ALBERTA TRANSPORTATION
LANDSLIDE RISK ASSESSMENT

SECTION A: GEOTECHNICAL FILE REVIEW

PEACE REGION (PEACE RIVER-HIGH LEVEL AREA)

SITE PH 10, (Old PH10, Sites #1@km 10.85 & #2@km 10.6

HIGHWAY CONTROL SECTION	Hwy 726:02, km 10.85 & 10.6
NEAREST LANDMARK:	8 km South of Worsley
LEGAL LOCATION:	NW12 & SW13-86-8-W6
DATE OF INITIAL OBSERVATION:	1988
DATE OF LAST INSPECTION:	June 2008
LAST INSPECTED BY:	Thurber Engineering Ltd. (TEL)
INSTRUMENTS INSTALLED:	6 Slope Inclinometers (2 in 1998, 3 in 2002 and 1 in 2008) 4 Pneumatic Piezometers (3 in 2002 and 1 in 2008) 5 Standpipe Piezometers (1988)
INSTRUMENTS OPERATIONAL:	3 Slope Inclinometers (1 in 1998, 1 in 2002 and 1 in 2008) 2 Pneumatic Piezometers (1 in 2002 and 1 in 2008)
RISK ASSESSMENT:	km 10.85 Site #1 PF(11) * CF(4) = 44 Km 10.9 Site #2 PF(12) * CF(5) = 60
LAST UPDATED:	Thurber Engineering Ltd., Jan. 2009
PREVIOUS UPDATE:	Amec Earth & Enviro. Ltd., Nov. 2000

1. LOCATION

The sites are located along Hwy 726:02 about 8 km south of Worsley as shown on Figure 1 attached.

Highway 726:02 crosses the valley of the Eureka River in a north-south direction, following the western valley wall south of the River. The valley of the Eureka River is approximately 30 m deep. The centerline of the crossing is at about km 10.91.

Previously, the PH10 Eureka River area encompassed three geohazard sites extending along a 1 km length of this highway on both sides of the box culvert. However, the area has now been subdivided into 2 separate "PH" areas using the culvert as a split, and PH10 now includes only two of these Sites (#1 and #2) located south of the culvert.

2. GENERAL DESCRIPTION OF SLOPE INSTABILITIES

Slope movements have occurred along this section of Highway 726:02 on the south side of the river since at least 1988, within a few months of construction of the new approaches and crossing. The slides extended through the road embankment cut/fill and into native soils.

At Site #1 closer to the River (km 10.85) cracks in the road and a slide occurred at in 1988, soon after road construction. Stone columns were installed in 1988. In 1997, a slope inclinometer downhill of the road indicated movement at 4.5 m depth. A gravel buttress, toe drains, and an interceptor drain were constructed in February, 1998. Settlements of up to 1 m occurred in the east shoulder, so the road was re-aligned uphill at this location later in 1998. The current slide is estimated to be about 50 m wide x 50 m long, with the scarp located east of the highway and the toe located at the river upstream of the culvert inlet.

At Site #2 (km 10.6), a fully developed slide about 100 m wide x 180 m long occurred in June 1988, having a 4 m high scarp and a toe that overrode the native peat and blocked the river. Stone columns were installed in 1988. There were also design measures prepared at that time for a shear key, a toe berm, light-weight fill (sawdust), and some drainage measures including a gravel basal blanket and trenches, but it is not clear whether they were implemented. The current slide at Site #2 is at least 150 m wide, with its scarp crossing the highway over an approximate 60 m width, and its toe at the river.

During the June, 2004 annual inspection a crack was noted in the pavement in between Sites #1 and #2 at about km 10.75. This crack had elongated to about 40 m long along the western half of the road (southbound driving lane and

shoulder) during the 2008 annual inspection. It is speculated that there could be one large slide block developing parallel to the River, linking Sites #1 and #2.

3. GEOLOGICAL/GEOTECHNICAL CONDITIONS

The Eureka River is located in a valley north of the Shaftesbury Channel Thalweg. The Alberta Bedrock map (1995) indicates less than 15 m of drift overlying bedrock in this area. Pawlowicz and Fenton (1995) do not report a pre-glacial valley in this area.

Based on information obtained from a single 2008 test hole by Thurber located alongside the east edge of the highway between Sites #1 and #2, the soil stratigraphy at this site consists of 16 m of high plastic lacustrine clay over clay till extending to a depth of 20 m. Six test holes drilled in 1988 by ATU at slide Site #2 indicated discontinuous clay fill, over discontinuous peat (up to 1 m thick), over lacustrine clay to depths up to 15.7 m; while two inclinometer test holes drilled by Thurber in 1998 at Site #2 (included in Part G of the binder) indicated gravel and likely clay fill up to 2 m overlying lacustrine clay to depths of 15.7 m.

The following map references were searched:

- Physiographic Region - Peace River Lowland.
- Bedrock Geology - Consists of Cretaceous age deposits: predominantly Dunvegan Formation deltaic to marine grey, fine-grained, feldsparthic sandstone, laminated siltstone and grey silty shale.
- Surficial Geology - Located on: Slump/Colluvium, mixed glacial and bedrock materials, mainly along flanks of valleys; but near Lacustrine clay/silt/sand, ranging from poor to well sorted deposits, commonly varved at depth.
- Hydrogeology - Unconsolidated deposits overlying Dunvegan Formation, with yields in the range of 0.1 to 0.4 litres/sec.

4. CHRONOLOGY/REFERENCES

Refer to Amec's November 2000 file review, where all references listed were included in Section G of the site binder. Nothing new was found during this file search. The following new developments are noted:

Aug. 1988 Six borehole summaries by ATU were found in the files, between Sta. 10+485 to Sta. 10+640 (Site #2). Their locations are identified by station numbers and centerline offsets. They are attached.

Jun. 2004 - Jun. 2008 — A crack was noted in the pavement in between Sites #1 and #2 at about km 10.75. This crack had elongated to about 40 m long along the western half of the road (southbound driving lane and shoulder) during the 2008 annual inspection.

Jan. 2008 — Thurber Engineering performed a geotechnical investigation in January 2008 in conjunction with site PH26 north of the river. It consisted of drilling one (1) test hole east of the highway approximately midway between Sites #1 and #2 at km 10.75 about 23 m east of the highway centerline, installing an inclinometer and a pneumatic piezometer, and performing laboratory index testing. The results/conclusions of this investigation are on-going, however small movements (of magnitudes less than 3 mm/year) were recorded at three separate base depths of 9 m, 13 m and 14.5 m in the inclinometer in October 2008. This information is included in Sections C and D.

NOTE: There was no information newer than 1988 available for viewing at TRANS Twin Atria office during this file review (May 28, 2008).

PART A: FILE REVIEW
LANDSLIDE RISK ASSESSMENT
PEACE REGION (PEACE RIVER VALLEY/HIGH LEVEL)

SITE PH10: EUREKA RIVER (SOUTH OF WORSLEY)

LEGAL LOCATION:	86-8-W6M
Location along Highway:	Station 10+600 and Station 10+850 (Station 10+910 is the centreline of the crossing):
AI FILE:	SH726:02
Date of Initial Observation:	1988
Date of Last Inspection:	not known
Instrument s Installed:	1 slope inclinometer, 5 standpipes
Instruments Operational:	none
Risk Assessment:	Station 10+600: PF(11) * CF(4) = **44,** Station 10+850: PF(9) * CF(4) = **36**
Last Updated:	AMEC Earth & Environmental Limited November 2000

INTRODUCTION

This section is a review of files made available by Alberta Infrastructure for the site. The file review was prepared prior to the site visit. The description of the sites is based on the information that was present in the file, topographical and geological information was added if it was not present in the file and if the site was familiar, previous observations were also included. A risk assessment, solely based on the file review is provided. The risk assessment may change once the observations made during the site visit are incorporated.

SH726:02 crosses the valley of the Eureka River in a north south direction. Figure 1 presents a plan of the area. The valley of the Eureka River is approximately 30 m deep at the crossing. The road climbs out of the valley following the valley wall. In 1988, a new crossing and approaches were constructed. Soon thereafter, two slides occurred along the road south of the crossing. Movement has again been noted in the last few years at these two sites. The active areas are as follows (Station 10+910 is the centreline of the crossing):

- Station 10+600: fully developed slide, stone columns installed in 1988;
- Station 10+850: cracks in road, stone columns installed in 1988, road was realigned in 1998.

Pawlowicz and Fenton (1995) do not report a pre-glacial valley in this area.

GEOTECHNICAL CONDITIONS

The soil conditions consist of clay fill, organic material (original ground level), lacustrine clay and clay till with sand and gravel layers. The clay fill is high plastic, it was probably derived from the clay till and the lacustrine clay. Sand and gravel layers are ubiquitous and are generally water bearing. In at least one borehole, peat layers were mixed in with clay layers, a sequence that would result where the toe of a slide overrides native peat.

The thickness of road fill in the area of the slides was up to 4 m.

The water table in the area of the slides appears to have been high. Even prior to construction of the road, seepage from the slopes was identified.

CHRONOLOGY

Table A1 provides the chronological background of the slides.

DESCRIPTION OF INDIVIDUAL SITES

In the following, the individual sites are described.

Station 10+600

Description of Instability

At Station 10+600, the road was constructed in cut and fill, along the sideslope of the valley. The valley slope below the road is inclined at 12 degrees. The slide occurred in June 1988, probably soon after construction of the road. The slide was 100 m wide and 180 m long. In the file, it was described as a shallow failure, approximately 4 m thick at the road and less than 2 m thick further down the slope. The slide had a well-developed toe, overriding the native peat. The toe of the slide blocked the river. The scarp of the slide extended into the backslope. Figure 2 is a cross section of the slide area. At the time, remedial measures were implemented. In 1997, settlement was again reported at this location.

Borehole logs drilled by ATU in 1987 indicated lacustrine clay overlain in some boreholes by peat and clay fill. In one of the boreholes, peat was 1 m thick. In many of the other boreholes, peat was not encountered. The logs for the slope inclinometer boreholes drilled by Thurber indicate lacustrine clay (to 15 m depth) overlain by gravel and clay (probably fill). The lacustrine clay was described as medium to high plastic. Slickensides were noted in both boreholes.

Past Investigations

A number of test pits were excavated at the slide. Five boreholes were drilled in the slide in 1988. Test pit logs and borehole logs are in the file.

In 1998, two slope inclinometers were installed in the slide. Borehole logs are in the file.

Remedial Measures

A design for remedial measures is in the file. It consisted of removal of the organic cover, construction of a shear key, toe berm and drainage trenches in the slide and in the uphill ditch. There is also a cross section in the file that shows stone columns, a gravel basal blanket and light-weight fill (sawdust). There is documentation in the file indicating that stone columns with lime were installed (750 mm diameter at a 2 m grid) to a depth of 12 m. Whether the shear key, the toe buttress or the light-weight fill were implemented is not clear.

Monitoring Results

The slope inclinometers installed in 1998 did not indicate significant movement over the brief period between March and May of 1998. Thereafter the slope inclinometers were not monitored anymore, presumably because there were no new signs of instability.

Assessment

Probable contributing factors to the slide were the following:

- loading of the slope by fill;
- increased pore pressure of the native material in response to the fill;
- weak high plastic, previously sheared clay;
- probably high initial pore water pressures in the clay.

Thurber carried out an investigation in 1998. Their assessment was that settlement may have been due to deterioration of layers of peat and sawdust light-weight fill. A design cross section of a repair using light-weight fill is in the file, but it is not clear that it was actually installed. Thus, the settlement of the road may be due to actual slide movement.

PF(11) * CF(4) = **44.** The slide appears active, even though no movement was recorded between March and May 1998. The slide cuts across the road surface, such that if significant movement occurs traffic would be affected.

Station 10+850

Description of Instability

The site is located just to the south of the large box culvert that channels the Eureka River under the road. The slide occurred in June 1988, probably soon after construction of the road. Signs of movement were cracks in the road (up to 75 mm wide). It appears that the slide did not experience large movement. During road construction, a gravel blanket had been placed between native ground and the fill.

In 1997, signs of instability developed. However, it is not clear what they were. Slope inclinometers were installed and they registered shearing at a depth of 4.5 m. The slide was approximately 50 m from scarp to toe (at the river). A gravel buttress was constructed in February 1998. In June 1998, after construction of the buttress, it was noted that the east shoulder of the road had settled 0.5 to 1.0 m.

Past Investigations

It appears that three boreholes were drilled in the slide in 1988, but borehole logs are not available.

In 1997, two slope inclinometers were installed. The borehole logs are not in the file.

Remedial Measures

There is documentation in the file indicating that stone columns with lime were installed (750 mm diameter at a 2 m grid to a depth of 12 m) in 1988.

A gravel buttress, toe drains and an interceptor drain were installed in February 1998. Since slide movement continued after installation of the remedial measures, later that year the road was shifted uphill. A volume of soil (16,000 cubic metres) was removed from the area.

Monitoring Results

In 1997, one slope inclinometer downhill of the road indicated movement at 4.5 m depth, one slope inclinometer uphill of the road did not register any movement.

The groundwater level in two standpipes was 2.0 and 4.5 m below ground level in 1998 (after construction of the gravel buttress and drains). Seepage was observed downhill of the interceptor drain, suggesting the drains were not fully functional.

It is our understanding that the instrumentation was destroyed when the remedial measures were implemented.

Assessment

PF(9) * CF(4) = **36.** In February of 1998, a gravel buttress and drains were installed at this location. Movement of the slide continued thereafter. The road was then shifted uphill, such that it was not located on the slide mass anymore, and the old road embankment was removed. It is not clear whether removal of the old road embankment has stabilized the slide. Since the road has been shifted, the slide would need to retrogress before it would affect the road. It appears that if the slide were to retrogress, the road could be shifted uphill temporarily.

TABLE A1: CHRONOLOGY

1985, 02 Letter from E. Waschuk to V. Fafard. Proposed Eureka alignment study.

1985, 03 Letter by L. Sharma to R. Foster. Geotechnical assessment of foundation conditions at Eureka River. Soil conditions are sandy clay till to 13 m depth, underlain by silty sand. There is evidence of distress at the existing bridge. A slope inclinometer was installed near the north pier, which indicated movement in the upper two metres.

1987, 05 Note to file by M. Pariti and J. Miller. Seepage zones observed at backslope. Slumping was observed at Station 10+500.

1987, 06 Typical cross section Station 10+780 to 10+900 indicating 5 m fill height and gravel drainage blanket covering lower part of slope. Fifteen test pits excavated. Soil profile is high plastic clay. At Station 10+600 sequence of peat, clay, peat, clay, peat (indicative of previous landsliding); at Station 10+940 clay (fill) underlain by gravel and at Station 11+015 clay underlain by sand; organic layers (probably original ground) were encountered in five of six boreholes.

1988, 06 Letter by V. Diyaljee to R. Callioux. Inspection of two slides at Stations 10+562 and Station 11+000.

- Slide between Station 10+562 and 10+662, approximately 100 m wide, 180 m long. Slide at cut and fill transition zone. Subsoils were high plastic slickensided clays with silt lenses. Fill height varied from 1 to 3 m. Slide was believed to have happened as a consequence of high pore water pressures following heavy rainfall. A total of 175 mm was recorded in May and June. Movement on organic layer and silt layer at 3 to 5 m below ground. Toe at 170 m from centreline. Sliding at 2 m depth, 45 m from centreline. Proposed remedial measures: removal of organic layer, construction of gravel shear key, gravel drainage trenches, construction of a toe berm, construction of a trench drain in uphill ditch.

- Slide between Station 10+790 and 10+880, cracks 50 to 75 mm in roadway. A gravel drainage blanket had been incorporated in the construction. Proposed remedial measure: extend trench drain in uphill ditch.

1988, 06	Drilled 6 boreholes. Soil is stiff grey clay and clay till.
1988, 08	Note by E. Tislak. Slide at Eureka River between Station 10+485 and 10+640. Area of 60 m x 80 m sank one metre. Soil profile consisted of clay with wet sand layers. Clay was soft, hole squeezing in.
1988, 08	Attempt to stabilize slide using stone columns. Two hundred and twelve stone columns installed at Station 10+540, 600 were being installed between Station 10+740 and 10+800. Toe of slide has blocked river. A cross section at Station 10+590 shows a design with a gravel blanket, stone columns with lime injection and a woven geotextile reinforced light-weight fill embankment. It appears that this was not constructed.
1988, 08	Note to file by M. Pariti. Ice and snow are prevalent in fill material.
1998, 06	Site inspection by H. Heinz of Thurber Engineering. At Site 1 (Station 10+790 and 10+880) the shoulder of the highway had settled 0.5 m to 1.0 m over a length of 30 to 40 m within the area where a gravel buttress had been constructed in February 1998. The groundwater level in two standpipes was 2.0 and 4.5 m below ground level. It appears that an interceptor trench was installed previously. Seepage was observed downhill of the interceptor trench, suggesting it was not fully functional.
1998, 06	Report by Thurber Engineering on slope inclinometers. At Site 1 (Station 10+790 and 10+880), slope inclinometers 97-2 uphill of the road did not show movement, 97-3 downhill of the road did indicate movement at 4.5 m depth. It was concluded that the installation of the drains in the February did not stabilize the slope. At Site 2 (Station 10+562 and 10+662), a depression of the highway was noted in November 1997 and active sliding at the toe of the slope was observed. Slope inclinometers 98-1 and 98-2 were installed in March 1998. No significant movement was recorded by the slope inclinometers. It was their interpretation that the settlement of the road was related to aerobic deterioration of the sawdust.
1998, 08	Letter by D. Proudfoot on slide repair at Station 10+790 and 10+880. It was recommended that the road be shifted uphill and that a volume of fill be removed. This would raise the factor of safety by 20 %.
1998, 09	Fax by D. Proudfoot indicating that construction was being undertaken.