full drainage plan for the upgraded road.

### 2.4.2 Drainage of Asphalt-Paved Road

If the road is upgraded with an asphalt surface, it is recommended that mountable-curb and gutter or full urban curb and gutter be provided to handle the pavement runoff. Catch basins and a storm sewer would be needed to properly discharge the water. Further, it is recommended that the ditch on the west side be deepened and made continuous. Cross drain culverts should be installed at more frequent intervals than exist now along the road. The outlets of these culverts should be provided with rip rap to reduce the amount of erosion that can occur at the downstream ends of the culverts where flow is concentrated.

It is recommended that a surface water hydrologist be engaged to prepare a full drainage plan for the upgraded road.

## 2.5 Preliminary Cost Estimates

OPG requested preliminary, order-of-magnitude estimates of the cost of constructing retaining structures and the pavement for the Glen Access Road. Note that the cost estimates do not include costs for the detailed design of the retaining structures and the pavement including drainage.

Based on an assumed unit cost of $300 to $400 per square metre (depending on the type of structure) and an assumed average height of 3 m, a total length of 1380 m of retaining structure (Table 4) is estimated to cost approximately $1.2 to $1.7 million. With similar assumptions, the preliminary, order-of-magnitude estimate of the

cost of retaining structures to support four lay-bys, each of assumed length of 100 m, is estimated to be $360,000 to $480,000. More accurate estimates would be obtained by carrying out a detailed design for each retaining structure and gathering estimates from local contractors.

OPG requested a preliminary, order-of-magnitude estimate of the cost of paving the Glen Access Road. Based on an assumed width of 5.5 m, an asphalt thickness of 70 mm (Table 7), a length of 1975 m, and an estimated cost of $100/tonne to supply, place and compact asphalt, it is estimated that the cost of asphalt would be approximately $170,000. The pavement design recommends the supply, placement, and compaction of 150 mm of Granular A base material, which is estimated to cost a further approximately $80,000, bringing the total to $250,000. Concrete curb and gutter, together with a subdrainage system would advance the cost further. Again, more accurate estimates of cost would be obtained by carrying out a detailed design of the pavement, curb and gutter, and drainage, and gathering estimates from local contractors.

# 3.0 NORTH SAB1 TAILRACE ROAD

The North SAB1 Tailrace Road is a loop road approximately 720 m long, north of the tailrace of SAB1, running from the start of its lower level at approximately 658997 m E, 4779386 m N, through a hairpin bend at approximately 658889 m E, 4779654 m N, to its terminus at the upper level, at approximately 658964 m E, 4779381 m N. Chainage was started at sta 50+000 m at the lower end point (approximately 658997 m E, 4779386 m N). The road is of very low standard, and has a minimal gravel surface. The total climb from lower level to upper level is about 12 m. To the west of the road lies the steep slope of the Niagara Escarpment up to the Niagara Parkway; to the east lies the slope down to the Niagara River, a short distance below. The site of the road is heavily treed.

## 3.1 Site Visit

A site visit of the Tailrace Road was carried out by the Golder engineer on the same day as the site visit to Glen Access Road, on July 13, 2012. Beyond the observations given above, the following were noted:

- the road is a very little-used track, is surfaced with crushed gravel, and is one lane wide;
- the width appears adequate for the use of the road;
- individual precast Jersey barriers provide protection on the east side of the upper leg of the road;
- a galvanized steel guide rail provides protection on the east side of the lower leg of the road;
- drainage is a concern, with storm water eroding the surface; and
- there is a stream, Smeaton Creek, contained in a culvert running beneath the road near the south end.

Based on the site visit, the following needs were identified:

- a survey of the edges of the road surface and centreline, together with elevation, to extend the existing survey (no information for the lower leg of the road);

- a program of auger borings through the road structure to determine the existing pavement layer thicknesses and materials. The information obtained would provide input to an assessment of the strength and adequacy of the road structure;
  - this was subsequently deemed outside the Scope of Work, and was not done. A set of boreholes had been drilled earlier along the line of the rock fence, but these boreholes did not penetrate the road structure;
- a check on the possibility of installing an interceptor ditch on the west side of the road (based on survey data to be collected). It is anticipated that there will be insufficient room to incorporate a ditch in the design section, therefore consider the provision of a French drain in the road structure.

## 3.2 Mapping

GPS terrain data for the upper and lower road leg was provided by OPG. The locations of the road edges and other features were provided by OPG and Larocque Group for the upper and lower legs of the road, respectively. The terrain data was used to model the slopes adjacent to the road. Using the Terrain module of RoadEng 6.0080 software, the terrain and road surface data sets were merged into a 3D digital elevation model (DEM). Plan and profile derived from the DEM are provided in Figure 3. It can be seen that there are some anomalies in the data as recorded in the field.

A road of various widths (red centreline, blue edges in Figure 3) was superimposed on the road as surveyed with GPS (black edges in Figure 3). By trial and error it was found that a width of 2.4 m (8 ft) fit the narrowest stretches of the road. According to the DEM, there is minimal flat ground beyond the edges of the road, or the line of concrete barriers.

## 3.3 Pavement Design

It is understood that the road is subjected to minimal pickup truck traffic, and that heavy trucks use it only very rarely. It is recommended that 100 mm of OPSS Granular A be placed and compacted on the road to improve it to an acceptable standard for the traffic it receives. Alternately, surplus road base material from the upgrading of the Glen Access Road could be used in place of the Granular A.

## 3.4 Drainage

During the site visit it was evident that a considerable amount of water flows down off the cliff to the west and across the road. A large catchment (Smeaton Creek) exists above the road as shown by the 3D image of the topography, Figure 4. This water is directed to a culvert under the road at about sta 50+035 m and sta 50+545 m.

There is a need for a ditch to intercept the flow of water across the road from west to east. However, there does not appear to be sufficient space for a ditch. Consequently, it is recommended that a drain be installed along the western edge of the upper leg of the road. The drain could be constructed by digging a shallow trench along the

edge of the road, before the road surface material is placed. While a design of the drain should be undertaken by a surface water hydrologist, it is anticipated that the trench for the drain should be approximately 0.5 m wide and 1 m deep (Figure 5). It should be lined with nonwoven geotextile with an apparent opening size (AOS) or filtration opening size (FOS) not exceeding 0.3 mm. A perforated pipe should be installed in the free-draining backfill material in the geotextile-lined trench. Once the pipe and fill are installed, the top flaps of the geotextile should be folded over the top of the fill, overlapping 0.5 m. Finally, additional free draining fill should be placed and compacted over the drain.

The perforated pipe should be connected to lateral pipes that carry the water either under or around the lower leg of the road, to outlets properly protected with rip rap.

It is recommended that a surface water hydrologist be engaged to prepare a full drainage plan for the upgraded road, including a survey of the existing culvert carrying the flow from the hanging valley under the road.

## 4.0 CLOSURE

It has been a pleasure to have the opportunity to work on this interesting project. If there are any questions, please do not hesitate to contact the undersigned.

# Report Signature Page

**GOLDER ASSOCIATES LTD.**

rdouglas@golder.com

Robert A. Douglas, P.Eng.
Senior geotechnical Engineer - Low Volume Roads

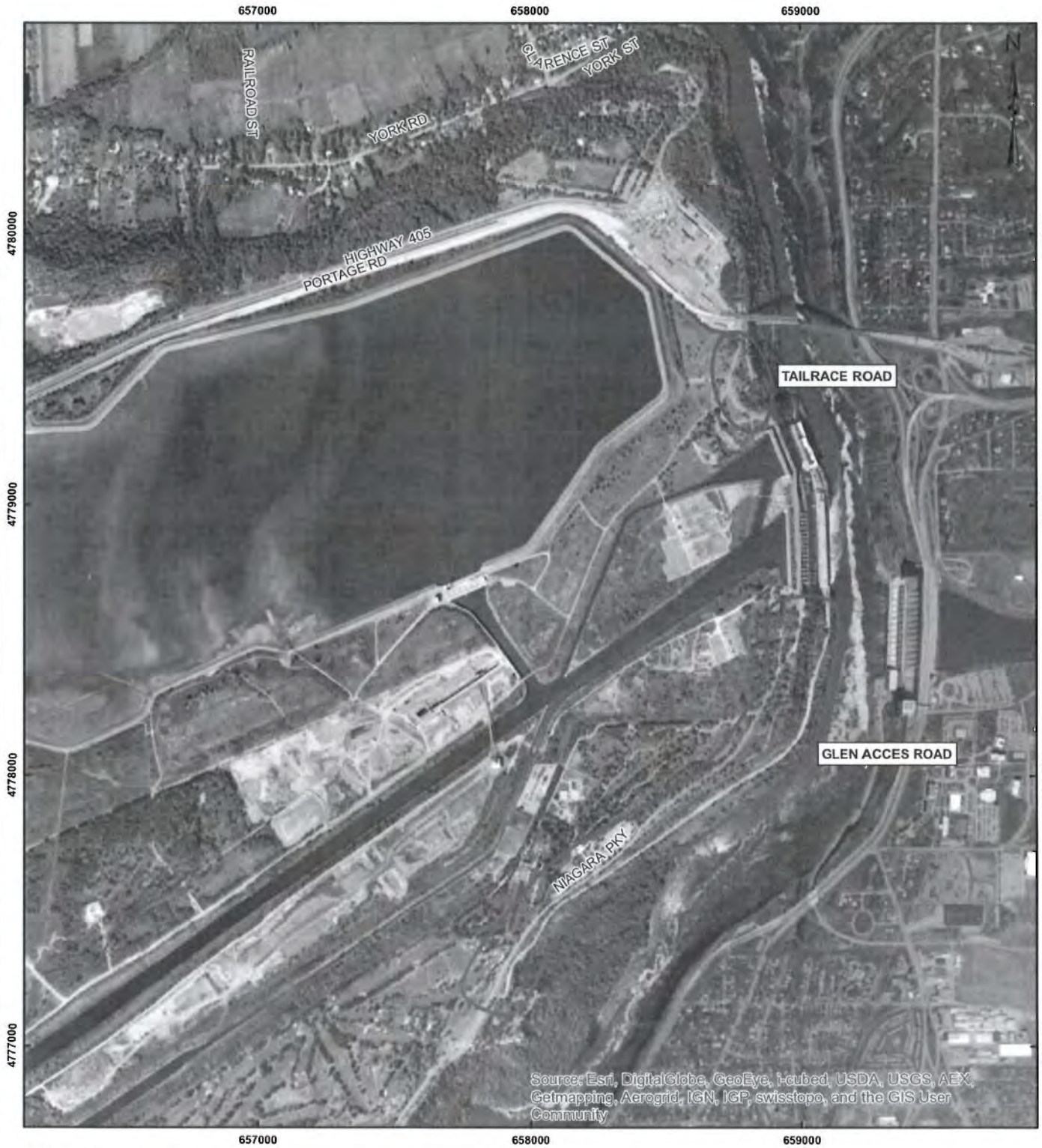
Gabriele Mellies, P.Eng.
Rock Mechanics Engineer

Ludomir Uzarowski, P.Eng.
Principal – Pavements and Materials Engineering

RAD/LU/rad/sm

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**LEGEND**

Study Areas

250 125 0 250 500 750

SCALE 1:20,000 METRES




PROJECT

OPG GLEN ACCESS ROAD / TAILRACE ROAD

TITLE

**KEY PLAN**

**REFERENCE**

Base Data - MNR LIO, obtained 2009
Produced by Golder Associates Ltd under licence from Ontario Ministry of Natural Resources, © Queens Printer 2012
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 17

Golder Associates
Mississauga, Ontario

| PROJECT NO. 11-1117-0037 | | | SCALE AS SHOWN | REV 0.0 |
|---|---|---|---|---|
| DESIGN | JO | 14 Nov. 2008 | | |
| GIS | JO | 20 Sep. 2013 | | |
| CHECK | RAD | 20 Sep. 2013 | | |
| REVIEW | RAD | 20 Sep. 2013 | | |

**FIGURE: 1**

ROADENG PARAMETERS

| TEMPLATES | STRATIGRAPHY | STRIPPING | FILL |
|---|---|---|---|
| DEFAULT | | | |

ONTARIO POWER GENERATION

# Glen Access Road Plan and Profile

| | | | |
|---|---|---|---|
| DESIGN | RAD | 2013 10 16 | |
| CADD | RAD | 2013 10 16 | |
| CHECK | GM | 2013 10 16 | |
| REVIEW | LJD | 2013 10 16 | |

Golder Associates

11-1117-0037 — FILE No.

SCALES AS SHOWN — REV

**FIGURE 2a**

Legend
- GUARDRAIL
- ROCK FENCE
- SAFETY ZONE BOUNDARY

Plan Scale 1:500

Plan Scale
0
50

Profile Vert Scale 1:100
Profile Horz Scale 1:500

L-Stn
0+650
0+600
0+550
L-Stn
0+600.0
-6.0
-6.1
MG-20-00-1
4777600.N

ROADENG PARAMETERS

| | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

ONTARIO POWER GENERATION

# Glen Access Road Plan and Profile

| | | | | |
|---|---|---|---|---|
| DESIGN | RAD | 2013 10 16 | (1-)117 0027 | FILE No |
| CADD | RAD | 2013 10 16 | SCALES AS SHOWN | REV |
| CHECK | GM | 2013 10 16 | | |
| REVIEW | LD | 2013 10 16 | | |

Golder Associates

**FIGURE 2b**

Legend

- GUARDRAIL
- ROCK FENCE
- SAFETY ZONE BOUNDARY

Plan Scale 1:500

Plan Scale

0 50

4777700:N

6584000:E

6583300:E

0+800

0+750

0+700

MS 24.00-1

Profile Vert Scale 1:100
Profile Horz Scale 1:500

L-Stn

L-Stn

0+800

0+750

0+700

130 132 134 136 138

136 138 140 142 144

0+800.0

0+750.0

0+700.0

-6.0

| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

ONTARIO POWER GENERATION

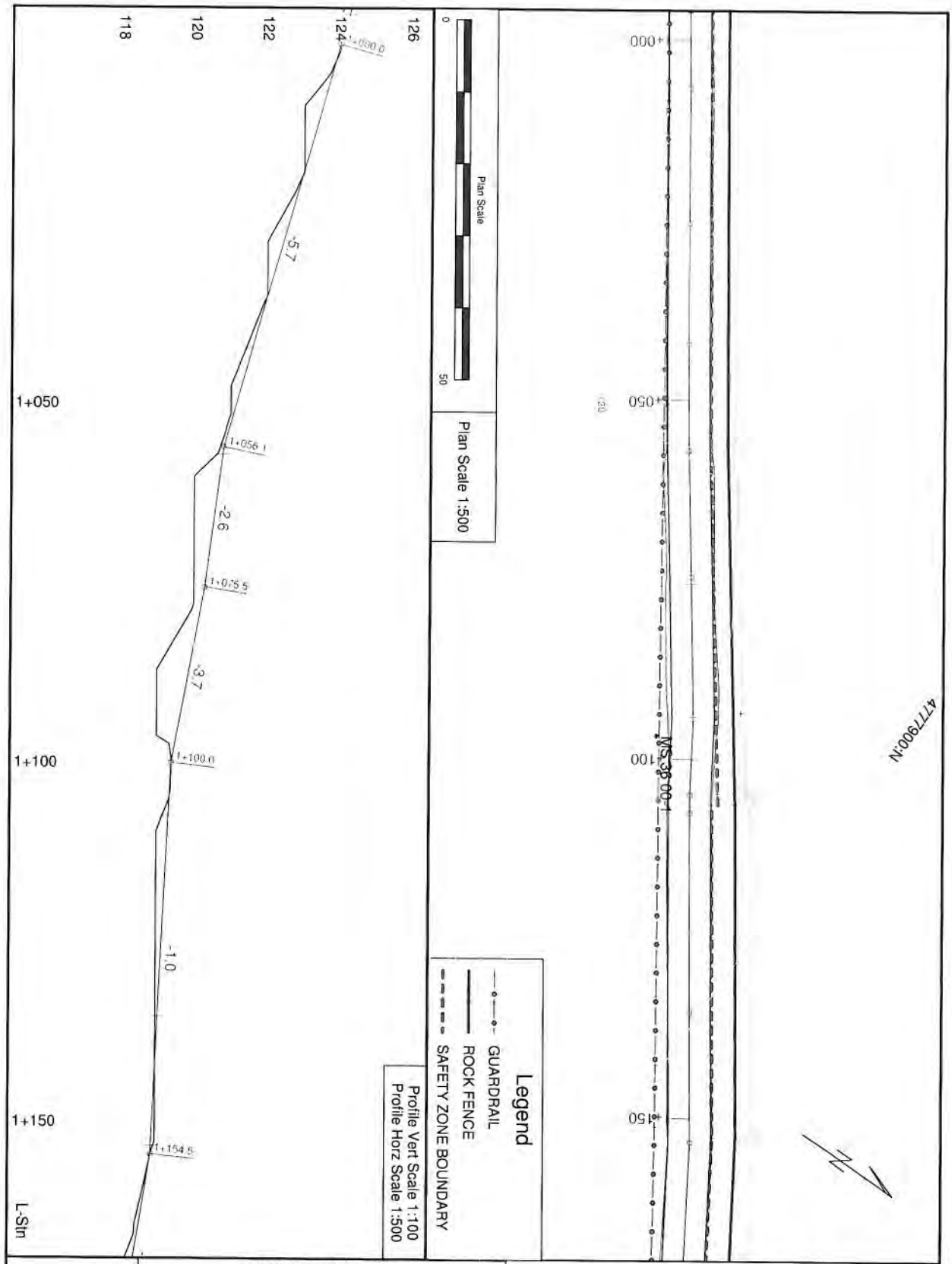
# Glen Access Road Plan and Profile

Golder Associates

| | | | |
|---|---|---|---|
| | | 11-1117-0037 | FILE No. |
| DESIGN | RAD | 2013 10 16 | SCALES AS SHOWN |
| CADD | RAD | 2013 10 16 | |
| CHECK | GM | 2013 10 16 | |
| REVIEW | LU | 2013 10 16 | |

REV

**FIGURE 2c**




| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

ONTARIO POWER GENERATION

# Glen Access Road Plan and Profile

Golder Associates

| | | | | |
|---|---|---|---|---|
| | | 11-1117-0037 | FILE No. | REV |
| DESIGN | RAD | 2013 10 16 | SCALES AS SHOWN | |
| CADD | RAD | 2013 10 16 | | |
| CHECK | GM | 2013 10 16 | **FIGURE 2d** | |
| REVIEW | LU | 2013 10 16 | | |

| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

ONTARIO POWER GENERATION

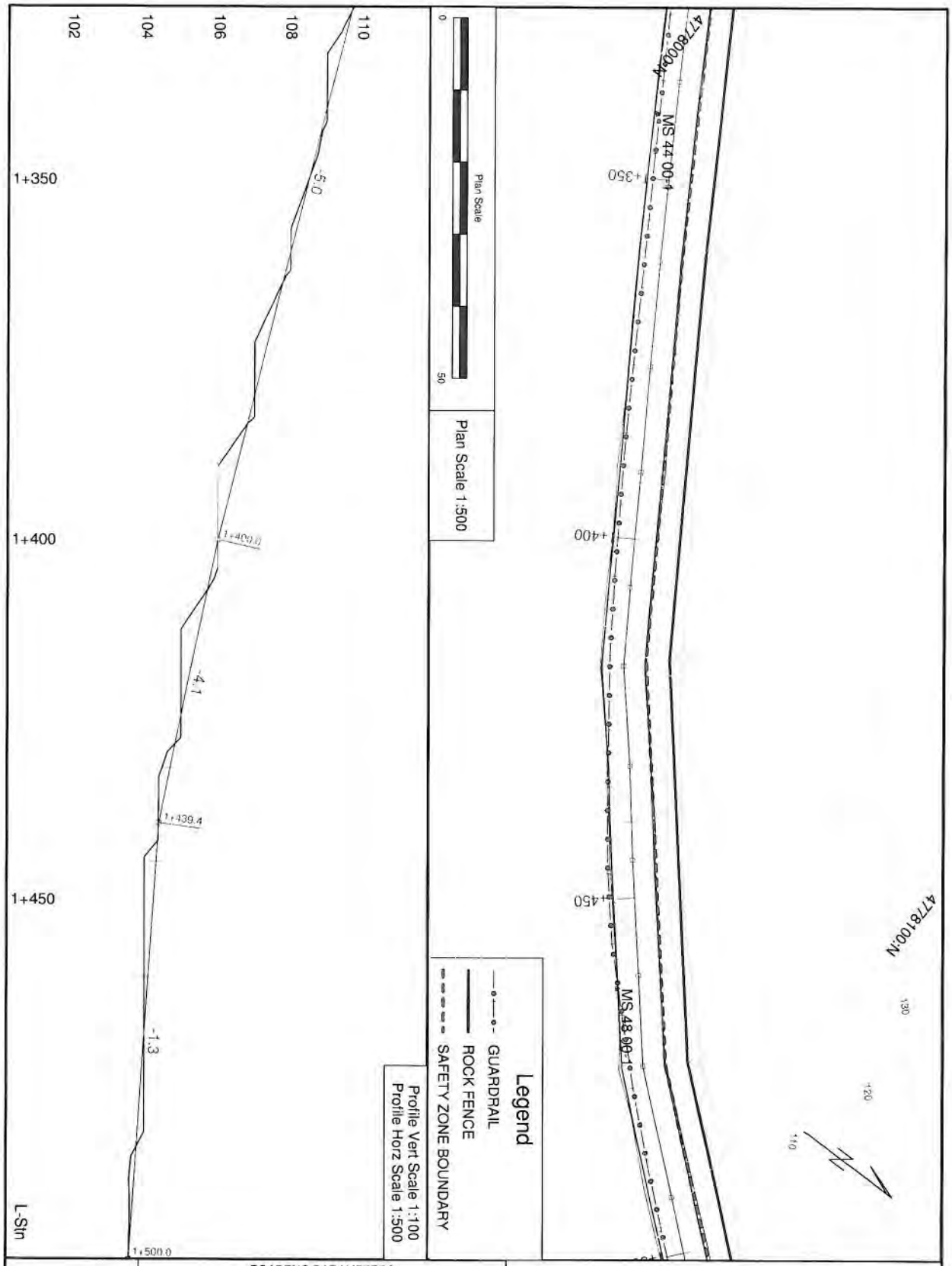
# Glen Access Road Plan and Profile

Golder Associates

| | | | |
|---|---|---|---|
| | | 11-1117-0037 | FILE No. |
| DESIGN | RAD | 2013 10 16 | SCALES AS SHOWN |
| CADD | RAD | 2013 10 16 | |
| CHECK | GM | 2013 10 16 | |
| REVIEW | LU | 2013 10 16 | |

REV

**FIGURE 2e**




| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

ONTARIO POWER GENERATION

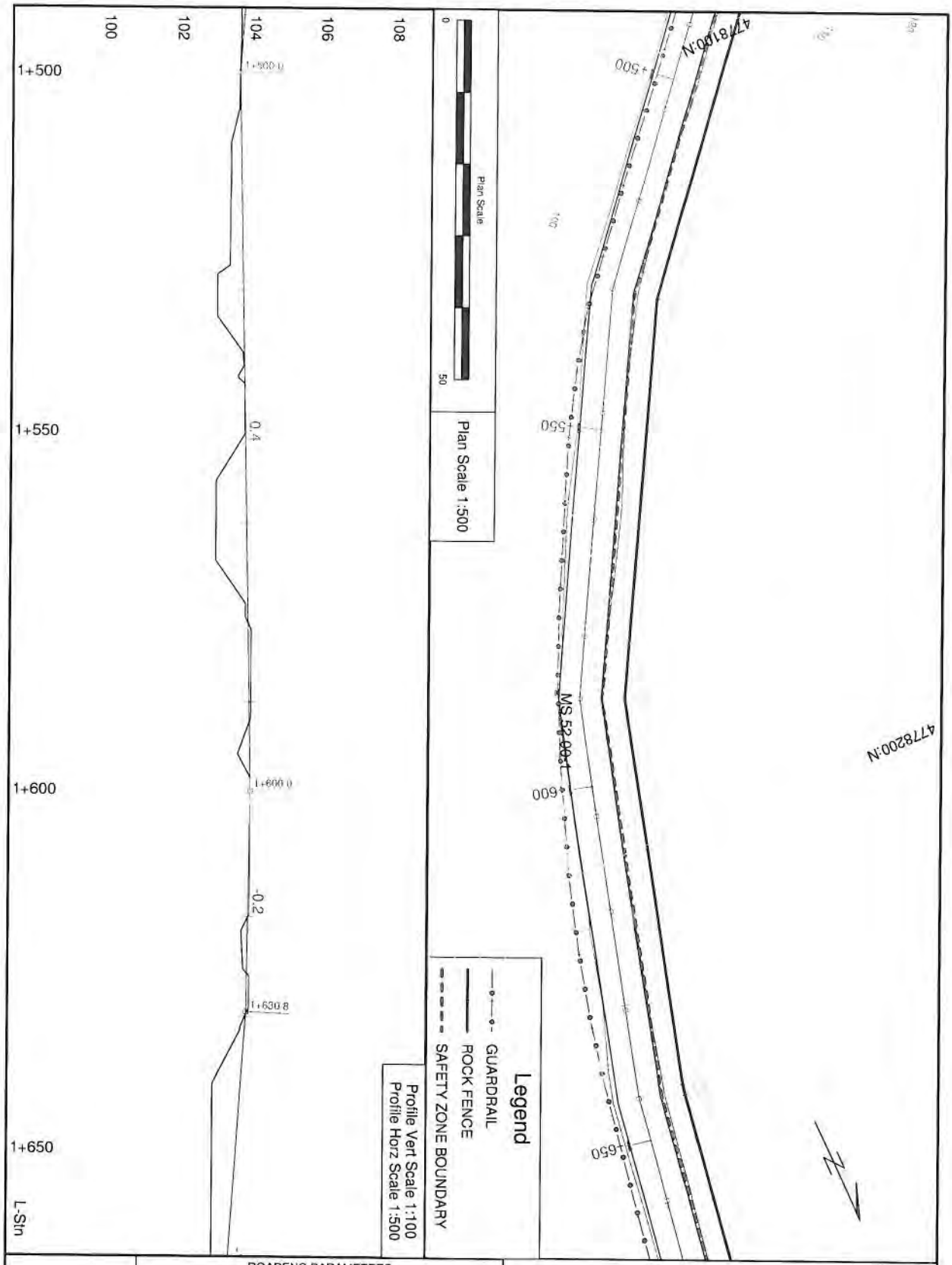
# Glen Access Road Plan and Profile

Golder Associates

| | | | |
|---|---|---|---|
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| DESIGN | RAD | 2013 10 16 | SCALES AS SHOWN |
| CADD | RAD | 2013 10 16 | |
| CHECK | GM | 2013 10 16 | |
| REVIEW | LU | 2013 10 16 | |

REV

**FIGURE 2f**




| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

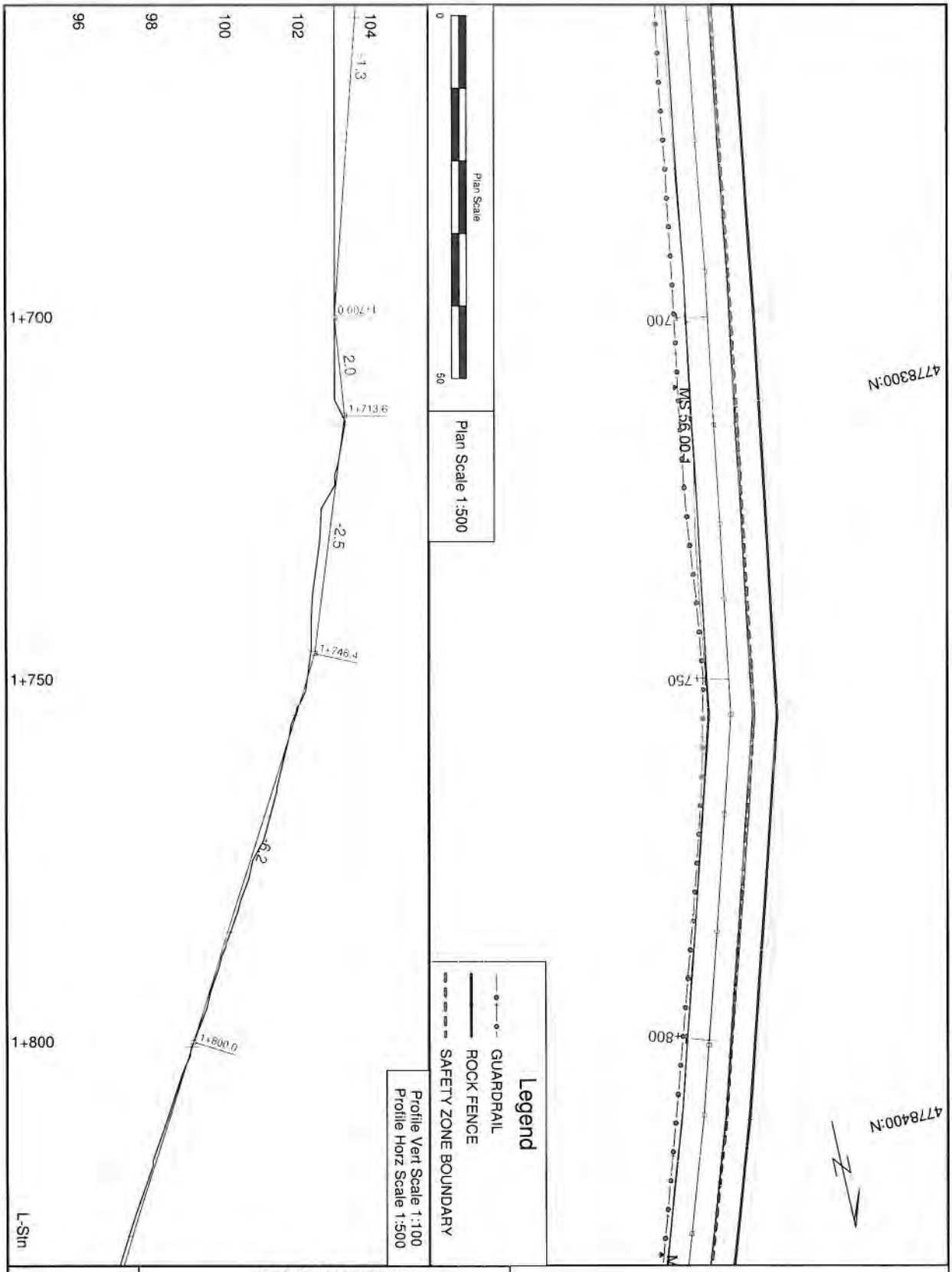
ONTARIO POWER GENERATION

# Glen Access Road Plan and Profile

Golder Associates

| | | | | |
|---|---|---|---|---|
| | | | 11-1117-0037 | FILE No. |
| DESIGN | RAD | 2013.10.16 | SCALES AS SHOWN | REV |
| CADD | RAD | 2013.10.16 | | |
| CHECK | GM | 2013.10.16 | | |
| REVIEW | LU | 2013.10.16 | | |

**FIGURE 2g**




| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

ONTARIO POWER GENERATION

# Glen Access Road Plan and Profile

Golder Associates

| | | | |
|---|---|---|---|
| | | 11-1117-0007 | FILE No. |
| DESIGN | RAD | 2013 10 16 | SCALES AS SHOWN |
| CADD | RAD | 2013 10 16 | |
| CHECK | GM | 2013 10 16 | |
| REVIEW | LD | 2013 10 16 | |

REV

**FIGURE 2h**

| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

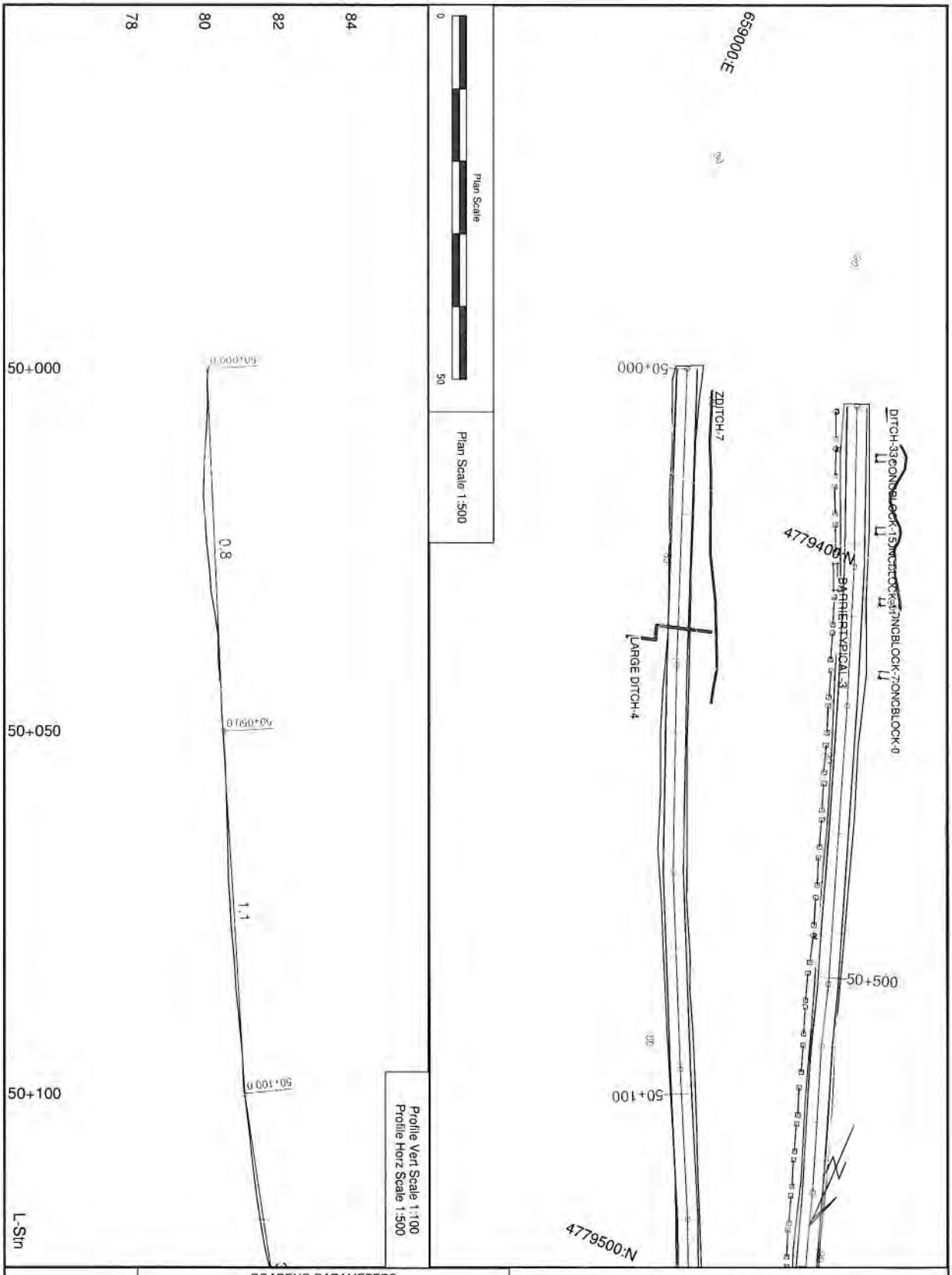
ONTARIO POWER GENERATION

# Glen Access Road Plan and Profile

Golder Associates

| | | | | |
|---|---|---|---|---|
| | | | 11-1117-0037 | FILE No. |
| DESIGN | RAD | 2013.10.16 | SCALES AS SHOWN | REV |
| CADD | RAD | 2013.10.16 | | |
| CHECK | GM | 2013.10.16 | | |
| REVIEW | LU | 2013.10.16 | | |

**FIGURE 2i**




| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

ONTARIO POWER GENERATION

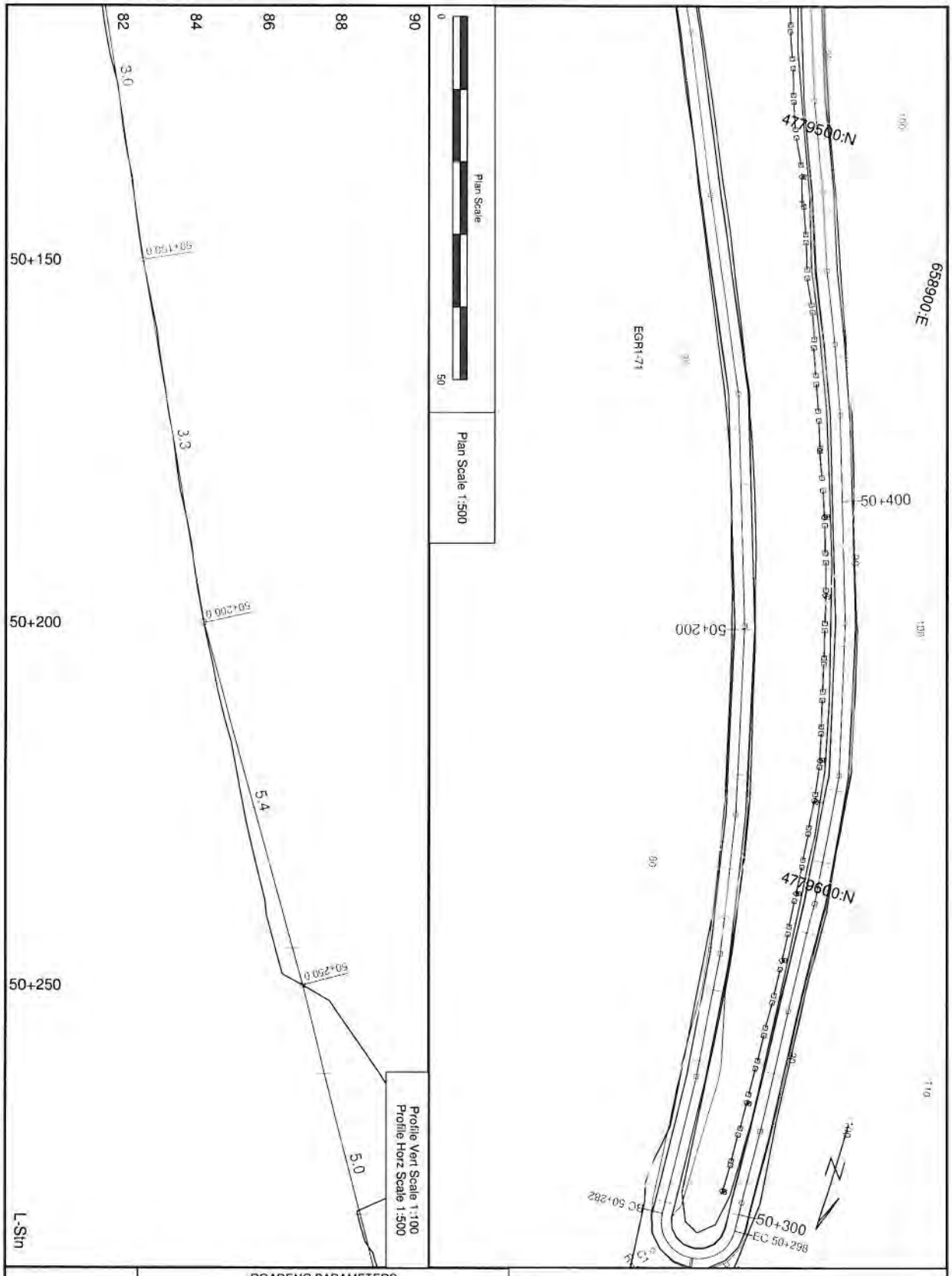
# Tail Race Road Plan and Profile

Golder Associates

| | | | |
|---|---|---|---|
| | | 11-1117-0037 | FILE No. |
| DESIGN | RAD | 2013 09 26 | SCALES AS SHOWN |
| CADD | RAD | 2013 09 26 | |
| CHECK | GM | 2013 09 26 | |
| REVIEW | LU | 2013 09 26 | |

REV

**FIGURE 3a**




| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

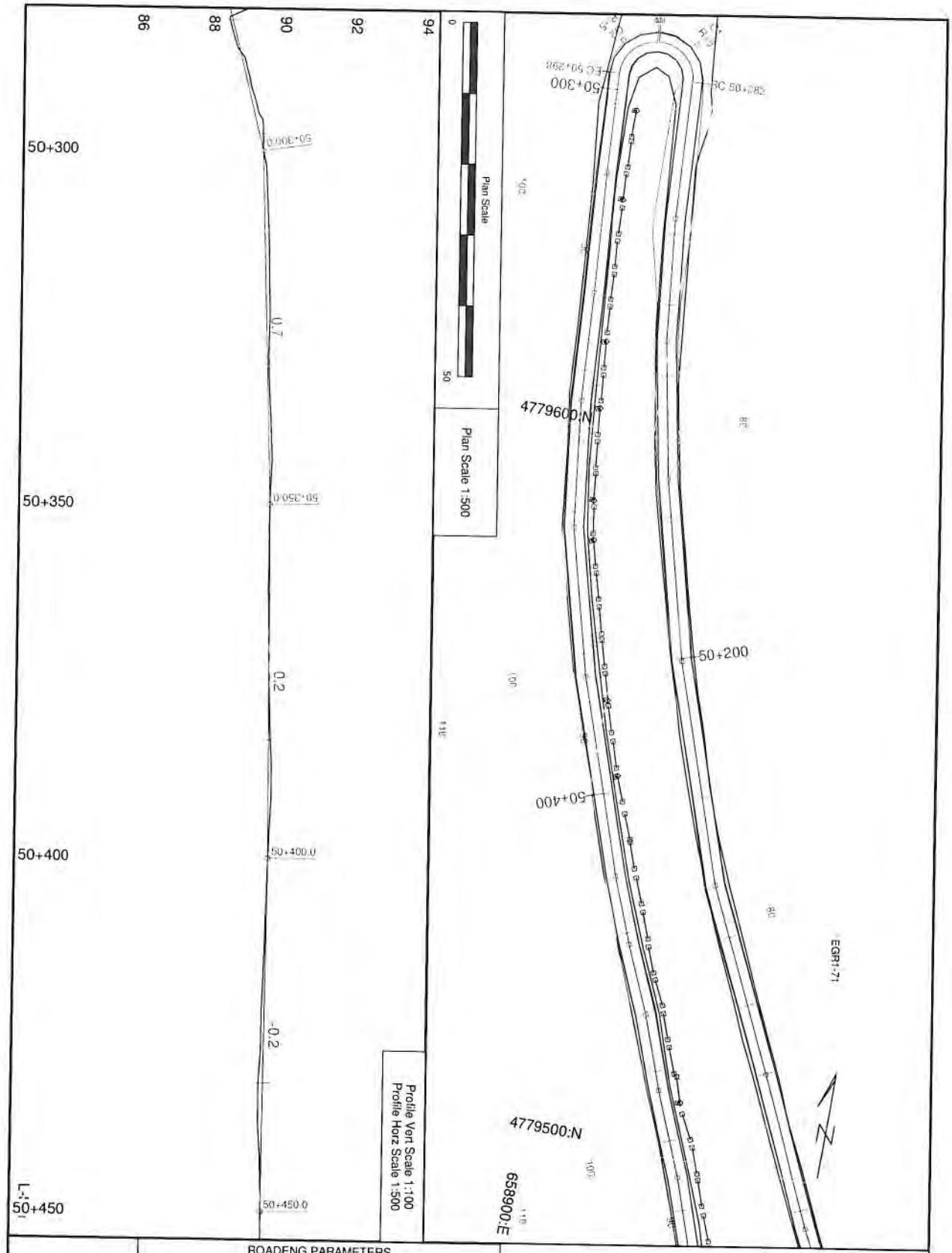
ONTARIO POWER GENERATION

# Tail Race Road Plan and Profile

Golder Associates

| | | | | |
|---|---|---|---|---|
| | | | 11-1117-0037 | FILE No. |
| DESIGN | RAD | 2013 09 26 | SCALES AS SHOWN | REV |
| CADD | RAD | 2013 09 26 | | |
| CHECK | GM | 2013 09 26 | | |
| REVIEW | LH | 2013 09 26 | | |

**FIGURE 3b**




| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

ONTARIO POWER GENERATION

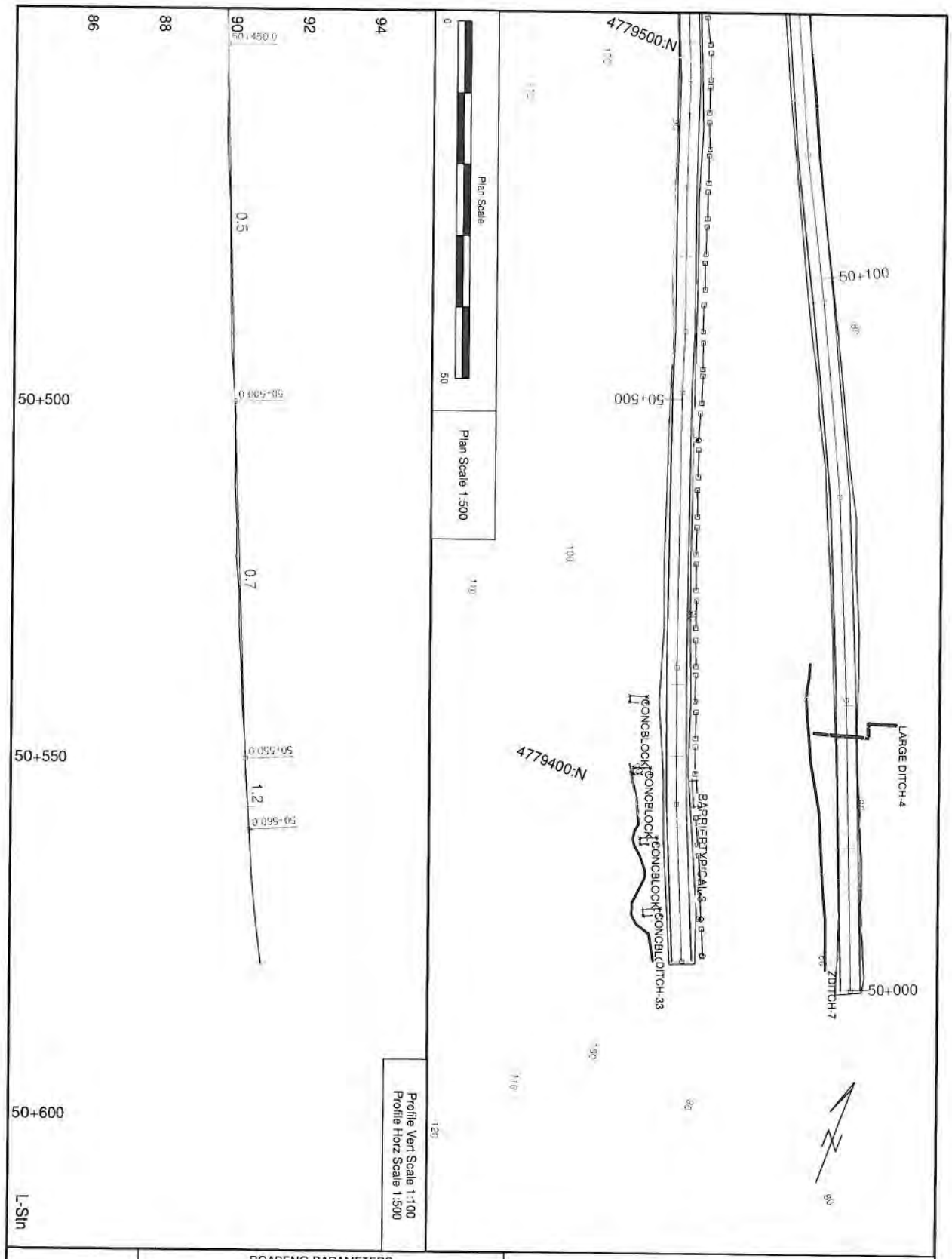
# Tail Race Road Plan and Profile

Golder Associates

| | | | |
|---|---|---|---|
| | | 11-1117-0037 | FILE No. |
| DESIGN | RAD | 2013.09.26 | SCALES AS SHOWN |
| CADD | RAD | 2013.09.26 | |
| CHECK | GM | 2013.09.26 | |
| REVIEW | LU | 2013.09.26 | |

REV

**FIGURE 3c**




| ROADENG PARAMETERS | |
|---|---|
| TEMPLATES | DEFAULT |
| STRATIGRAPHY | |
| STRIPPING | |
| FILL | |

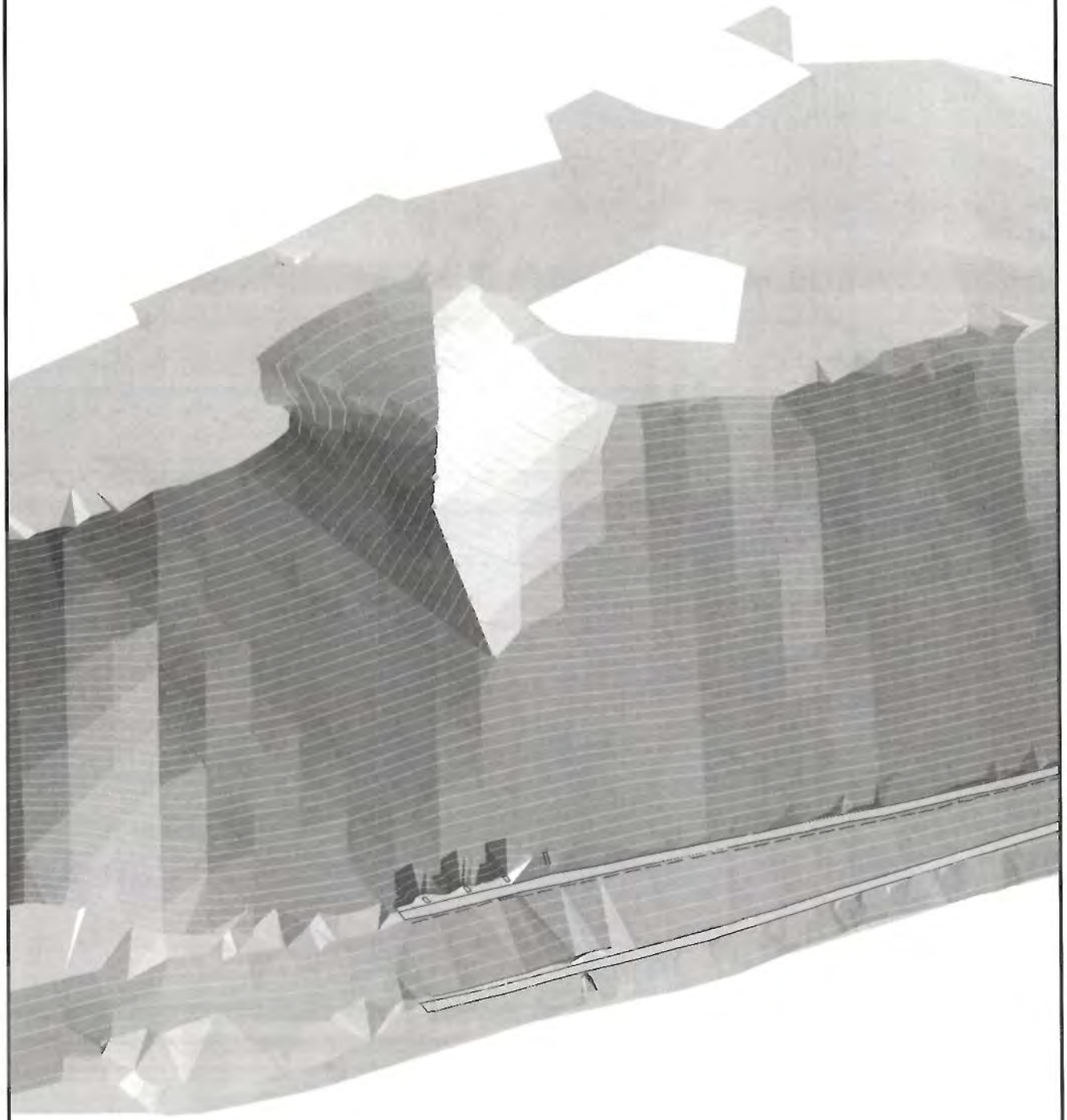
ONTARIO POWER GENERATION

# Tail Race Road Plan and Profile

Golder Associates

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|---|---|---|---|---|
| | | | 11-1117-0037 | FILE No. |
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| CADD | RAD | 2013.09.26 | | |
| CHECK | GM | 2013.09.26 | | |
| REVIEW | LIJ | 2013.09.26 | | |

**FIGURE 3d**



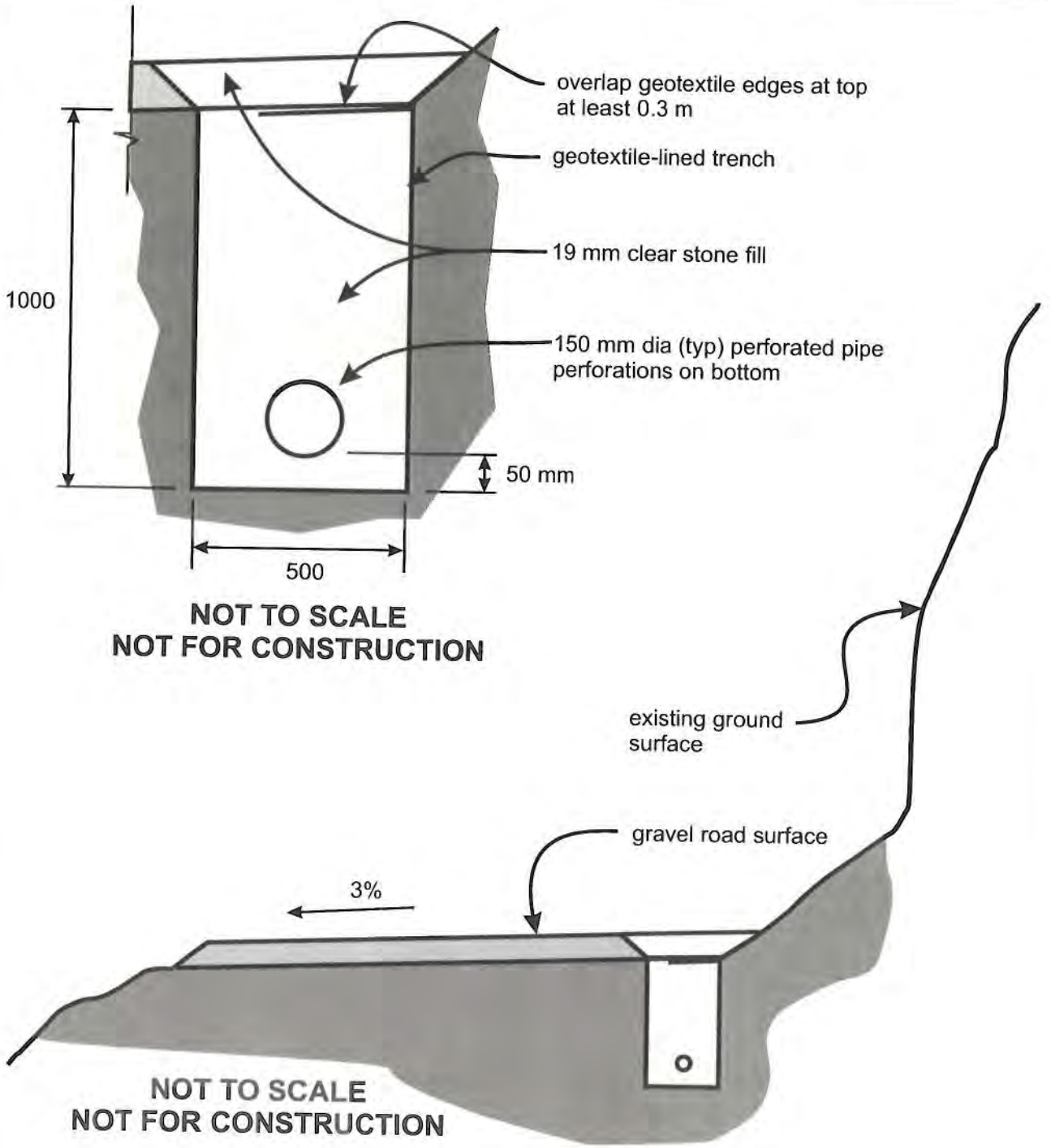
Golder Associates

OPG GLEN ACCESS ROAD / TAILRACE ROAD

**HANGING VALLEY ABOVE TAILRACE ROAD**

| PROJECT NO. 11-1117-0037 | | |
|---|---|---|
| DESIGN | RAD | 2013 09 30 |
| CHECK | RAD | 2013 09 30 |
| REVIEW | RAD | 2013 09 30 |

**FIGURE 4**




Golder Associates

OPG GLEN ACCESS ROAD / TAILRACE ROAD

TAILRACE ROAD - FRENCH DRAIN

| PROJECT NO. 11-1117-0037 | | |
|---|---|---|
| DESIGN | RAD | 2013 09 30 |
| CHECK | RAD | 2013 09 30 |
| REVIEW | GM | 2013 09 30 |

FIGURE 5

# APPENDIX A

## Important Information and Limitations of this Report

# IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

**Standard of Care:** Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

**Basis and Use o f the Report:** This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

**Soil, Rock and Ground water Conditions:** Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

**Sample Disposal:** Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

**Follow-Up and Construction Services:** All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

**Changed Conditions and Drainage:** Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

# APPENDIX B

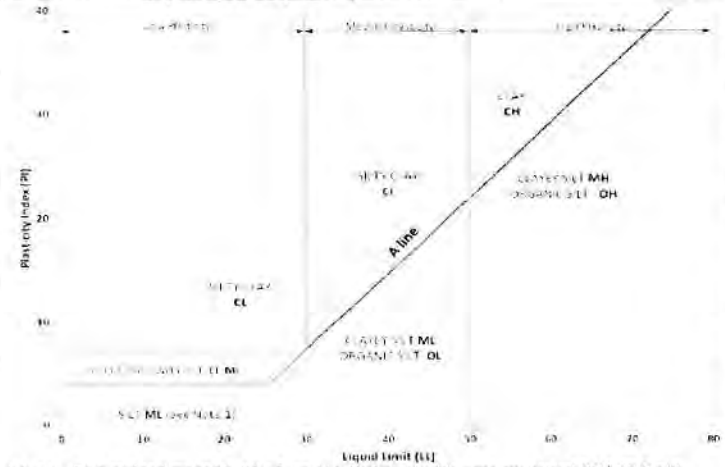
## Method of Soil Classification
## Abbreviations and terms Used on Record of Boreholes and Test Pits
## List of Symbols
## Record of Borehole Sheet

# METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

| Organic or Inorganic | Soil Group | Type of Soil | | Gradation or Plasticity | $Cu = \frac{D_{60}}{D_{10}}$ | $Cc = \frac{(D_{30})^2}{D_{10} x D_{60}}$ | Organic Content | USCS Group Symbol | Group Name |
|---|---|---|---|---|---|---|---|---|---|
| INORGANIC (Organic Content ≤30% by mass) | COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm) | GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm) | Gravels with ≤12% fines (by mass) | Poorly Graded | <4 | ≤1 or ≥3 | ≤30% | GP | GRAVEL |
| | | | | Well Graded | ≥4 | 1 to 3 | | GW | GRAVEL |
| | | | Gravels with >12% fines (by mass) | Below A Line | n/a | | | GM | SILTY GRAVEL |
| | | | | Above A Line | n/a | | | GC | CLAYEY GRAVEL |
| | | SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm) | Sands with ≤12% fines (by mass) | Poorly Graded | <6 | ≤1 or ≥3 | | SP | SAND |
| | | | | Well Graded | ≥6 | 1 to 3 | | SW | SAND |
| | | | Sands with >12% fines (by mass) | Below A Line | n/a | | | SM | SILTY SAND |
| | | | | Above A Line | n/a | | | SC | CLAYEY SAND |

| Organic or Inorganic | Soil Group | Type of Soil | | Laboratory Tests | Field Indicators | | | | | Organic Content | USCS Group Symbol | Primary Name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Dilatancy | Dry Strength | Shine Test | Thread Diameter | Toughness (of 3 mm thread) | | | |
| INORGANIC (Organic Content ≤30% by mass) | FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm) | SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below) | | Liquid Limit <50 | Rapid | None | None | >6 mm | N/A (can't roll 3 mm thread) | <5% | ML | SILT |
| | | | | | Slow | None to Low | Dull | 3mm to 6 mm | None to low | <5% | ML | CLAYEY SILT |
| | | | | | Slow to very slow | Low to medium | Dull to slight | 3mm to 6 mm | Low | 5% to 30% | OL | ORGANIC SILT |
| | | | | Liquid Limit ≥50 | Slow to very slow | Low to medium | Slight | 3mm to 6 mm | Low to medium | <5% | MH | CLAYEY SILT |
| | | | | | None | Medium to high | Dull to slight | 1 mm to 3 mm | Medium to high | 5% to 30% | OH | ORGANIC SILT |
| | | CLAYS (PI and LL plot above A-Line on Plasticity Chart below) | | Liquid Limit <30 | None | Low to medium | Slight to shiny | ~ 3 mm | Low to medium | 0% to 30% (see Note 2) | CL | SILTY CLAY |
| | | | | Liquid Limit 30 to 50 | None | Medium to high | Slight to shiny | 1 mm to 3 mm | Medium | | CI | SILTY CLAY |
| | | | | Liquid Limit ≥50 | None | High | Shiny | <1 mm | High | | CH | CLAY |
| HIGHLY ORGANIC SOILS (Organic Content >30% by mass) | | Peat and mineral soil mixtures | | | | | | | | 30% to 75% | PT | SILTY PEAT, SANDY PEAT |
| | | Predominantly peat, may contain some mineral soil, fibrous or amorphous peat | | | | | | | | 75% to 100% | | PEAT |




**Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.**

**Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.**

**Dual Symbol** — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

**Borderline Symbol** — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to ~~or~~ indicates a range of similar soil types within a stratum.

# ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

**PARTICLE SIZES OF CONSTITUENTS**

| Soil Constituent | Particle Size Description | Millimetres | Inches (US Std. Sieve Size) |
|---|---|---|---|
| BOULDERS | Not Applicable | >300 | >12 |
| COBBLES | Not Applicable | 75 to 300 | 3 to 12 |
| GRAVEL | Coarse<br>Fine | 19 to 75<br>4.75 to 19 | 0.75 to 3<br>(4) to 0.75 |
| SAND | Coarse<br>Medium<br>Fine | 2.00 to 4.75<br>0.425 to 2.00<br>0.075 to 0.425 | (10) to (4)<br>(40) to (10)<br>(200) to (40) |
| SILT/CLAY | Classified by plasticity | <0.075 | < (200) |

**MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS**

| Percentage by Mass | Modifier |
|---|---|
| >35 | Use 'and' to combine major constituents (*i.e.*, SAND and GRAVEL, SAND and CLAY) |
| > 12 to 35 | Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable |
| > 5 to 12 | some |
| ≤ 5 | trace |

**PENETRATION RESISTANCE**

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.).

Cone Penetration Test (CPT)
An electronic cone penetrometer with a 60° conical tip and a project end area of 10 $cm^2$ pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ($q_t$), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); $N_d$:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

**PH:** Sampler advanced by hydraulic pressure
**PM:** Sampler advanced by manual pressure
**WH:** Sampler advanced by static weight of hammer
**WR:** Sampler advanced by weight of sampler and rod

**SAMPLES**

| | |
|---|---|
| AS | Auger sample |
| BS | Block sample |
| CS | Chunk sample |
| DO or DP | Seamless open ended, driven or pushed tube sampler – note size |
| DS | Denison type sample |
| FS | Foil sample |
| RC | Rock core |
| SC | Soil core |
| SS | Split spoon sampler – note size |
| ST | Slotted tube |
| TO | Thin-walled, open – note size |
| TP | Thin-walled, piston – note size |
| WS | Wash sample |

**SOIL TESTS**

| | |
|---|---|
| w | water content |
| PL , $w_p$ | plastic limit |
| LL , $w_L$ | liquid limit |
| C | consolidation (oedometer) test |
| CHEM | chemical analysis (refer to text) |
| CID | consolidated isotropically drained triaxial test[1] |
| CIU | consolidated isotropically undrained triaxial test with porewater pressure measurement[1] |
| $D_R$ | relative density (specific gravity, Gs) |
| DS | direct shear test |
| GS | specific gravity |
| M | sieve analysis for particle size |
| MH | combined sieve and hydrometer (H) analysis |
| MPC | Modified Proctor compaction test |
| SPC | Standard Proctor compaction test |
| OC | organic content test |
| $SO_4$ | concentration of water-soluble sulphates |
| UC | unconfined compression test |
| UU | unconsolidated undrained triaxial test |
| V (FV) | field vane (LV-laboratory vane test) |
| γ | unit weight |

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

**NON-COHESIVE (COHESIONLESS) SOILS**

**Compactness[2]**

| Term | SPT 'N' (blows/0.3m)[1] |
|---|---|
| Very Loose | 0 - 4 |
| Loose | 4 to 10 |
| Compact | 10 to 30 |
| Dense | 30 to 50 |
| Very Dense | >50 |

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects.
2. Definition of compactness descriptions based on SPT 'N' ranges from Terzaghi and Peck (1967) and correspond to typical average $N_{60}$ values.

**Field Moisture Condition**

| Term | Description |
|---|---|
| Dry | Soil flows freely through fingers. |
| Moist | Soils are darker than in the dry condition and may feel cool. |
| Wet | As moist, but with free water forming on hands when handled. |

**COHESIVE SOILS**

**Consistency**

| Term | Undrained Shear Strength (kPa) | SPT 'N'[1] (blows/0.3m) |
|---|---|---|
| Very Soft | <12 | 0 to 2 |
| Soft | 12 to 25 | 2 to 4 |
| Firm | 25 to 50 | 4 to 8 |
| Stiff | 50 to 100 | 8 to 15 |
| Very Stiff | 100 to 200 | 15 to 30 |
| Hard | >200 | >30 |

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

**Water Content**

| Term | Description |
|---|---|
| w < PL | Material is estimated to be drier than the Plastic Limit. |
| w ~ PL | Material is estimated to be close to the Plastic Limit. |
| w > PL | Material is estimated to be wetter than the Plastic Limit. |

Unless otherwise stated, the symbols employed in the report are as follows:

## I. GENERAL

| | |
|---|---|
| $\pi$ | 3.1416 |
| ln x | natural logarithm of x |
| $\log_{10}$ | x or log x, logarithm of x to base 10 |
| g | acceleration due to gravity |
| t | time |

## II. STRESS AND STRAIN

| | |
|---|---|
| $\gamma$ | shear strain |
| $\Delta$ | change in, e.g. in stress: $\Delta\sigma$ |
| $\varepsilon$ | linear strain |
| $\varepsilon_v$ | volumetric strain |
| $\eta$ | coefficient of viscosity |
| $\upsilon$ | Poisson's ratio |
| $\sigma$ | total stress |
| $\sigma'$ | effective stress ($\sigma' = \sigma - u$) |
| $\sigma'_{vo}$ | initial effective overburden stress |
| $\sigma_1$, $\sigma_2$, $\sigma_3$ | principal stress (major, intermediate, minor) |
| $\sigma_{oct}$ | mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$ |
| $\tau$ | shear stress |
| u | porewater pressure |
| E | modulus of deformation |
| G | shear modulus of deformation |
| K | bulk modulus of compressibility |

## III. SOIL PROPERTIES

### (a) Index Properties

| | |
|---|---|
| $\rho(\gamma)$ | bulk density (bulk unit weight)* |
| $\rho_d(\gamma_d)$ | dry density (dry unit weight) |
| $\rho_w(\gamma_w)$ | density (unit weight) of water |
| $\rho_s(\gamma_s)$ | density (unit weight) of solid particles |
| $\gamma'$ | unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$) |
| $D_R$ | relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly $G_s$) |
| e | void ratio |
| n | porosity |
| S | degree of saturation |
| w | water content |
| $w_l$ or LL | liquid limit |
| $w_p$ or PL | plastic limit |
| $I_p$ or PI | plasticity index = $(w_l - w_p)$ |
| $w_s$ | shrinkage limit |
| $I_L$ | liquidity index = $(w - w_p) / I_p$ |
| $I_C$ | consistency index = $(w_l - w) / I_p$ |
| $e_{max}$ | void ratio in loosest state |
| $e_{min}$ | void ratio in densest state |
| $I_D$ | density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density) |

* Density symbol is $\rho$. Unit weight symbol is $\gamma$ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

### (b) Hydraulic Properties

| | |
|---|---|
| h | hydraulic head or potential |
| q | rate of flow |
| v | velocity of flow |
| i | hydraulic gradient |
| k | hydraulic conductivity (coefficient of permeability) |
| j | seepage force per unit volume |

### (c) Consolidation (one-dimensional)

| | |
|---|---|
| $C_c$ | compression index (normally consolidated range) |
| $C_r$ | recompression index (over-consolidated range) |
| $C_s$ | swelling index |
| $C_\alpha$ | secondary compression index |
| $m_v$ | coefficient of volume change |
| $c_v$ | coefficient of consolidation (vertical direction) |
| $c_h$ | coefficient of consolidation (horizontal direction) |
| $T_v$ | time factor (vertical direction) |
| U | degree of consolidation |
| $\sigma'_p$ | pre-consolidation stress |
| OCR | over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$ |

### (d) Shear Strength

| | |
|---|---|
| $\tau_p$, $\tau_r$ | peak and residual shear strength |
| $\phi'$ | effective angle of internal friction |
| $\delta$ | angle of interface friction |
| $\mu$ | coefficient of friction = tan $\delta$ |
| c' | effective cohesion |
| $c_u$, $s_u$ | undrained shear strength ($\phi = 0$ analysis) |
| p | mean total stress $(\sigma_1 + \sigma_3)/2$ |
| p' | mean effective stress $(\sigma'_1 + \sigma'_3)/2$ |
| q | $(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$ |
| $q_u$ | compressive strength $(\sigma_1 - \sigma_3)$ |
| $S_t$ | sensitivity |

**Notes:** 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

# TABLE B1
# RECORD OF BOREHOLES
OPG - Glen Access Road



| | BOREHOLE LOG | | | | LABORATORY TESTING | |
|---|---|---|---|---|---|---|
| **Borehole No.** | Depth (mm/m) | Description | Sample Depth (mm) | Frost Susceptibility | Water Content (%) | Gradation |
| Location | Station 12+00, offset 5.0 m Lt of Guiderail, Datum 0 | | | | | |
| BH 1 | 0 - 1.20 | (GM) Crushed GRAVEL, brown, moist | | | | |
| | 1.20 - 1.20 | NFP ShRk/BR | | | | |
| Location | Station 20+00, offset 4.5 m Lt of Guiderail, Datum 0 | | | | | |
| BH 2 | 0 - 600 | (GM) Crushed GRAVEL, brown, moist | 300 - 600 | | | Figure C1 |
| | 600 - 600 | NFP ShRk/BR | | | | |
| Location | Station 24+00, offset 3.5 m Lt of Guiderail, Datum 0 | | | | | |
| BH 3 | 0 - 650 | (GM) Crushed GRAVEL, brown, moist | 200 - 500 | | 1.0 | |
| | 650 - 1.30 | (ML) CLAYEYEY SILT, with sand, with gravel, red-brown, moist | 900 - 1.20 | | 7.6 | Figure C2 |
| | 1.30 - 1.30 | NFP ShRk/BR | | | | |
| Location | Station 32+00, offset 4.0 m Lt of Guiderail, Datum 0 | | | | | |
| BH 4 | 0 - 900 | (GM) Crushed GRAVEL, brown, moist | 600 - 900 | | | |
| | 900 - 900 | NFP ShRk/BR | | | | |
| Location | Station 36+00, offset 4.5 m Lt of Guiderail, Datum 0 | | | | | |
| BH 5 | 0 - 650 | (GM) Crushed GRAVEL, brown, moist | 200 - 500 | | 1.7 | Figure C1 |
| | 650 - 1.20 | (CL) SILTY CLAY, with sand, trace gravel, red-brown, moist | 600 - 900 | | 4.5 | |
| | 1.20 - 1.20 | NFP ShRk/BR | | | | |
| Location | Station 40+00, offset 5.0 m Lt of Guiderail, Datum 0 | | | | | |
| BH 6 | 0 - 750 | (GM) Crushed GRAVEL, brown, moist | 0 - 300 | | | |
| | 750 - 1.30 | (CL) SILTY CLAY, with sand, trace gravel, red-brown, moist | 900 - 1.20 | | 4.9 | Figure C2 |
| | 1.30 - 1.30 | NFP ShRk/BR | | | | |
| Location | Station 44+00, offset 4.0 m Lt of Guiderail, Datum 0 | | | | | |
| BH 7 | 0 - 870 | (GM) Crushed GRAVEL, brown, moist | 0 - 300 | | 1.4 | |
| | 870 - 1.30 | (CL) SILTY CLAY, with sand, trace gravel, red-brown, moist | 900 - 1.20 | | 8.2 | |
| | 1.30 - 1.30 | NFP ShRk/BR | | | | |
| Location | Station 52+00, offset 4.0 m Lt of Guiderail, Datum 0 | | | | | |
| BH 8 | 0 - 1.25 | (GM) Crushed GRAVEL, brown, moist | 0 - 1.00 | | | |
| | 1.25 - 1.25 | NFP BR | | | | |
| Location | Station 55+75, offset 5.0 m Lt of Guiderail, Datum 0 | | | | | |
| BH 9 | 0 - 1.20 | (GM) Crushed GRAVEL, brown, rock fragment at 650, moist | 0 - 300 | | 2.10 | Figure C1 |
| | 1.20 - 1.20 | NFP ShRk/BR | | | | |
| Location | Station 60+00, offset 4.5 m Lt of Guiderail, Datum 0 | | | | | |
| BH 10 | 0 - 600 | (GM) Crushed GRAVEL, brown, moist | 300 - 600 | | 0.9 | |
| | 600 - 1.20 | (CL) SILTY CLAY, with sand, trace gravel, red-brown, moist | 600 - 900 | | 5.2 | Figure C2 |
| | 1.20 - 1.25 | NFP ShRk/BR | | | | |

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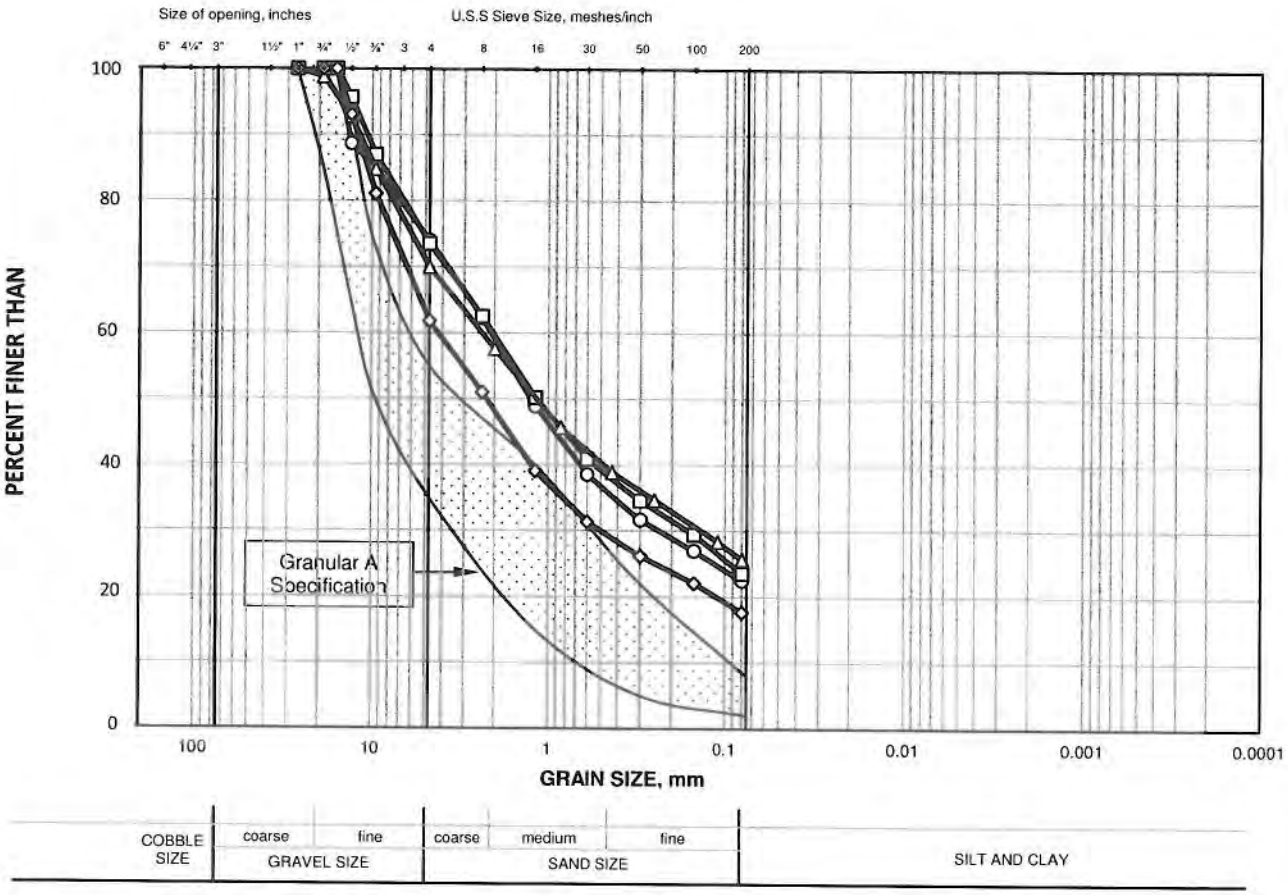
# APPENDIX C

## Laboratory Test Results

# GRAIN SIZE DISTRIBUTION

**FIGURE C1**

## GRANULAR BASE MATERIAL




**LEGEND**

| SYMBOL | BOREHOLE | SAMPLE | LOCATION | STATION | OFFSET | DEPTH (m) |
|---|---|---|---|---|---|---|
| ○ | 5 | 1 | Glen Access | 36+00 | 4.5 m lt of g rail | 200-500 |
| □ | 9 | 1 | Glen Access | 55+75 | 5.0 m lt of g rail | 0-300 |
| △ | 9 | 1 | PROCTOR | 55+75 | 5.0 m lt of g rail | 0-600 |
| ◇ | 10 | 1 | Glen Access | 60+00 | 4.5 m lt of g rail | 300-600 |

Date 2013 09 26
Project 11-1117-0037

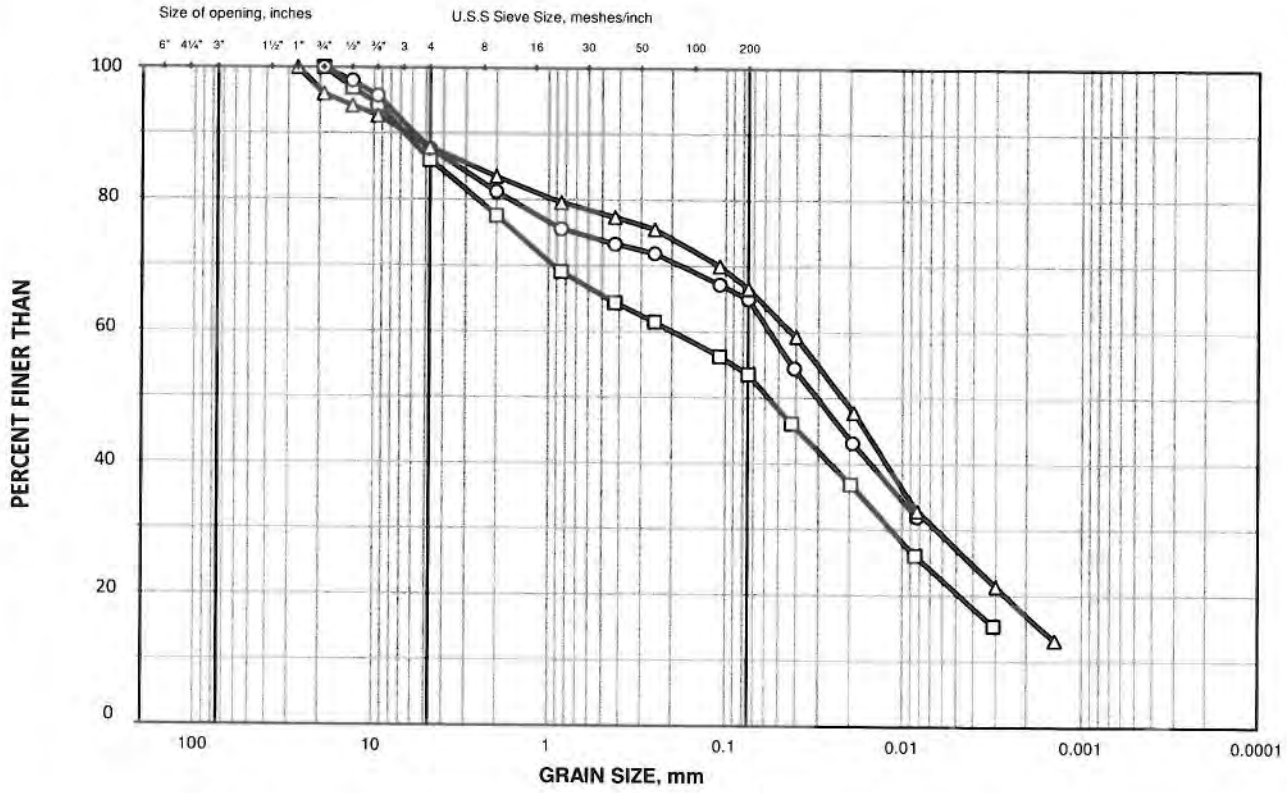
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# GRAIN SIZE DISTRIBUTION

**FIGURE C2**

## SILTY CLAY




**LEGEND**

| SYMBOL | BOREHOLE | SAMPLE | LOCATION | STATION | OFFSET | DEPTH (m) |
|---|---|---|---|---|---|---|
| ○ | 3 | 2 | Glen Access | 24+00 | 3.5 m lt of g rail | 900-1200 |
| □ | 6 | 2 | Glen Access | 44+00 | 5.0 m lt of g rail | 900-1200 |
| △ | 10 | 2 | Glen Access | 60+00 | 4.5 m lt of g rail | 600-900 |

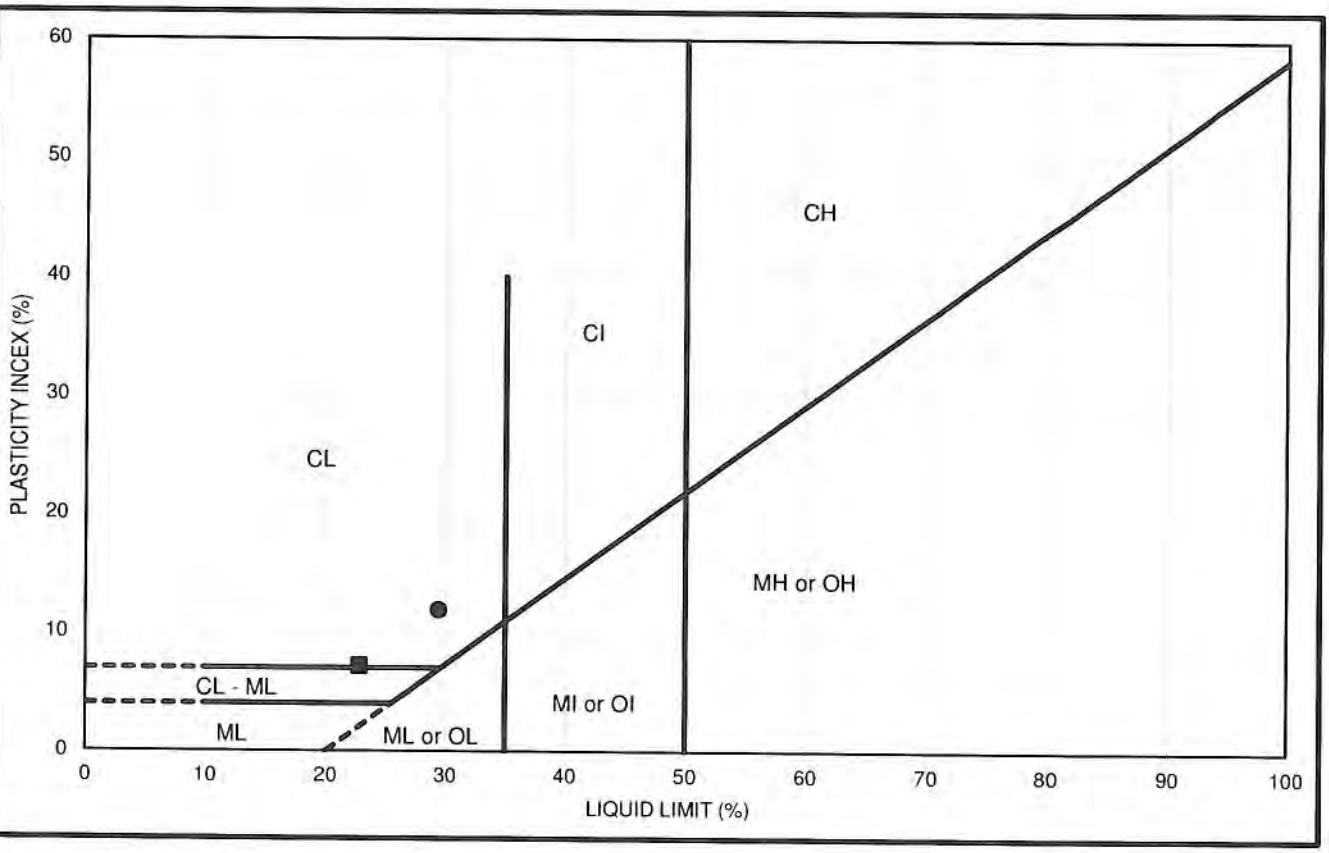
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Project 11-1117-0037

**Golder Associates**

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# PLASTICITY CHART

**FIGURE C3**




**LEGEND**

| SYMBOL | BOREHOLE # | SAMPLE # | LOCATION | STATION | OFFSET | DEPTH (mm) |
|---|---|---|---|---|---|---|
| ● | 3 | 2 | GLEN ACCESS | 24+00 | 3.5 m lt of g rail | 900-1200 |
| ■ | 6 | 2 | GLEN ACCESS | 40+00 | 5.0 m lt of g rail | 900-1200 |

Date 2013 09 26
Project 11-1117-0037

**Golder Associates**

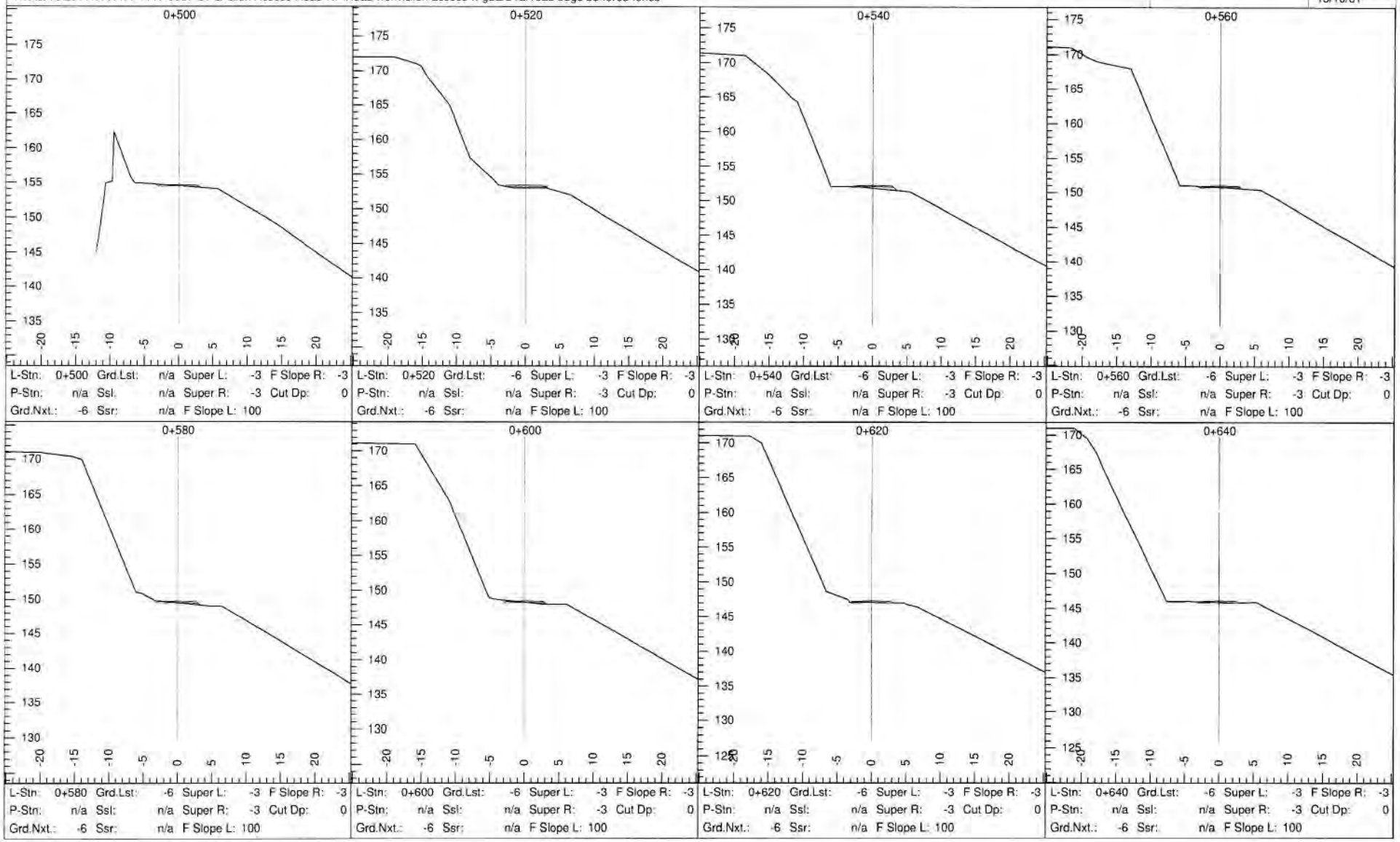
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# APPENDIX D

## Cross Sections, Glen Access Road

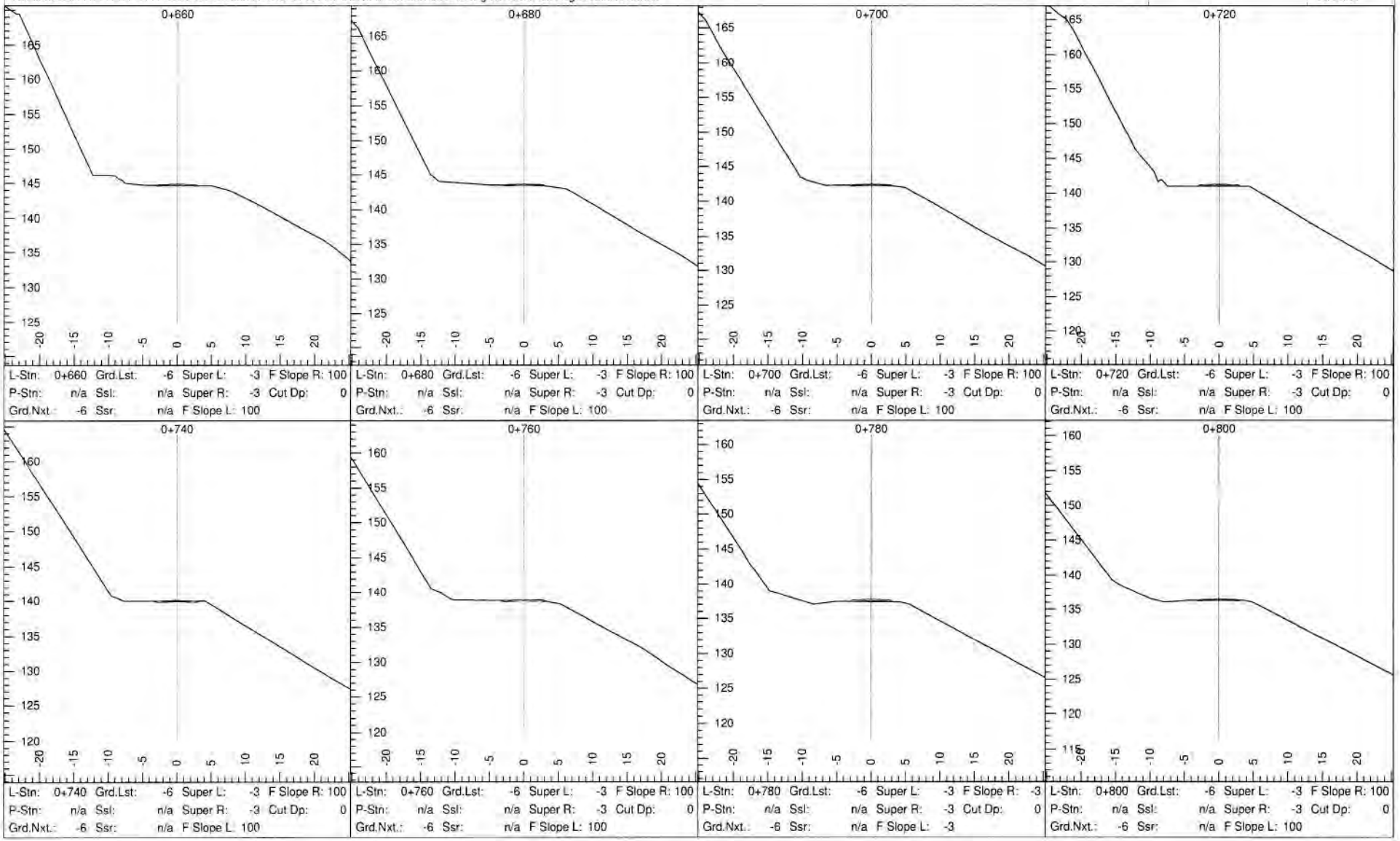
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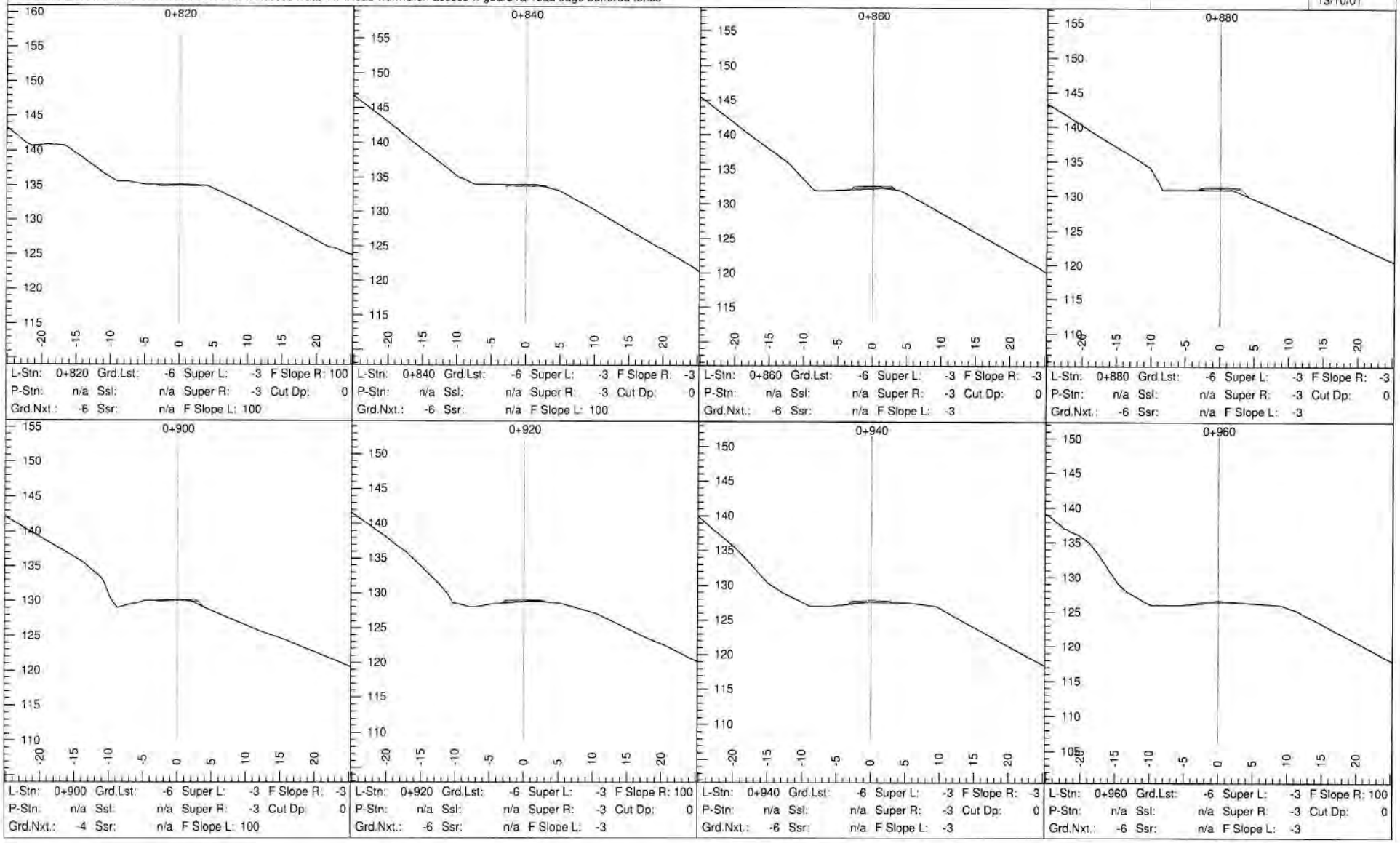


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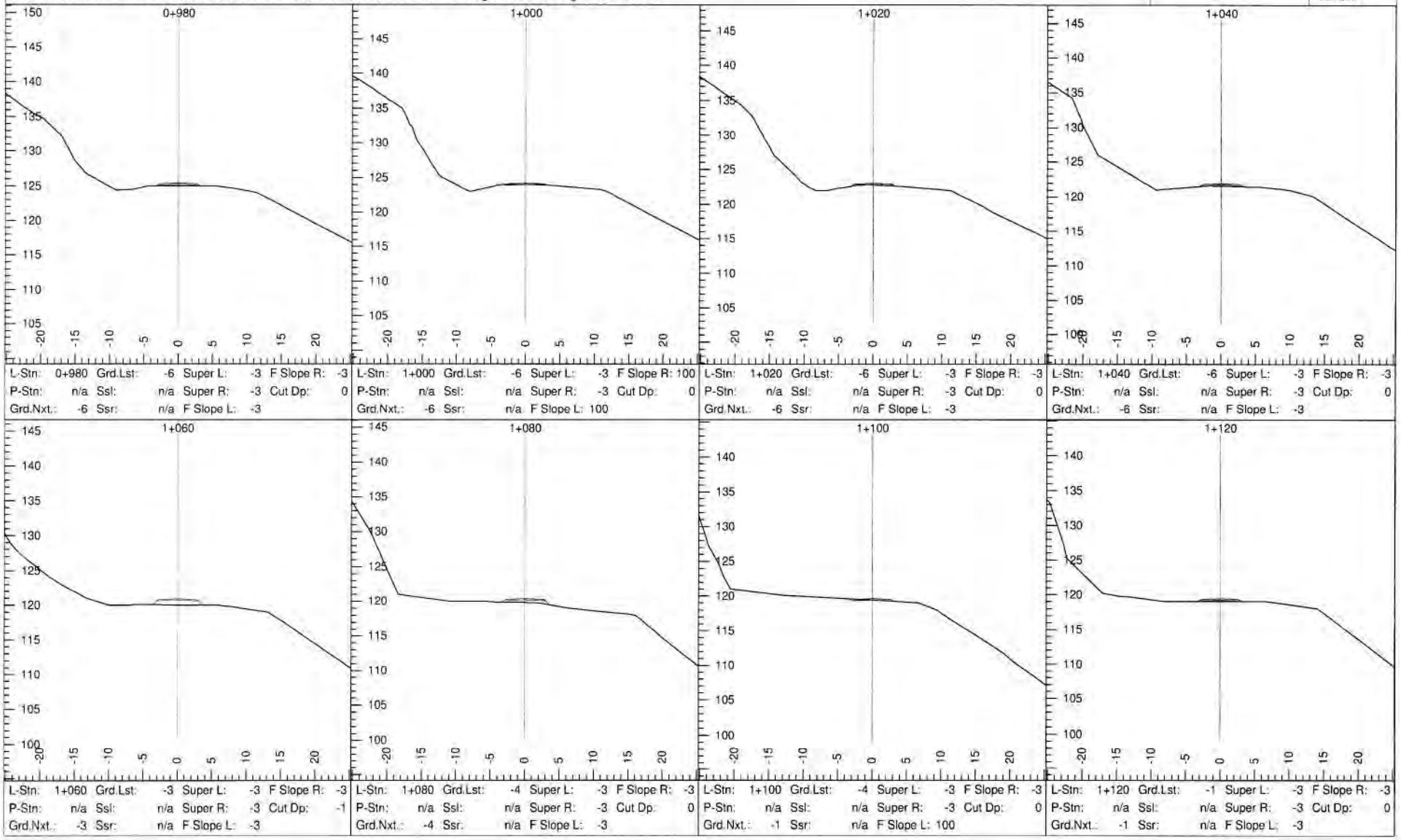
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13/10/01



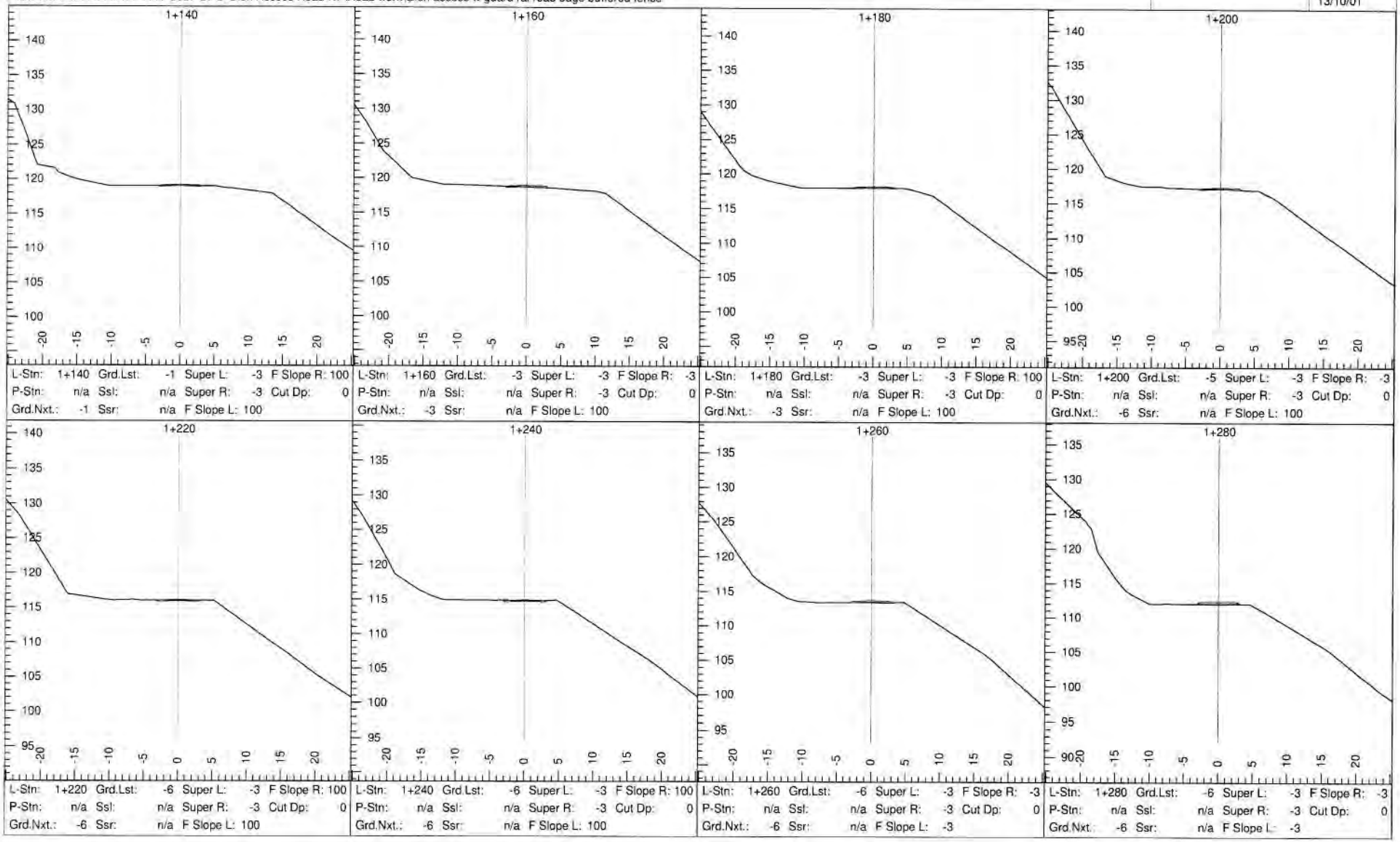
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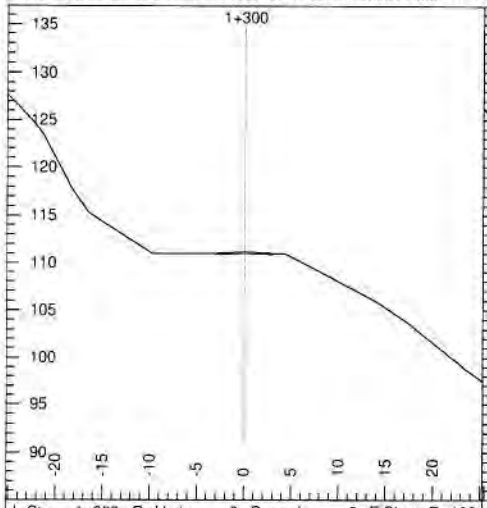
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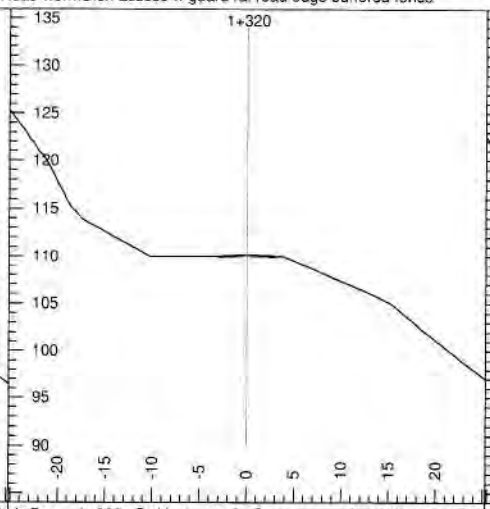
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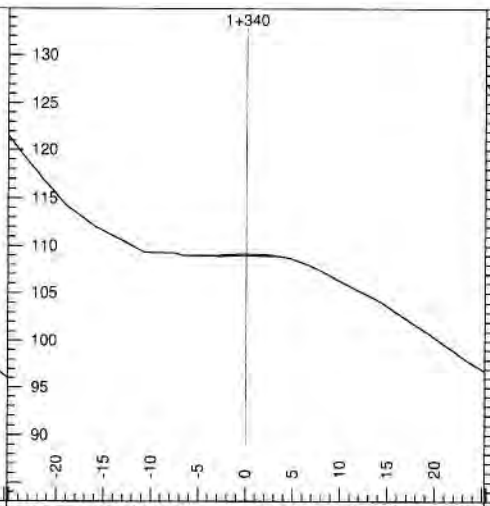
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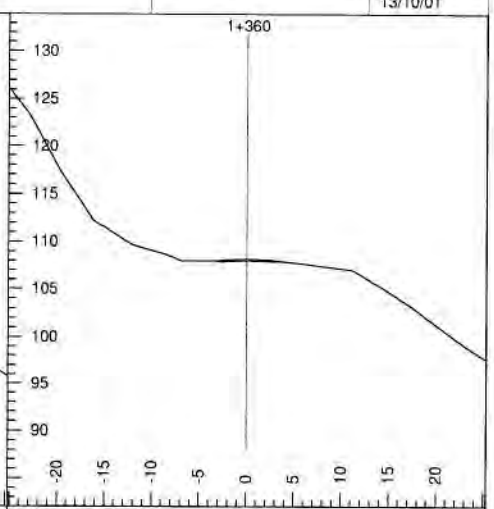
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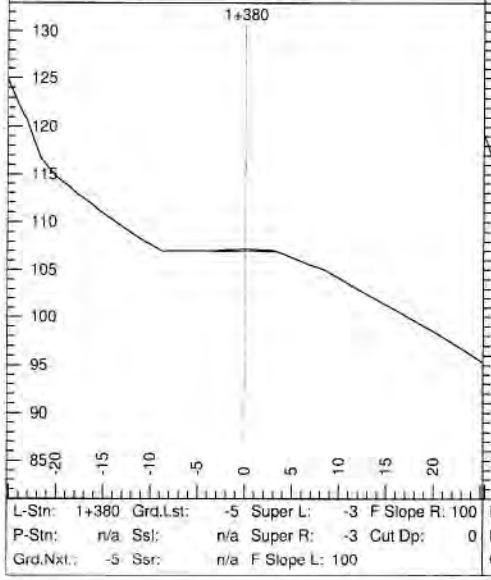
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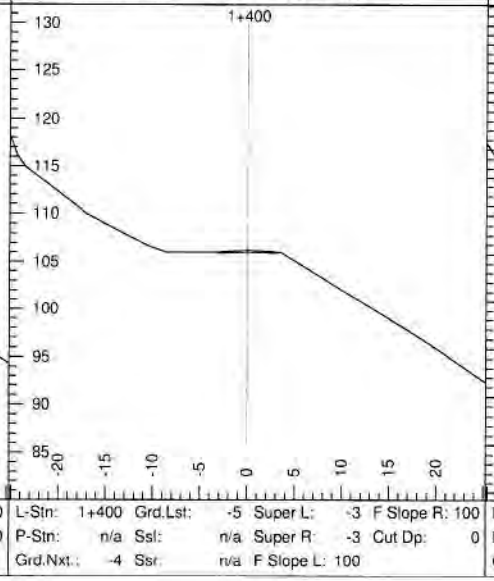


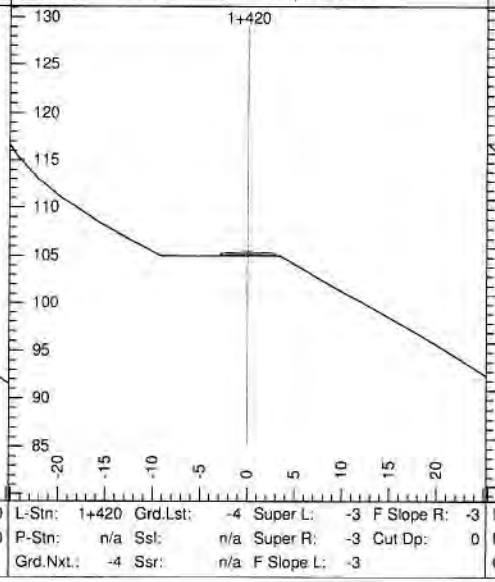



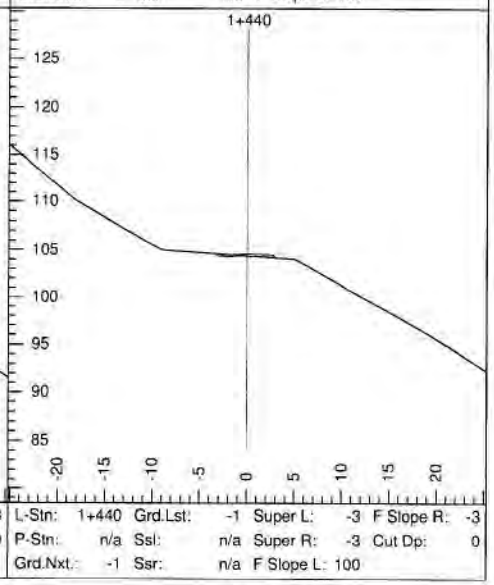



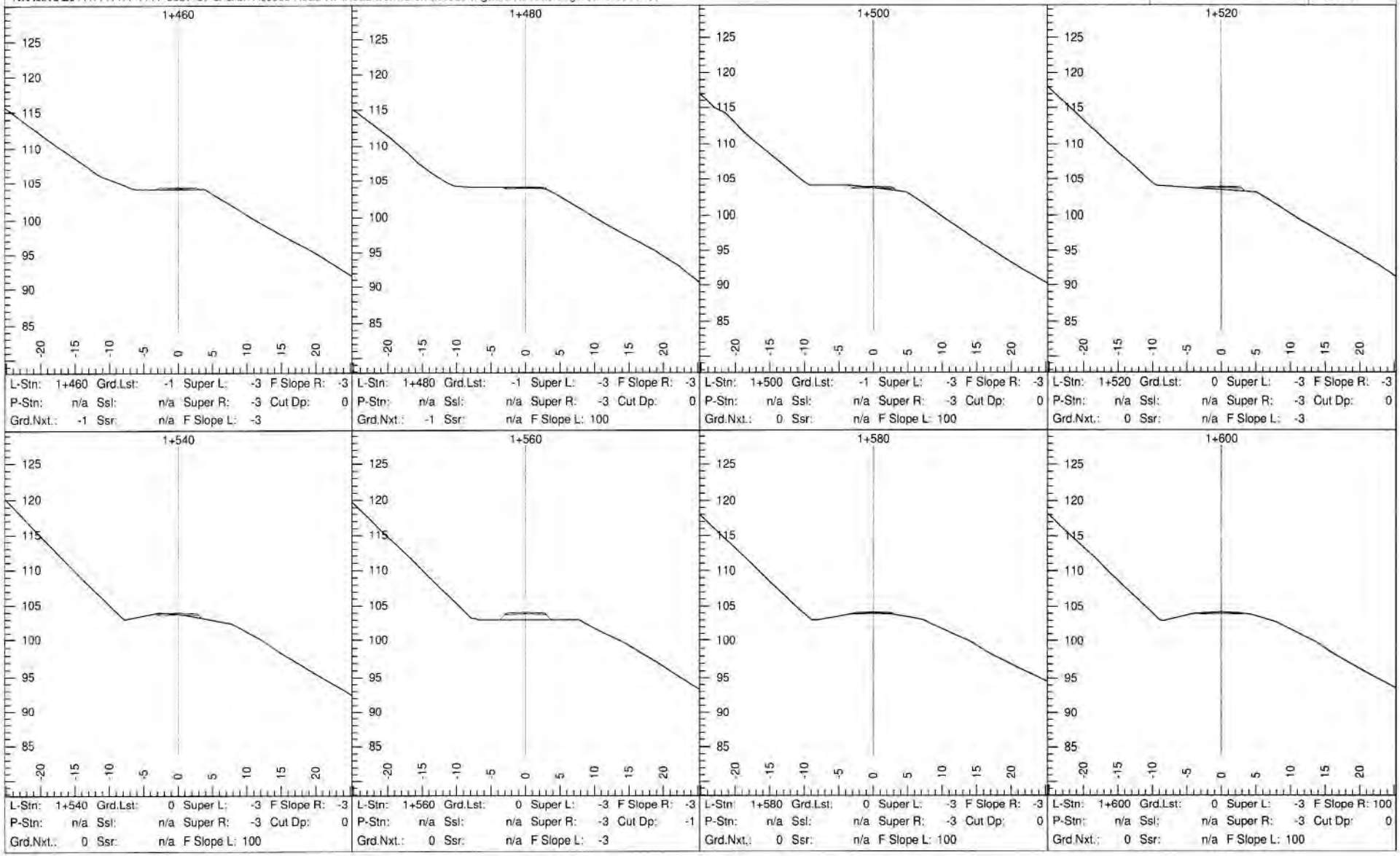




1+460
L-Stn: 1+460 Grd.Lst: -1 Super L: -3 F Slope R: -3
P-Stn: n/a Ssl: n/a Super R: -3 Cut Dp: 0
Grd.Nxt.: -1 Ssr: n/a F Slope L: -3
1+480
L-Stn: 1+480 Grd.Lst: -1 Super L: -3 F Slope R: -3
P-Stn: n/a Ssl: n/a Super R: -3 Cut Dp: 0
Grd.Nxt.: -1 Ssr: n/a F Slope L: 100
1+500
L-Stn: 1+500 Grd.Lst: -1 Super L: -3 F Slope R: -3
P-Stn: n/a Ssl: n/a Super R: -3 Cut Dp: 0
Grd.Nxt.: 0 Ssr: n/a F Slope L: 100
1+520
L-Stn: 1+520 Grd.Lst: 0 Super L: -3 F Slope R: -3
P-Stn: n/a Ssl: n/a Super R: -3 Cut Dp: 0
Grd.Nxt.: 0 Ssr: n/a F Slope L: -3
1+540
L-Stn: 1+540 Grd.Lst: 0 Super L: -3 F Slope R: -3
P-Stn: n/a Ssl: n/a Super R: -3 Cut Dp: 0
Grd.Nxt.: 0 Ssr: n/a F Slope L: 100
1+560
L-Stn: 1+560 Grd.Lst: 0 Super L: -3 F Slope R: -3
P-Stn: n/a Ssl: n/a Super R: -3 Cut Dp: -1
Grd.Nxt.: 0 Ssr: n/a F Slope L: -3
1+580
L-Stn: 1+580 Grd.Lst: 0 Super L: -3 F Slope R: -3
P-Stn: n/a Ssl: n/a Super R: -3 Cut Dp: 0
Grd.Nxt.: 0 Ssr: n/a F Slope L: 100
1+600
L-Stn: 1+600 Grd.Lst: 0 Super L: -3 F Slope R: 100
P-Stn: n/a Ssl: n/a Super R: -3 Cut Dp: 0
Grd.Nxt.: 0 Ssr: n/a F Slope L: 100

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com


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