GEOTECHNICAL EVALUATION REPORT
BLENHEIM-GILBOA POWER GENERATION FACILITY
ROCK CUT STABILIZATION
LOWER RESERVOIR SPILLWAY
GILBOA, NEW YORK

PREPARED FOR:

NEW YORK POWER AUTHORITY
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AUGUST 23, 2007

STATE OF NEW YORK
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1.0 INTRODUCTION

Tectonic Engineering & Surveying Consultants P.C. has completed an investigation of existing rock cuts located east of the Lower Reservoir Dam's spillway channel at the Blenheim-Gilboa Pumped Storage Power facility located between Blenheim and Gilboa, New York. It is our understanding that the investigation was requested by the New York Power Authority due to a recent rock cut failure that resulted in rocks falling on an adjacent manhole cover that provides access to the dam's lower level outlet controls. The purpose of the investigation was to identify whether future rock falls could be expected, and if yes, identify the most appropriate means to remediate the rock fall hazard at the site. This report presents the findings of the investigation, our assessment of the long-term stability of the cut, and our recommendations. Also presented are brief summaries of the performed scope of services and descriptions of the site and the performed investigation.

2.0 SCOPE OF SERVICES

The following services were performed for the New York Power Authority, herein referred to as Client:

- Review of readily available background materials including geologic maps, published literature, in-house information, and a topographic survey that was provided by the Client.
- Performance of field mapping to identify the characteristics of the rock mass comprising the rock outcrops that impact the stability of the cuts and the means by which the cut can be stabilized.
- Analysis of the results of the field mapping data.
- Preparation of this geotechnical engineering report describing the performed investigation, the findings and our recommendations.

3.0 SITE DESCRIPTON

The project site is located at the Blenheim-Gilboa Power Generating Station, which is located between Blenheim and Gilboa, New York, adjacent to the spillway channel of the Lower Reservoir Dam. The subject rock cuts are located within a sedimentary bedrock exposure that begins approximately 12 feet southeast of the spillway channel

and approximately 150 feet northwest of the crest of the dam as shown in Figure 1. The rock exposure containing the cuts projects out of the earthen embankment dam that impounds the Schoharie Creek. It is our understanding that the cuts were formed during the construction of the dam, which went into operation around 1972.

As shown in Figure 1, the rock cuts that were the subject of the investigation are located on the southwest side of an asphalt paved road and parking area that access and service entrance portals for the lower level outlet controls. These cuts are identified as Cuts A through E. There are also cuts located on the north side of the entrance driveway and the east side of the parking lot, but these are relatively small and were not addressed in the investigation.

The main rock cut approximately parallels the driveway as well as the crest of the dam. This cut is divided by a channel made for the installation of the lower level outlet piping. As identified in Figure 1, the main cut located southeast of the channel has been identified as Cut A and the cut to the northwest of the channel has been identified as Cut B. Photographs of Cuts A and B are shown in Figures 2 and 3, respectively. The channel, which is oblique to the main cut alignment, ranges in width from approximately 12 to 20 feet. The channel has an approximately 2 Horizontal to 1 Vertical backfill slope that results in two additional tapering rock cuts. These cuts are identified as Cuts C and D on Figure 1. Cut C bounds the east side of the channel and Cut D bounds the west side of the channel. A photograph of Cut C is shown in Figure 4. Cut D can be seen in the photograph of Cut B in Figure 3. The fifth cut, Cut E, is offset approximately 12 feet from the dam's spillway channel and approximately parallels the channel. A photograph of this cut is shown in Figure 4. The length, height and trend (the alignment expressed in terms of the compass orientation) of each of these cuts are identified in the following table:

Cut Identification	Approximate Length (feet)	Approximate Height (feet)	Approximate Trend (degrees)
A	60	8.5 to 20	320
B	30	26	320
C	25	0 to 20	358
D	45	0 to 26	353
E	50	0 to 26	43

Existing structures in the vicinity of the rock cuts include the previously referenced road and parking lot and the dam's spillway channel. The road has a width of approximately 15 feet where it passes between Cut A and the smaller rock cut located to the northeast of the road. The pavement of the road and adjacent parking area is variably located from approximately 6 to 18 inches from the toe of the rock cuts. The spillway channel is of concrete construction and it slopes down towards the parking area where there is a steel guard rail. Concrete of the spillway channel appears to extend to the edge of Cut E, which is roughly 12 feet from the crest of the channel.

Other structures in the area include two entrance portals to the lower level outlet controls. One is an above ground structure located within the parking lot. The second consists of a concrete slab with a manhole located adjacent to the asphalt pavement of the driveway and several feet from the toe of Cut D.

Rock cuts A through D appear to have been originally formed approximately vertically through the apparent use of line drilling and/or post-split blasting. Half circumference holes can be observed on these cuts within the more resistant sedimentary beds at spacings estimated to range from 6 to 16 inches. Within Cut D, there are areas where the upper beds were not trimmed back to the holes leaving them overhanging the lower beds.

All of the investigated rock cuts were highly irregular in profile due to the differential weathering of individual beds of the sedimentary rock comprising the cuts. More easily eroded beds locally resulted in the undermining of overlying, more resistance beds by

distances up to several feet. Undermined beds had locally failed and blocks ranging from cobble size up to several cubic feet were observed on the slope between the cuts made for the lower level outlet. Based on discussions with site personnel, we understand that some of these blocks had fallen on the manhole and surrounding concrete slab adjacent to the cut. Undermined beds of more resistance rock layers within Cuts B and D can be seen in the vicinity of the referenced manhole in Figure 3. Figure 4 shows undermined beds near the intersection of Cuts A and C.

4.0 INVESTIGATION

The geotechnical investigation consisted of the performance of geologic structure mapping of the previously identified rock cuts on April 10, 2007. The mapping, which was performed by a licensed Professional Engineer and Professional Geologist, consisted of identifying the presence of naturally occurring discontinuities within the rock, and where present, identifying the orientation and the characteristics of the discontinuities that influence the shear strength of the discontinuities. Specifically recorded were the dip and dip direction of the discontinuities and the variation of the dip and dip direction over the length of the discontinuities. Also recorded were the discontinuity's spacings and lengths, how the discontinuities are terminated, and the discontinuities roughness and infilling characteristics. Observations were also made of the rock composition and the degree of weathering. Results of the mapping are described in Section 5 of this report.

5.0 GEOLOGY AND ROCK CUT CONDITIONS

The following subsections present a summary of the regional geology, descriptions of the general rock characteristics and descriptions of the mapped discontinuities.

5.1 Regional Geology

The regional bedrock geology at the site consists of sedimentary units of the Genesee Group, Gilboa Formation, which are marine units that are underlain and overlain by sandstones laid down in fresh water (Isachsen et al., eds. 2000). The uppermost and youngest layers are comprised of siltstones, mudstones and

shales from the Devonian Era. Underlying this are older layers of softer shale and harder, more durable sandstones. Within these units are inter-layered calcareous mudstones.

5.2 General Rock Characteristics

The rock comprising the cuts was observed to consist of gently inclined, interbedded layers of sandstone, siltstone, mudstone and shale of varying degrees of hardness and weathering. Generally, the upper 7.5 to 9 feet consists of thinly bedded shale layers separated by approximately 1.5 to 2 feet thick layers of siltstone. These are underlain predominately by thickly bedded sandstone layers with occasional layers and seams of shale, mudstone and siltstone.

The sandstones layers are typically fine to medium grained, slightly to moderately weathered and hard. The shale layers are typically soft to moderately hard and moderately to highly weathered. The shale layers are often fissile, being easily split along bedding planes, and they are often friable, being easily crumbled in hand. The siltstone layers are thinly to moderately bedded, soft to moderately hard, and moderately weathered. The mudstone layers exhibit similar hardness and weathering characteristics as the shale and they are occasionally friable.

5.3 Discontinuity Characteristics

Figure 5 shows the combined rock structure data obtained from the mapping of rock cuts. This data is presented in stereographic projection on a stereonet with each point on the stereonet representing a bedding plane or a joint identified during the investigation. An explanation of the interpretation of the figure is included following Figure 5. As can be seen from this figure, the discontinuities can be divided into three general, approximately orthogonal sets.

The dominant discontinuity set, identified as Set 1, consists of bedding planes whose dip directions typically range from approximately 290 to 335 degrees and averages approximately 318 degrees. The bedding planes dip at angles varying from 2 to 16 degrees and have an average dip of approximately 8 degrees. The spacing of the bedding plane surfaces varies with rock type. As noted, the shale and siltstone layers were typically thinly bedded with bedding planes surfaces occurring at spacings ranging from fractions of an inch to several inches. The sandstone layers were more thickly bedded with bedding plane surfaces occurring at spacings ranging from several inches to several feet. The mudstone occurs in relatively thin layers. The bedding plane surfaces, by nature, are highly persistent, often being traceable for the length of the rock cuts. The bedding plane surfaces are typically rough and undulating to rough and irregular.

The second most common discontinuity set, identified as Set 2, consists of joints that dip down steeply to the northwest, or occasionally, are overturned and dip down steeply to the southeast. Where not overturned, these joints have dip directions ranging from 275 to 315 degrees and averaging 296 degrees. They have dips ranging from 78 to 89 degrees and averaging 85 degrees. This joint set was observed to have spacings ranging from 0.5 feet to 7 feet along the lines mapped. The average spacing of this joint set was slightly over 3 feet. The measured persistence of this joint set ranged from 2 to 14 feet but most typically was in the range from 5 to 8 feet. They typically terminated at bedding plane contacts with other rock types. The joint surfaces were typically rough and irregular and they were often stepped. They also have highly varying aperture widths ranging from being very tight up to having joint wall separations ranging up to several inches being displaced by the excavation and/or weathering processes.

The third identified joint set dips down steeply to the northeast. This joint set has dip directions that range from 13 to 57 degrees and average 31 degrees and dips that range from 75 to 89 degrees and average 85 degrees. They are relatively

infrequent and they have low persistence, only being noted within isolated beds in the cut orientations where these joints would be most prominent; cuts C, D and E. In beds containing these joints, they had spacings ranging from approximately 1.5 feet to over 15 feet. The observed persistence ranged up to approximately 2 feet. These joints are also generally rough and irregular and they have apertures ranging from being tight up to several inches, being displaced by the excavation and/or weathering processes.

There were also several isolated joints mapped that slope down steeply to the southwest. These joints have similar characteristics to Set 2 except that they are much less common.

No groundwater seepage was observed from the rock cut during the site visit. However, minor seepage was previously observed from the rock cuts during a prior site visit on January 22, 2007. These were evidenced by minor ice flows.

6.0 DISCUSSION AND DESIGN CONSIDERATIONS

Since the identified discontinuities are either shallowly dipping bedding planes or steeply dipping jointing, the rock cuts are not subject to the development of large scale plane shear or wedge shaped failure geometries. The shear strength along the bedding planes surfaces provides a sufficient factor of safety against sliding failure along these discontinuities when incorporating probable water pressure distributions and seismic loading. Although the Set 3 joints fall in a plane shear orientation for the main rock cuts fronting the road and parking area, Cuts A and B, the combination of their steepness and limited occurrence and persistence result in their only being capable of contributing to minor localized back-break. It is noted also that if the cut is shallower that the dip of the Set 3 joints, which ranged from 75 to 89 degrees, these joints would result in no back-break. Similar conclusions can be made for the joint sets impacting Cuts C, D and E, whether acting singly in plane shear or in combination with a second joint set in forming wedges whose line of intersection slopes down very steeply.

The operating failure mechanism is therefore one of progressive raveling resulting from the differential weathering of the shale, siltstone and mudstone beds and the resulting undermining and failure of the more competent sandstone beds. Failure of these blocks will occur when the beds are undermined to a degree that it reaches a natural discontinuity and can fall loose or it fails through flexure. The former is believed to be the case for the failure that impacted upon the manhole structure. As this is a progressive failure mechanism, future rock falls should be anticipated. It is estimate that failures on the order of several hundred pounds to several tons can occur in the near future along Cut C where it meets Cut A, the area depicted in Figure 4. Similar sized failures can occur along Cut B and along Cut D where it meets Cut B, the area that can be seen in Figure 3. Smaller raveling type failures appear more likely in the section of Cut A away from Cut C and the section of Cut E away from Cut B.

As New York Power Authority personnel and their contractors need to access areas adjacent to the cuts, either by driving adjacent to the cut in a vehicle or walking near the toe accessing the manhole, remedial measures need to be incorporated to protect people and property from rock falls. The traditionally utilized remedial measures are broken down into three general groups: installing stabilization measures to prevent rock falls; providing passive measures to safely contain rock falls, or modifying the rock cut geometry to be in a stable configuration. For this site, the possible stabilization measures include the performance of scaling, localized trimming and the application of shotcrete and/or cast concrete in combination with drains to bind and support the rock and prevent future raveling. Passive stabilization measures include the installation of cable nets in conjunction with the scaling and localized trimming of large unsupported rock slabs. Rock cut geometry modifications would involve forming the cuts to have a batter such that back-break along the discontinuities can be minimized or eliminated, and in the process, removing the highly weathered, undercut zones comprising the existing cuts. The new cut face would be formed utilizing line drilling techniques so that the cut is minimally disturbed. It is noted that the new cuts could also be benched, forming two rock cuts with heights ranging up to approximately 13 feet separated by a sub-horizontal bench. This offers the advantage that in the event of a future rock fall, the fall height, and consequently, the

energy of the impact is reduced. However, based on the previously described rock characteristics and the total height of the bedrock exposures, the additional expense associated with line drilling the second cut and the excavation of the additional rock is not considered warranted.

Of these options, reforming the cut is preferred as it does not require having personnel work near the toe of the unstable cuts. Crawler mounted hydraulic drills can perform the line drilling safely behind the crest of the cut. Once the line drilling is completed, the rock can be trimmed back to the line drilled holes using an excavator, a small hoe-ram or by hydraulic splitters (wedges) operated from a man lift. The removed rock material can be loaded with an excavator or loader. The other methods would require personnel utilizing hand tools working on the face of the cut or near the toe of the cut. The longevity of this stabilization approach can be conservatively gauged based on the time frame over which the cuts weathered into their present unstable condition. If the subject cuts were formed at the time the main dam was constructed, the time frame could be on the order of 25 to 35 years. This estimate is indicated to be conservative as the proposed line drilling and excavation methodology described in the following section should produce a more stable cut that originally created. The main drawback to this proposed methodology is that rock debris will fall on the manhole structure. Although the manhole and surrounding concrete pad can be protected by a steel road plate, access to the manhole will be at least temporarily restricted.

As it has been indicated that it is not known when the recommended stabilization measures could be implemented, consideration should be given to implementing temporary stabilization and protection measures until the permanent stabilization is completed. Temporary stabilization should include the installation of concrete "Jersey" barriers placed to contain rock falls and keep vehicles away from the toe of the cuts. It should also include the performance of localized scaling and trimming of the rock cuts in the area of the manhole structure. Recommendations for temporary stabilization are provided in Section 7. It should be emphasized, however, that these interim containment and stabilization measures are not the equivalent of the permanent stabilization measures

and that rock falls may still occur. The area of most concern is in the vicinity of the manhole structure. Although it is unlikely that a failure would occur at the time personnel are accessing the manhole, the possibility does exist. Therefore, we do not recommend accessing the manhole prior to completing the permanent stabilization unless it is an emergency situation.

7.0 RECOMMENDATIONS

The following provides recommendations for the permanent and temporary remediation of the rock cuts.

7.1 Permanent Stabilization

As discussed in Section 6, we recommend that the rock cut be stabilized by reforming the cut to a more stable configuration. To achieve this, we recommend that the rock cut be trimmed as indicated on the attached Typical Rock Cut Section, Figure 6. As indicated on the section, we recommend that the rock cut be line drilled with 3-inch diameter holes at spacings ranging from 6 inches to 12 inches and at a batter not exceeding 70 degrees. The utilization of this maximum slope angle will minimize or preclude the chance of encountering a joint or combination of joints on the relocated cut line that could result in localized back-break of the cut and localized undermining. The exact hole spacing required will need to be identified during the performance of the slope modifications based on the degree of cut disturbance that results from the larger hole spacing. The cut line will need to be located so that it passes behind the highly eroded rock zones near the base of the cuts.

Rock would then be excavated utilizing an excavator or a small hoe-ram. If excessive breakage of the upper shale and siltstone dominated layers occurs utilizing this equipment, the final cut face may need to be exposed utilizing hydraulic splitters within the lined drilled hole.

All of the rock cuts except Cut E should be formed in this fashion. Cut E can be sufficiently stabilized by scaling.

7.2 Temporary Stabilization

As discussed in Section 6, temporary stabilization measures should include the installation of concrete "Jersey" barriers to keep vehicles away from the toe of the rock cuts and to contain rock falls. The Jersey barriers should be installed in a continuous row on the asphalt pavement adjacent to Cuts A and B. They should also be installed in the area between Cuts A and B in a configuration that will prevent rocks from rolling or sliding into the manhole structure. This will require local regrading and possibly the utilization of smaller sections of concrete barriers. The concrete barriers should be located at a minimum distance of 4 feet from the toe of the cuts.

The temporary stabilization should also include the scaling and trimming of the cuts in the vicinity of the manhole structure as directed by the geotechnical engineer. This includes Cut B near the intersection of Cut A, and Cuts C and D near their intersection of these cuts. The trimming should be performed utilizing drilling and hydraulic wedges. The hole spacing and location should be as directed by the geotechnical engineer.

8.0 PRELIMINARY CONSTRUCTION COST ESTIMATE

The cost of the proposed rock cut modifications has been preliminary estimated to range between $125,000 and $175,000. This is based on RSMeans Heavy Construction Cost Data assuming line drilling on 9 inch spacings and hauling removed rock 1 mile for disposal.

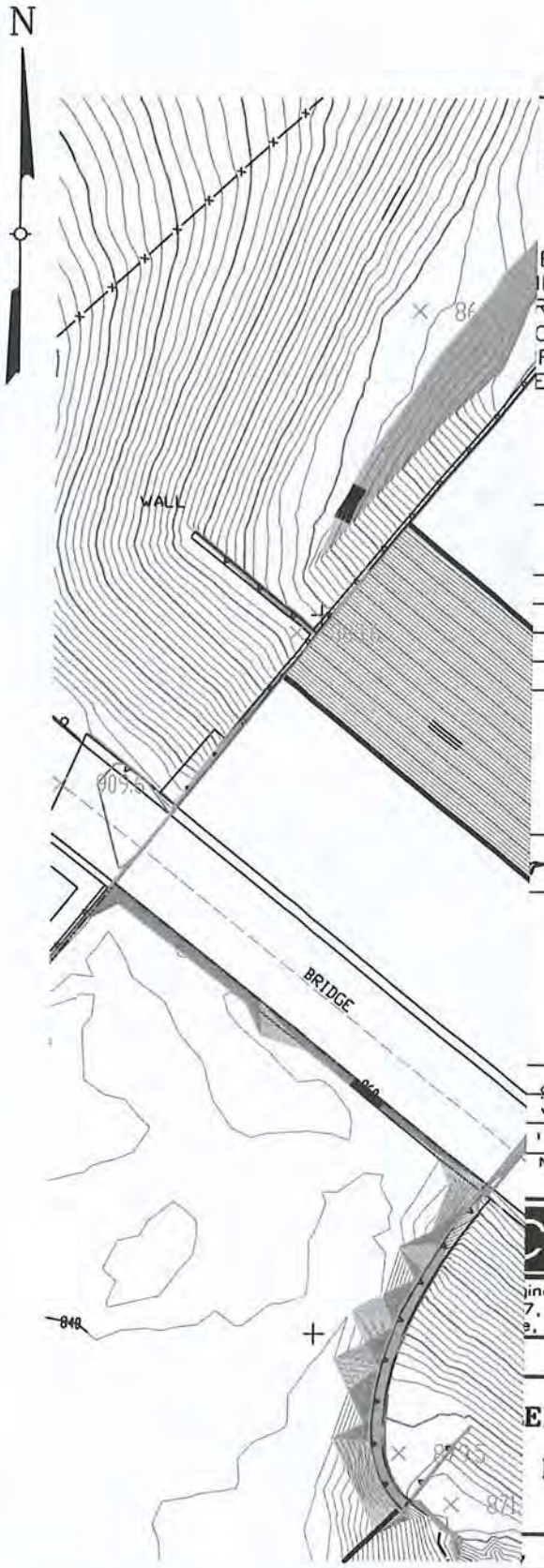
9.0 LIMITATIONS

This report has been prepared for the exclusive use of the New York Power Authority for the specific application to the rock cut evaluation detailed in this report. Our professional services have been performed using that degree of care and skill ordinarily

exercised under similar circumstances by reputable geotechnical engineers and geologists practicing in this or similar situations. The interpretation of the field data is based on good judgment and experience. However, subsurface conditions cannot always be predicted beyond the points of actual observation. No other warranty, expressed or implied, is made as to the professional advice included in this report.

GPM \G:\Geo\4730 Gilboa Rock Slope\4730geoinv_report Rev 3.doc

FIGURES



NOTES

BASED ON A FIELD SURVEY BY TVGA

ENTITLED: "NEW YORK POWER AUTHORITY
EIM-GILBOA PUMPED STORAGE PROJECT -
R RESERVOIR 2004 BATHYMETRIC AND
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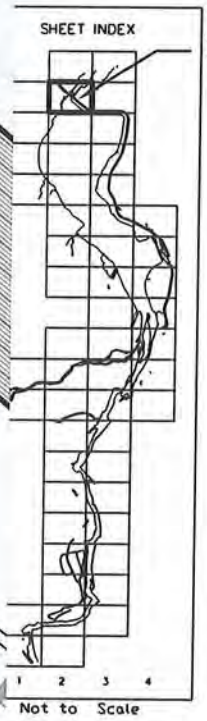

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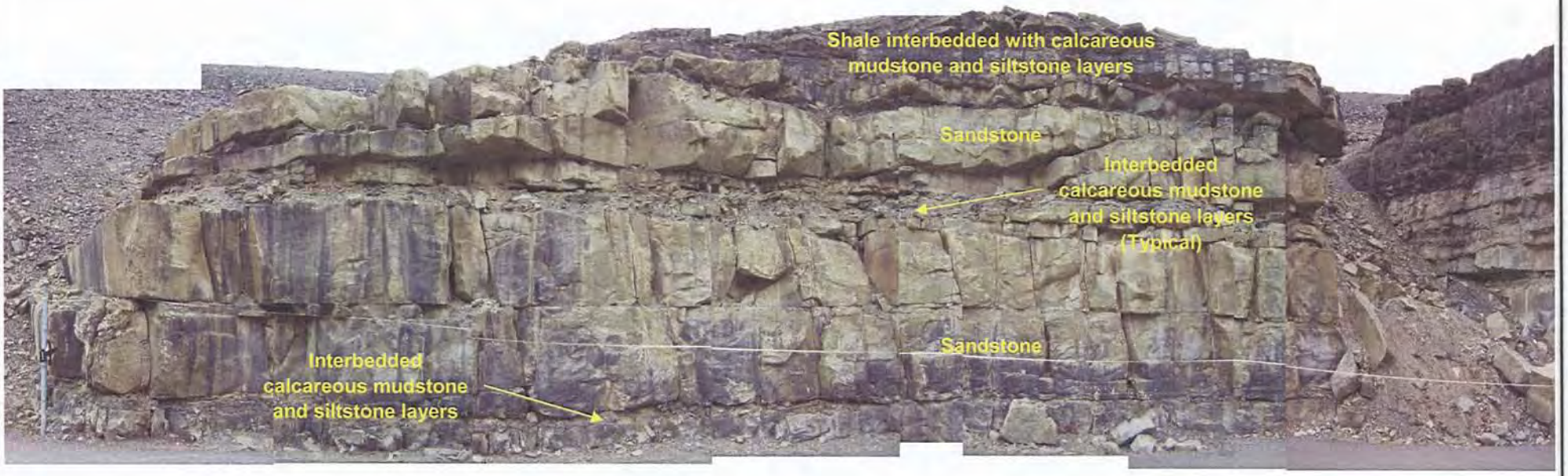
ROCK CUT LOCATION PLAN

ENHEIM-GILBOA POWER FACILITY
ROCK CUT STABILIZATION
LOWER RESERVOIR SPILLWAY
GILBOA, NEW YORK

Work Order	Drawing No.	Rev
4730.01	FIGURE 1	0



Photographs taken by G. Murphy
Tectonic Engineering & Surveying Consultants P.C.
April 10, 2007

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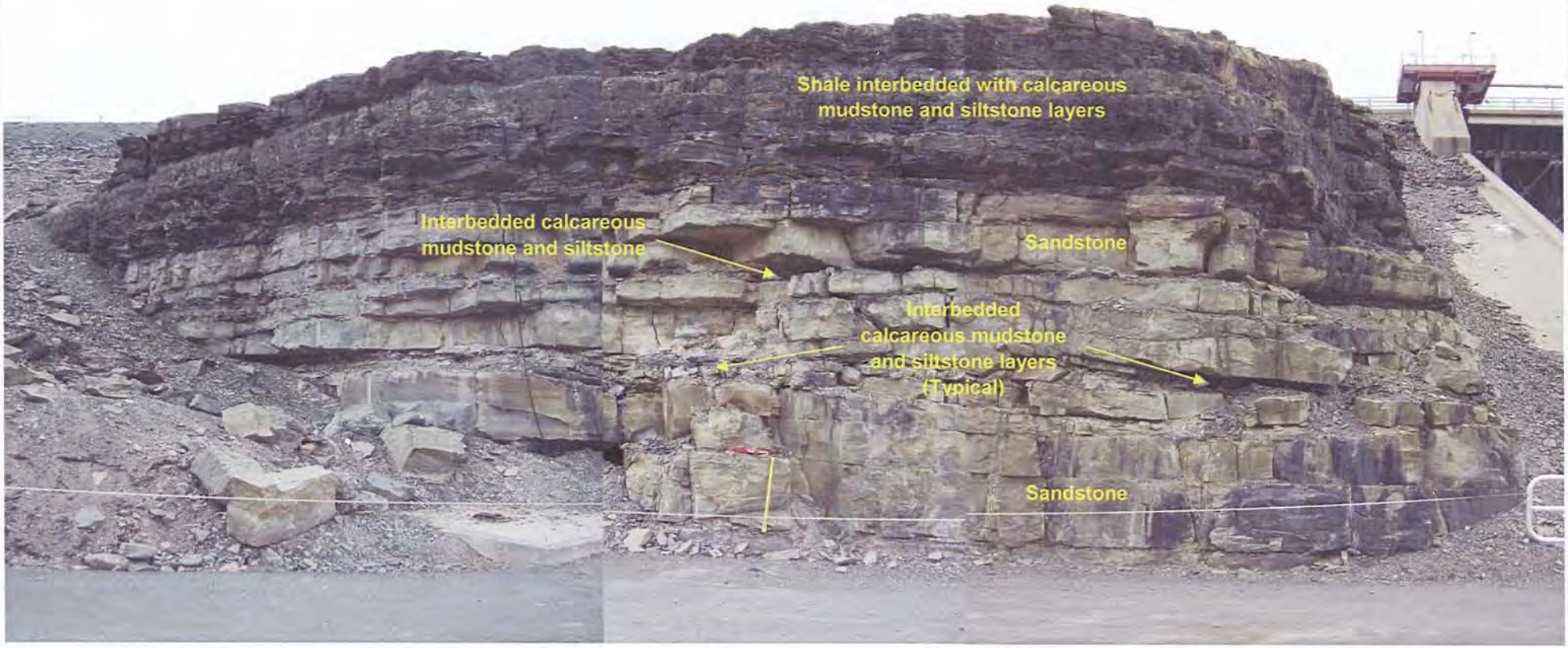
ROCK CUT A

BLENHEIM-GILBOA ROCK CUT STABILIZATION
LOWER RESERVOIR SPILLWAY
BLENHEIM-GILBOA, NEW YORK

Date 4/16/07	Work Order	Drawing No.	Rev
Scale NTS	4730.01	FIGURE 2	0



Photographs taken by G. Murphy
Tectonic Engineering & Surveying Consultants P.C.
April 10, 2007

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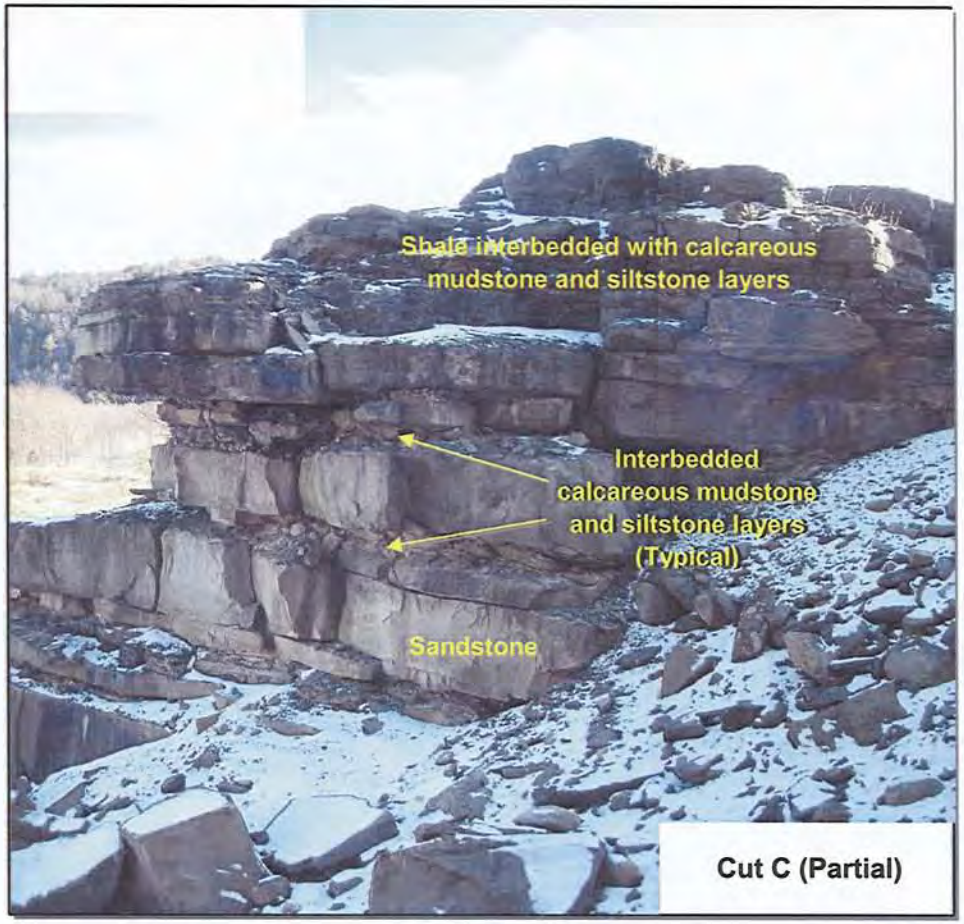
ROCK CUTS B & D

BLENHEIM-GILBOA ROCK CUT STABILIZATION
LOWER RESERVOIR SPILLWAY
BLENHEIM-GILBOA, NEW YORK

Date 4/16/07	Work Order	Drawing No.	Rev
Scale NTS	4730.01	FIGURE 3	0



Cut C (Partial)

Cut E

Photographs taken by G. Murphy
Tectonic Engineering & Surveying Consultants P.C.
January 22, 2007

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ROCK CUTS C & E

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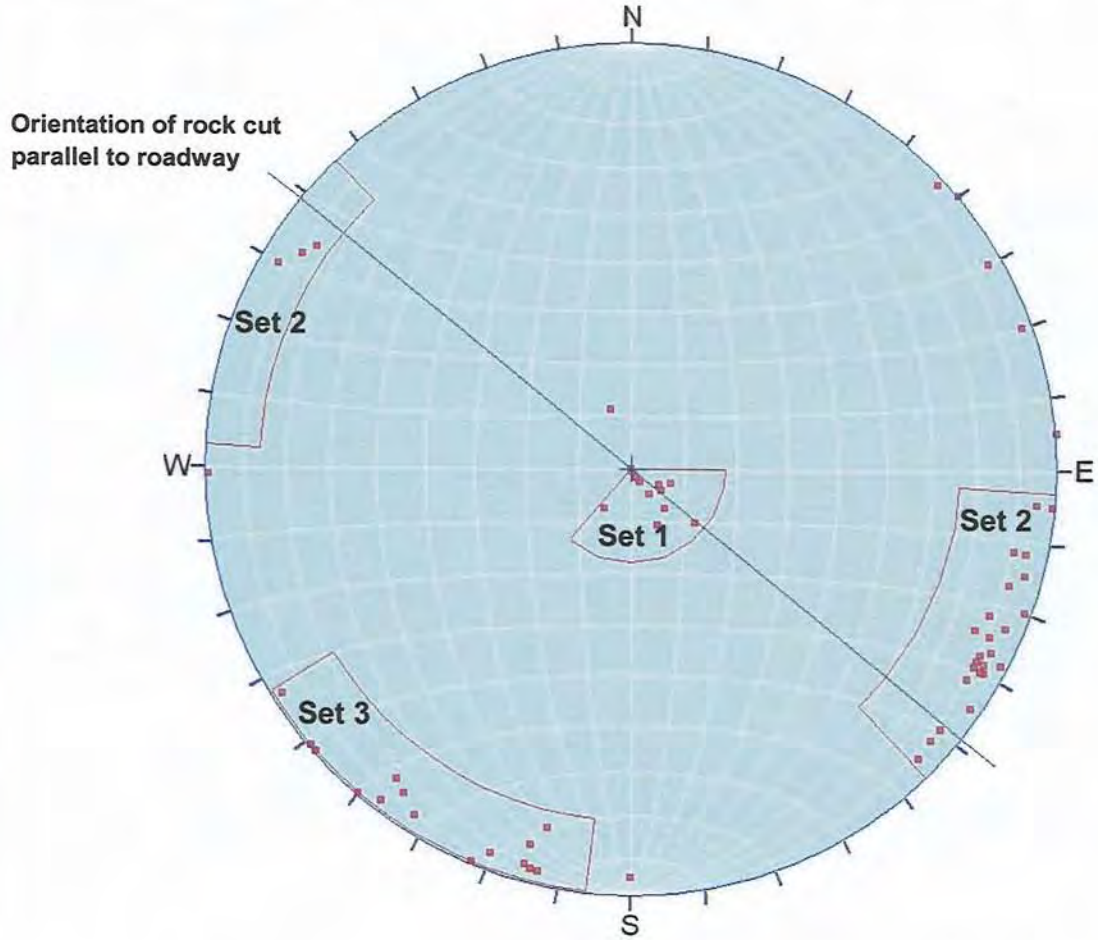
LOWER RESERVOIR SPILLWAY
BLENHEIM-GILBOA, NEW YORK

Date 4/16/07	Work Order	Drawing No.	Rev
Scale NTS	4730.01	FIGURE 4	0



Poles

Equal Area
Lower Hemisphere
63 Poles
63 Entries

Combined Discontinuity Data From All Sources

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STEREOGRAPHIC PROJECTION

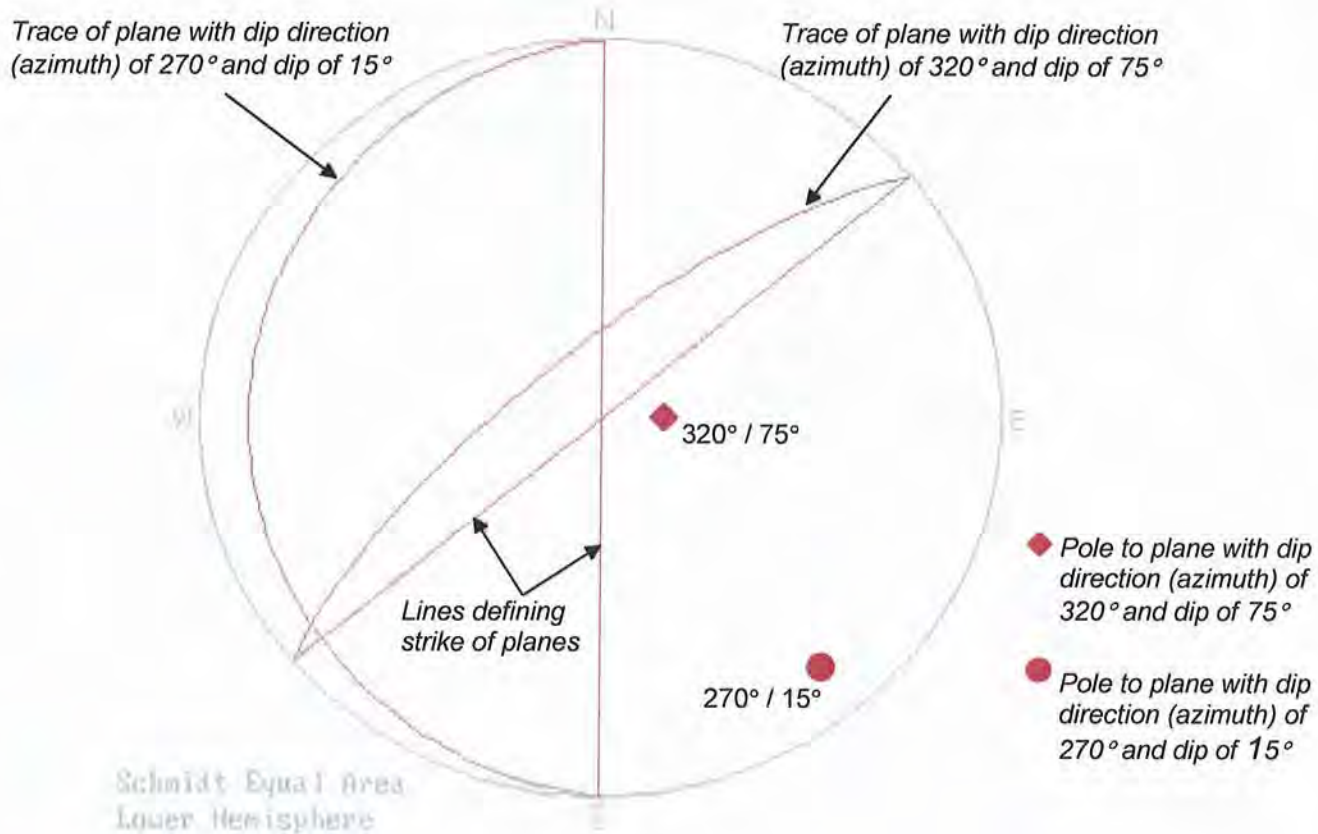
BLENHEIM-GILBOA ROCK CUT STABILIZATION
LOWER RESERVOIR SPILLWAY
BLENHEIM-GILBOA, NEW YORK

Date 4/16/07	Work Order	Drawing No.	Rev
Scale NTS	4730.01	FIGURE 5	0

INTERPRETATION OF STEREONETS

The analysis of structural geology data involves the plotting of poles representing the origin of each discontinuity. This technique aids in identifying discontinuity sets, for which both the average orientation and the scatter (dispersion) can be determined. The stereonet can be interpreted utilizing the geometries identified in the figure below. The orientation of a plane such as a joint can be shown in the two dimensions of a stereonet by the trace that the plane would make passing through the lower hemisphere of an imaginary sphere, with the plane passing through the center of the sphere. All non horizontal and non vertical planes form an arc shaped trace where it intersects the lower hemisphere. The steeper the dip angle of a plane, the narrower the arc that is formed on the stereonet. Vertical planes form a line and horizontal planes form a perfect circle. The midpoint of the arc points in the down dip direction of the represented plane. The line connecting the end points of the arc define the direction of strike of that plane.

Representation of Planes and Poles to Planes on Stereonet



To allow easier interpretation of multiple planes on a single stereonet, the planes are plotted as single points oriented normal (at 90 degrees) to the plane. These points in a stereographic projection are referred to as *poles to the plane*, and plot diametrically across from the line defining the strike of the plane. Therefore, as shown in this figure, a pole plotting slightly east (to the right) of the center of the circle qualitatively indicates that the plane dips down to the west at a shallow angle. A pole plotting close to the southeast edge of the circle represents a steeply dipping plane dipping to the northwest.

CONCEPTUAL ROCK CUT STABILIZATION DETAIL

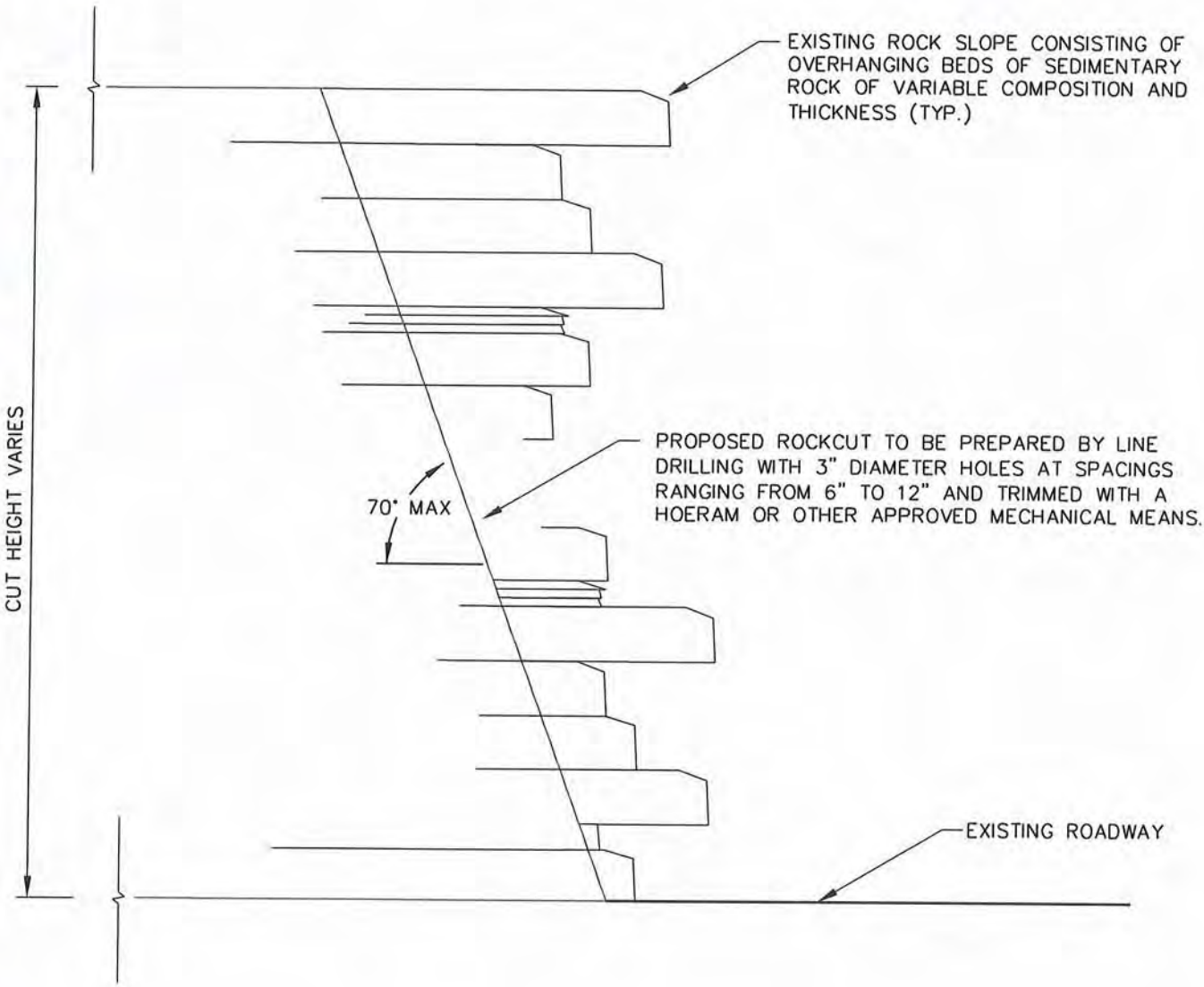


FIGURE 6

BLENHEIM-GILBOA ROCK CUT STABILIZATION
LOWER RESERVOIR SPILLWAY
GILBOA, NEW YORK

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05/10/2007
Revision 0

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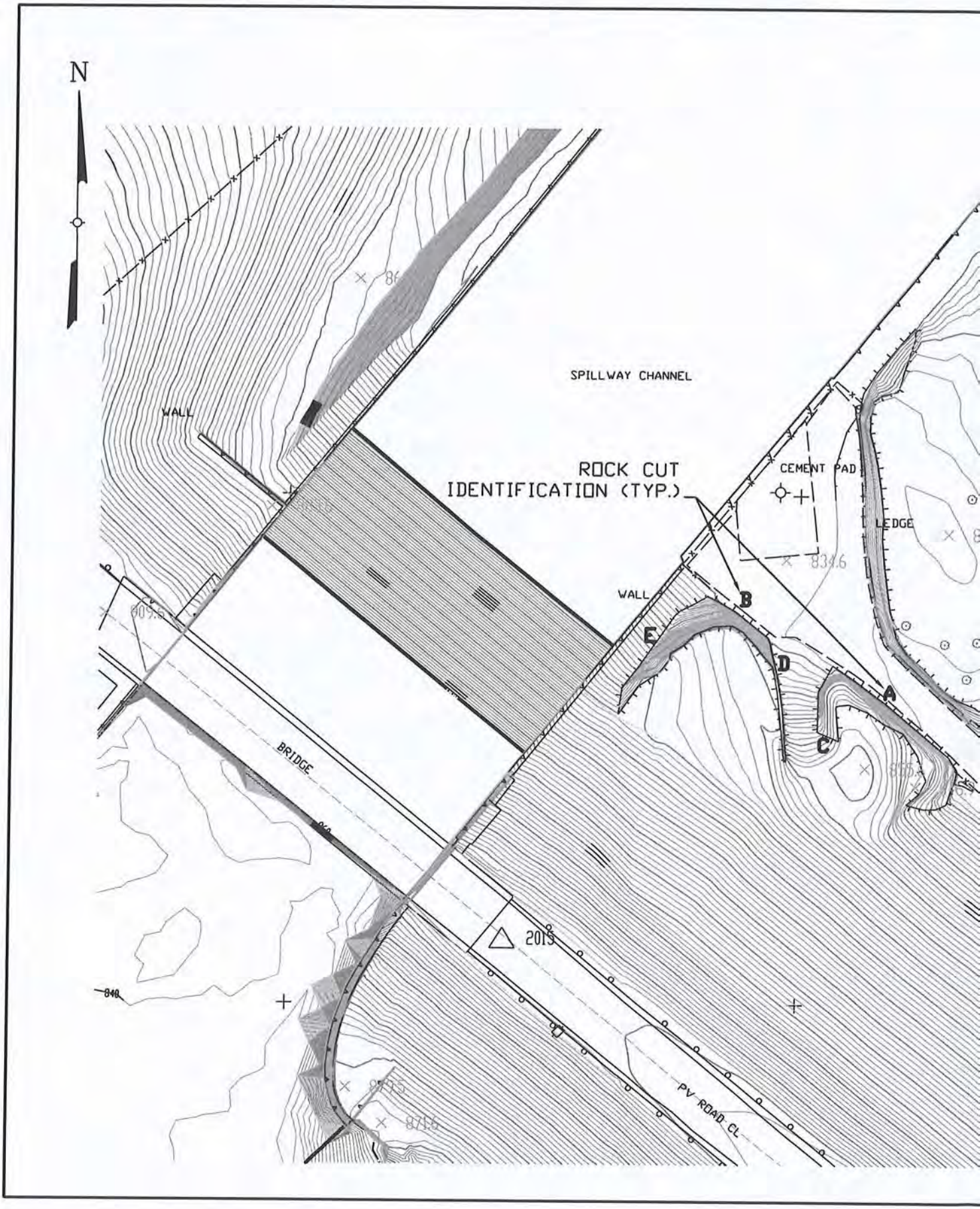
N
SPILLWAY CHANNEL
WALL
ROCK CUT
IDENTIFICATION (TYP.)
CEMENT PAD
LEDGE
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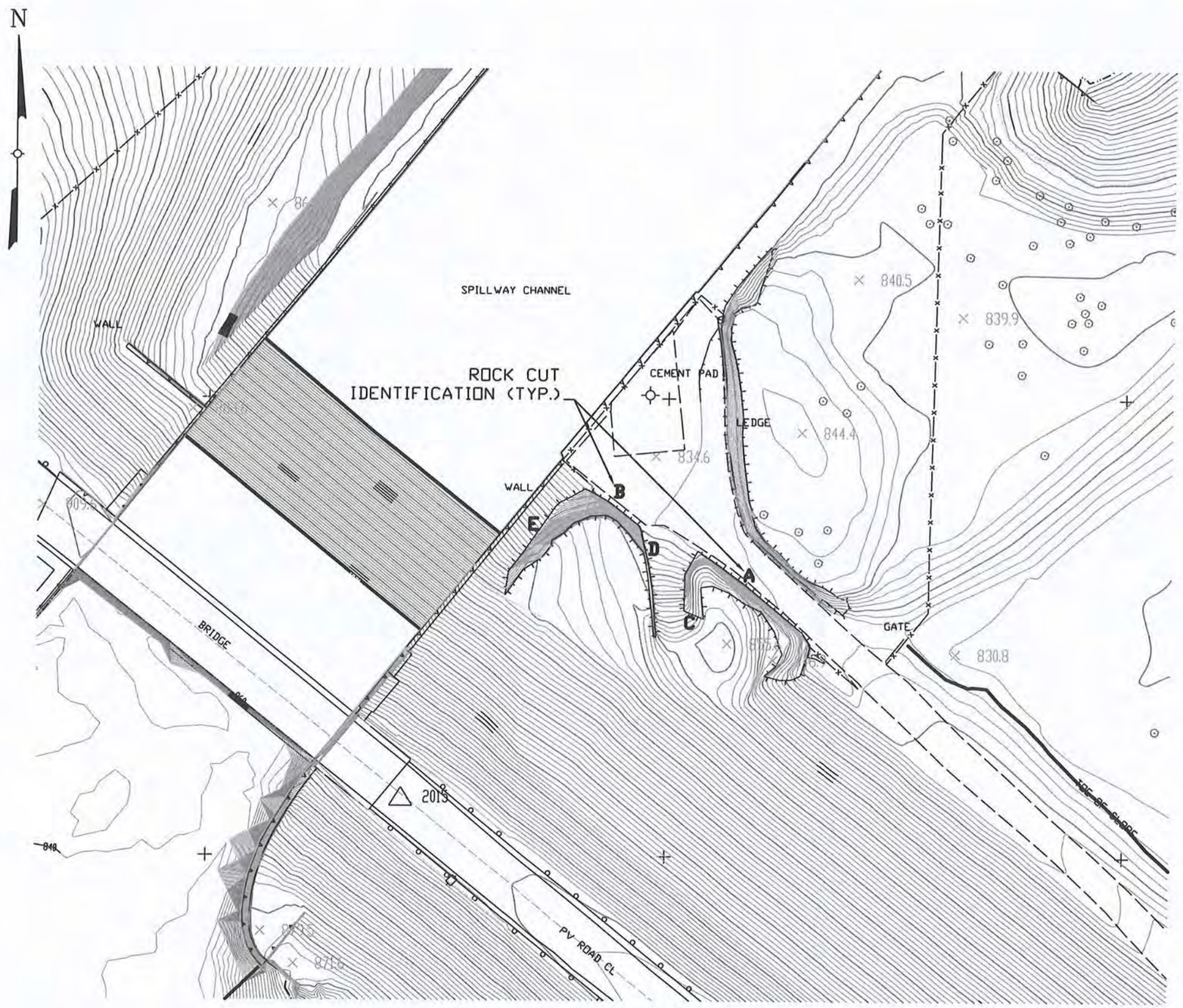
2015
PV ROAD CL

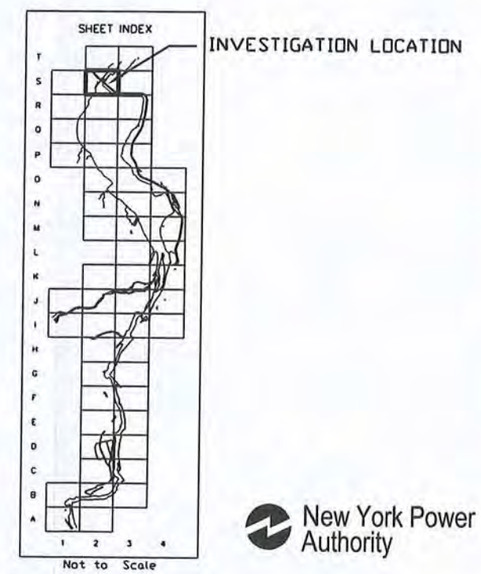


GENERAL NOTES

1. THIS PLAN IS BASED ON A FIELD SURVEY BY TVGA CONSULTANTS.

REFERENCES:

(A) MAP ENTITLED: "NEW YORK POWER AUTHORITY BLENHEIM-GILBOA PUMPED STORAGE PROJECT - LOWER RESERVOIR 2004 BATHYMETRIC AND PHOTOGRAMMETRIC SURVEY," DRAWING SHEET NO. 2S, PREPARED BY TVGA CONSULTANTS, 1000 MAPLE ROAD, ELMA, NEW YORK 14059-9530.



New York Power Authority

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ROCK CUT LOCATION PLAN

BLENHEIM-GILBOA POWER FACILITY
ROCK CUT STABILIZATION
LOWER RESERVOIR SPILLWAY
GILBOA, NEW YORK

Date	Work Order	Drawing No.	Rev
04/27/2007	4730.01	FIGURE 1	0
Scale 1"=50'			