ALBERTA INFRASTRUCTURE
LANDSLIDE RISK ASSESSMENT

SECTION A: GEOTECHNICAL FILE REVIEW

PEACE REGION
(SWAN HILLS)

SITE SH1: SWAN HILLS RETAINING WALL

LEGAL LOCATION:	**5-67-9-W5M**
NEAREST LANDMARK:	**9 KM NORTH OF SWAN HILLS**
Highway Control Section:	**HWY 33:12**
Date of Initial Observation:	**1969**
Date of Last Inspection:	**1999**
Last Inspected By:	**GAEA Engineering Ltd. (GAEA)**
Instruments Installed:	**21Slope Inclinometers (4 in 1990, 7 in 1991, 3 in 1992 and 7 in 1994), 7 Pneumatic Piezometers (4 in 1990 and 3 in 1994)**
Instruments Operational:	**4 Slope Inclinometers, 4 Pneumatic Piezometers (2000)**
Risk Assessment:	PF(8) * CF(4) = 32

1. LOCATION

The site is located along Hwy 33:12 about 9 km north of Swan Hills as shown on Figure SH1-1, Section F.

2. GENERAL DESCRIPTION OF SLOPE INSTABILITY

The site stretches over a 400 m long section of highway oriented approximately in a south to north direction. The south 200 m of the highway is located in a sidehill cut with a 30 m high steep backslope on the east side. The north 200 m of highway crosses a gully with an embankment fill height of 10 to 14 m, as shown on Figures SH1-2 and SH1-3, Section F.

The site has had a long history of instability going back to 1969, 2 years after initial construction, when the backslope area failed and took out the 1200 mm CSP at the gully crossing. The highway was relocated 30 m to the east and the slumped material was used to infill the gully on each side of the highway, effectively blocking off natural runoff and groundwater that previously ran through the gully area.

Ongoing instability of the backslope and highway fill at the gully crossing was treated over the period from 1969 to1989 by the following methods:

- Highway surface maintenance initially with imported pit run gravel and later (after paving) with asphalt to maintain a smooth surface
- Installation of a Big O subdrain below the upslope (east) highway ditch and horizontal drains at various locations below the highway

In 1989, an 81 m long reinforced concrete pile wall was installed along the shoulder of the embankment fill to try to stabilize the slide. However the wall did not extend deep enough and movements continued. In 1992 two rows of tie-back anchors were installed to anchor the wall to the bedrock below the slip surface of the slide.

The approximate locations of the drainage measures and the pile wall are shown on Figure SH1-2, Section F. A detail of the subdrain installation and one of 4 culverts used to drain the seepage water from the subdrain to the west side of the highway, is provided on Figure SH1-4. Details of the pile wall and tie back anchors are shown on Figures SH1-5 through SH1-8, Section F.

Over the years several slope indicators and pneumatic piezometers have been installed at various locations along the site to monitor ground movements and piezometric levels. The locations of the instruments are shown on Figure SH1-2, Section F and the test hole logs and deflection plots for discontinued SI's are included in Section G. Only 4 SI's and 4 pneumatic piezometers are still functional and the latest readings for these are provided in Sections C and D.

The recent and previous readings have been reviewed and the depth of the slide shear zone at each SI location is noted on Figure SH1-2, Section F. Where no definite slip zone is apparent, the word neg. (negligible) has been noted. In the SI's where ongoing movements have been observed, the creep rate of the slide since tie-back installation, has been estimated and indicate that the tie-back anchors have reduced the creep rates over the north 2/3 of the wall to about 3 to 6 mm/year. Over the south 1/3 of the wall the creep rate is slightly higher (15 mm per year) and over a distance of about 70 m south of the wall the creep rate is significantly higher (45 to 50 mm/year.

Notes available in the files suggest that most of the previous drainage measures are likely no longer functional or are currently functioning at a limited capacity.

The SI's suggest that the instability in the high backslope cut is likely not currently directly linked to the instability in the highway embankment at the former gully crossing. The backslope appears to have been cut at an initial angle that was too steep and has been in an unstable condition over most of the period following initial highway construction.

3. GEOLOGICAL/GEOTECHNICAL CONDITIONS

Physiographic Region: Swan Hills Upland (1969, Atlas of Alberta, University and Government of Alberta) north of the Athabasca River.

Bedrock Geology: The bedrock geology is quite complex through the project area and ranges from Tertiary Swan Hills gravels to Upper Paskapoo Formation of Tertiary Age consisting of nonmarine grey to greenish grey, thick bedded, sandstone, siltstone and mudstone, to Scollard Formation of Tertiary to Upper Cretaceous age consisting of nonmarine grey sandstone, dark grey bentonitic mudstone and thick coal beds.

Surficial Geology: no information available

Hydrogeology: Upper bedrock formations may be able to provide up to 2L/s of groundwater flow, however, in most of the township the potential groundwater yields are less than about 0.4 L/s. Groundwater flow directions are mostly downward with possible discharge areas and contact springs along slopes.

Stratigraphy:

A stratigraphic cross-section available in the AI files has been included as Figure SH1-3, Section F and indicates a stratigraphy of silty clay or silty clay fill overlying clay shale bedrock. The fill depth increases to a maximum depth of about 12 m at the centre of the gully crossing and the clay fill contains occasional thin layers of wet sand fill. Topsoil and organics were noted at the fill /native soil contact in a few holes. A thin coal layer was noted at the top of the bedrock sequence in a few holes.

Some of the test holes for the slope indicator and piezometer installations were logged (refer to Section G) and indicate that the upper portion of the shale bedrock is weathered and softened or that clay is present between the fill and bedrock. A stratigraphic cross-section sketch of the failed backslope cut, prepared by others during a site visit in 1979, indicates that the cut was made through silty clay (till?) overlying shale bedrock. Seepage was noted at the contact between the clay and shale.

The pneumatic piezometers indicate that the groundwater levels in the bedrock are typically at about elevation 1136 m , at the centre of the gully crossing while the levels at the contact between the fill and clay fluctuate from about 1.4 to 3.4 m below ground surface. Over the last 9 years the maximum fluctuation in piezometric levels have been about 3 m.

4. CHRONOLOGY

A memo in the file from Charles Rondeau provides the following history from 1967 to 1978

1967

Initial highway construction.

1969

The hill (backslope area?) failed suddenly taking out the highway and burying a 1.2 m dia. (48") culvert located immediately northeast of the hill. Traffic was carried on a detour constructed to the north of the slide for the rest of the summer and winter.

1970

The highway was re-constructed about 30 m (100 ft) to the left of the original alignment and much of the slumped earth was hauled or pushed into the draw on either side of the road.

1970 - 1976

The hill kept sliding and the road kept settling. Every summer $2,000 to $3,000 was spent moving the sliding earth and repairing the road surface with pit run gravel.

1976 - 1977

The hill and highway remained relatively stable only requiring ditch cleaning maintenance.

1978

In the summer the highway started to settle a bit. During backslope regrading work in the fall, the road settled 0.6 to 0.9 m over a 30 m long section. Pit run gravel was hauled in to regrade the road. The backslope was levelled off and regraded three to four times and each time it would slide again from about half way up the slope where springs were present. $23,000 was spent on these remedial measures in 1978.

April 30, 1979

A memo from J. Spicer indicates that a 82 m (269 ft) long section of road had failed due to the presence of springs above and to the east of the area. The area was poorly drained due to the original culvert ceasing to operate as a result of shifting and settlement of the existing grade over the last few years. Mr. Spicer recommended installation of a new culvert, perforated pipe drains on the slope and subdrains in the spring laden backslope.

July 6, 1979

G. Zinger inspected the slide area and prepared a stratigraphic cross-section and site plan which showed that the hill area consisted of silty clay over soft shale. He recommended that the clay be removed from the top of the slope area to help pinpoint the springs.

July 9, 1979

Nine 50 mm (2 inch) dia. slotted steel horizontal drains were installed on the left side of the grade at 3m (10 ft) to 7.5 m (25 ft) below centreline. Eight of the drains had steady seepage after installation while the ninth was moist. The drains were extended to the base of the slope using 50 mm dia. pipe.

October 3, 1979

A “Big O” drain pipe was installed in the ditch between the backslope and the road. The trench was typically 3 m (10 ft.) deep and 3 to 4.5 m(10 to 15 ft) wide, narrowing to 0.9 m (3 ft.) wide over the last 1/4 of it's length. Four 150 mm dia. solid lateral pipes (culverts) were used to drain the Big O drain at 60 m (200 ft.) intervals across under the highway fill. Tees from the smaller “Big O “ pipe were placed inside the culverts and covered with local granular material. A flow of one gallon per minute (GPM) was recorded from the northmost culvert increasing to 1.5 GPM by September 28, 1979. The remaining three culverts produced only a trace of water.

The road was regraded and the east ditch landscaped.

August 9-12, 1982

The road was paved sometime prior to 1982. On August 9, 1982 a slide occurred over a 21 m long section of the southbound lane. Longitudinal cracks were present south (east?) of centreline. The shoulder on the north (west?) side was deformed over a 57 m distance. At this time water was noted running in a narrow channel along the south (east?) shoulder. The drains installed in the large sidehill to the south were mostly non-operational, filled with silt and some were broken off.

September 1982

Five horizontal drains were installed in a fan shaped layout using a horizontal drill operating from the toe of the north (west?) facing embankment fill slope. The drains consisted of slotted PVC pipe and varied in length from 61 m to 73 m (200 ft to 240 ft). Flow from the drains varied from 0.5 to 3.75 litres/minute on September 30 to 0.17 to 1.33 litres/minute on October 8.

July 1988

A geotechnical investigation was carried out by AT&U consisting of 3 test pits on the sideslope, 2 test holes on the left shoulder and 4 test pits along the right ditch, offset 20 m from centreline. The results of the investigation are described in a Note to File by R. Skirrow and summarized on a stratigraphic section that was present in the highway file (Figure SH1-3, Section F). The note provides a discussion of alternative measures for stabilizing the roadway and concludes that a pile wall is the most practical for this site.

1989

A pile wall was installed along the left (northwest) shoulder of the highway over a distance of 81 m spanning between approx. Station 9+620 to 9+700. The pile wall consisted of eighty two 760 mm diameter cast-in-place reinforced concrete piles installed at a 1 m centre-to-centre spacing. The depth of the piles varied from 6 m to 12 m. The reason for the shorter piles was to avoid damaging existing drains which were present crossing below the highway within the wall section. The pile wall was installed by North American Caisson Ltd. and inspected by J.R. Paine & Associates Ltd. Design elevation and pile detail drawings are included as Figures SH1-5 and SH1-6, Section F.

Project notes indicate that four of the horizontal drainage pipes were encountered and ruptured during the pile installations. At three of these locations the piles were installed per original design blocking off the drains. The fourth, located at Pile #30, had a lot of water flowing through it, and the pipe section was backfilled with gravel and the pile poured above the drain.

March 12, 1990

A site visit was conducted by Mr. R. Skirrow , P.Eng. and Mr. B. Weins of AI who noted the following:

- a crack was present in the pavement behind the pile wall.
- the main scarp of the slide appeared to be in the backslope above the east side of the highway.
- the pile wall was in good condition with no visible displacement however some of the piles appeared to have been installed out of line with some spaces between the piles of 75 to 300 mm.
- ice blocks present on the valley slopes outside the fill areas suggested natural spring seepage.
- an ice block at the outlets of the PVC horizontal drains indicated that they were still working
- there was some water trapped in the upslope ditch due to insufficient gradient.

March 28 to April 4, 1990

New instrumentation consisting of 4 slope indicators (SI#1 to SI#4) and 4 high air entry pneumatic piezometers (12291,12305,12871,12872) were installed. The locations are shown on Figure SH1-2, Section F and the logs are enclosed in Section G.

August 1991

The highway was widened and repaved. Road surface cracking due to sliding occurred within 3 weeks. Slope indicators showed that there was a shear plane in the upper clay shale beneath the toe of the wall at a depth of 14 to 17 m.

September - November, 1991

Two rows of tie-backs were installed to anchor the wall to clay shale bedrock. The anchor rows were located at 1 m and 3 m below the top of wall and the anchors were spaced at 2.48 m on centre along the rows. The anchors were inclined at 30° and consisted of a 36 mm Dywidag Grade 150 steel rod inserted in a 125 mm diameter predrilled hole grouted over a length of 7.5 m in the clay shale. The heads of the anchors were locked off against steel walers. The design anchor force was 1550 kN (1253 kN/m of wall). The anchors were installed by Beck Environmental Services Inc. Details of the tie-back anchors are shown on Figures SH1-7 and SH1-8, Section F.

Upon completion of anchor installation the front of the wall was backfilled with sawdust enclosed in geotextile and capped to provide a sideslope downslope of the wall.

Seven Slope indicators (SI#5 to SI#11) were installed along the back and to the south of the wall. Core samples were obtained from one of the installation holes.

September 1992

Three slope indicators were installed (SI#12, #13 and #14) and pressuremeter testing was carried out in 4 test holes.

Aug. - Sept. 1994

An August 29, 94 note to file from Karl Li, P.Eng. indicates that a crack is developing in the road surface to the south of the wall and there may be a need to extend the wall 50 to 100 m further south. Seven slope indicators (SI#15 to 21) and three pneumatic piezometers (PE 17,18A,18B) were installed in September to monitor the area south of the retaining wall.

1995

Based on discussions with Mr. Fred Bickle of AI a cold mix asphalt swale was placed along the west edge of the road over the top of the wall around 1995 to control slope erosion due to water running off the edge of the road.

Some slope offloading at the high backslope was carried out in November and December.

1996

Some additional slope offloading was carried out from the east backslope area by Prairie Excavators. The excavated material was hauled offsite and placed in an old borrow pit.

1997

Based on Discussions with Mr. Fred Bickle of AI, a layer of asphalt was placed from SI 17 to north of the retaining wall to level the road surface, followed by a chip seal.

June 1999

A site visit was carried out by GAEA who made the following observations and recommendations:

- It was recommended that an asphalt curb be installed along the top of the wall to prevent water spilling from the road surface from softening the sideslope area (This has not been carried out to date).

- The highway pavement surface south of the wall was still showing signs of distress. They suggested that the wall may need to be extended another 30 to 40 m to the south.

REFERENCES

1. Alberta Transportation and Utilities, 1978 to Present. Hwy File 33:12, Volumes 1 to 4.

2. J.R. Paine & Associates Ltd., July 17 - 22, 1989. "Pile Retaining Wall Highway 33 Near Swan Hills, Alberta."

3. Alberta Transportation and Utilities, May 1990. "Geotechnical Report Slide - North of Swan Hills, Inclinometers and Piezos, Hwy 33:12, Region 509."

4. Alberta Transportation and Utilities, 1991. Untitled bound report containing photographs of the wall tie-back construction carried out between September 6 to November 12, 1991.

5. Thurber Engineering Ltd., September 27, 1991. "Highway 33:12 Swan Hills Investigation Plan - Slope Indicator Installation."

6. Alberta Transportation and Utilities, October 24, 1991. "Swan Hills Retaining Wall, Hwy 33:12 Tie-backs Design Report."

7. Alberta Transportation and Utilities, Sept - Oct., 1991. "Hwy 33:12 Swan Hills Tie-backs Acceptance Test Reports."

8. Alberta Transportation and Utilities, 1991 - 1992. "Tie-back Installation, Landslide Area, Swan Hills, Hwy 33:12 North of Swan Hills Sta. 9+620 - Sta. 9+700, Job #R706H."

9. Alberta Transportation and Utilities, Jan 1993. "Geotechnical Field Report Pressuremeter Testing & Inclinometer Installations, PH33:12 - Slide - North of Swan Hills, Region 5, District 9."

10. J.R. Paine & Associates Ltd., Sept. 29, 1994. "Slope Indicator Installation Highway 33, Control Sections 12 and 19 Near Swan Hills, Alberta."

11. Alberta Transportation and Utilities binder containing slope indicator and piezometer readings for Swan Hills Retaining Wall (Hwy 33:12) up to and including 1996.

12. GAEA Engineering Ltd., July 1999. "Annual Geotechnical Review 1999, Various Slide Areas, Peace River / High Level Group and Swan Hills Group."

13. Alberta Infrastructure Slope Indicator Plots 1999.