January 7, 2002 File: 15-76-11

Alberta Transportation
Room 223, Provincial Building
4709 – 44 Avenue
Stony Plain, Alberta
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Attention: Mr. Rob Lonson, P.Eng.

NORTH CENTRAL REGION LANDSLIDE ASSESSMENT
SH 661:02 NEAR NORTHEAST BOUNDARY OF
TOWN OF FT. ASSINIBOINE (NC14)
2001 ANNUAL INSPECTION REPORT

Dear Sir;

This letter documents the 2001 annual site inspection of a portion of Secondary Highway 661:02 located on the northeastern boundary of the Town of Ft. Assiniboine. The work was undertaken by Thurber Engineering Ltd. (Thurber) in partial fulfillment of our Geotechnical Services, Monitoring and Assessment of Instrumentation and Landslides contract with Alberta Transportation (AT).

The site inspection was undertaken by Mr. Don Law, P.Eng of Thurber on June 8, 2001. The site visit was carried out in the presence of Mr. Roger Skirrow, P.Eng. of AT.

1. BACKGROUND

The slope has had a history of slope failure, and of drainage measures undertaken to mitigate the effects of groundwater on the slide area since the slide was first reported in 1978. A description of the slope instability and chronology of events as interpreted from the AT geotechnical files was provided in Section A of the documentation submitted for this site.

An assessment and recommendations for remedial measures were provided by AGRA Earth and Environmental (AGRA) in letter reports to the MD of Woodlands dated October 10, 1997 and January 22, 1999. These reports are included in Section G of the site binder.

A brief summary of the background is as follows:

- At the mid-hill failure location the embankment is approximately 18 m high. The stratigraphy at this location consists of 5 m of loose to compact sand fill overlying interbedded native sand and clay layers. A scarp crack has formed in the roadway pavement over a 50 m length of the southeast bound (i.e. down slope) lane of the highway. This crack feature in the mid-hill slide area is shown on Figure NC14-1 and NC14-2 in Section F.

- Settlement of the road surface in the mid-hill failure area has occurred since 1978. It was reported that a portion of the toe of the slope was removed below the roadway to allow for housing development, and the side slope was stripped of vegetation in some areas. A drop in the roadway was observed in 1978-79 over a 60 m length above the area of toe removal. A number of “slip zones” developed in the side slope and several home owners at the toe of the slope experienced water in their back yards and basements.

- Water seepage has been noted over the years to be exiting the side slope below the roadway in the mid-hill failure area. Horizontal drains were drilled into the slope in 1979 (likely from about midslope), however these drains did not develop significant flow. After further roadway distress from slope movement was observed in 1985, additional horizontal drains were installed from the toe of the slope. Significant flow from these wells was initially observed, however discharge of the collected groundwater into an underlying gravel layer via a vertical well (located approximately as shown on the site plan) was not successful. There is no record of subsequent observations of the flow from these drains in the geotechnical files.

The following trench drain installations were undertaken. It is understood that the primary purpose of the drains was to address the icing problem in the upslope ditch:

a) 1979 - A trench drain was installed in the upslope ditch in the lower section of the hill, located approximately as shown on the site plan.

b) 1985 - The trench drain was extended upslope from the 1997 installation, however installation difficulties in wet silt led to the pipe being installed unconnected.

c) 1991 – Additional drains were proposed for the lower section of the hill (i.e. downhill of the active slides) to control water from flowing wells located upslope of the roadway. This drain was designed such that it would be connected to an existing manhole at the bottom of the slope. It is not clear from the files if this drain was installed.

d) 1998 – Additional trench drain was installed in the upslope ditch adjacent to the slide area. The extent of the drain was not reported in the files.

It is understood that the trench drains have been ineffective at reducing the groundwater levels in the vicinity of the slide.

A number of remedial measures were considered in the 1997 AGRA report, including a toe berm, slope flattening (i.e. vertical and/or horizontal grade change, and additional horizontal drains). The favoured alternative was to excavate and rebuild the slope with geogrid reinforced granular fill. A directionally drilled horizontal drain alternative was put forward in the 1999 AGRA report, however it was noted that there is some risk that the drains will be ineffective based on the past performance of horizontal slope drains at this site.

Toe bulging had caused deflection of the walls of a house located at the toe of the failed slope, as documented in a letter to the MD of Woodlands by AGRA dated May 21, 1999. The house has since been removed from the site.

2. SITE OBSERVATIONS

The highway roadway surface, back slopes and side slopes were inspected during the 2001 reconnaissance in the mid and upper hill areas of the site. The side slope in the lower portion of the hill was also inspected. Photographs of the site taken during the reconnaissance are included in Section F of the site binder.

The following features and observations were noted during the site reconnaissance. The approximate locations of these features are shown on the site plans, Figures NC14-1 (overview) and NC14-2 (detail of the mid-hill slide area), updated for 2001 and attached for inclusion in Section F of the binder. A stratigraphic cross section from the previous AGRA report has previously been provided as Figure NC14-3 in Section F.

Mid-Hill Slide Area

- A 50 m section of roadway continues to be impacted by the mid-hill slide feature. This area is shown in detail on Figure NC14-2, and includes the approximate location of instrumentation installed previously. The side slope at this location averages approximately 24° (2.2H:1V) over an 18 m height. The crack pattern has not changed significantly since the 2000 site reconnaissance, however overall the area appears to have dropped over the year period. The differential height across the crack in the central portion of the crack feature has increased to about 30 mm from the 5-8 mm observed in 2000, and extends further as shown on Figure NC14-2. In addition, the portion of the crack with a 3-5 mm differential height located further upslope has also extended since 2000. The upslope lane (i.e. right hand lane as you travel uphill) still appears to be relatively unaffected by the slope movements.

- The water level in SP97-2 was estimated to be within approximately 3 m of the ground surface, based on a sounding undertaken with a pebble dropped into the pipe. This is higher than the water level shown on Figure NC14-3, where the measured water level in 1998 was about 5 m below ground surface.

- One new (2001) slump feature was noted near the toe of the slope in the vicinity of the roadway distress. The slump was about 1 m high and extended over a distance of about 14 m along the toe of the slope. The trees were leaning significantly in this area, and some minor seepage was noted in the west end of the scarp. Some seepage was also noted further up the slope in the vicinity of the spring noted in 1997, located approximately as shown on Figure NC14-2.

- Water was heard trickling through the existing collection well at the toe of the mid-hill slope, indicating that it is still functional.

Uphill Roadway Distress

- A 30 m long shallow dip in the roadway shoulder and guardrail (down slope side) was noted at a location approximately 100 m uphill from the mid-hill slide feature. The size of this dip feature has approximately doubled since the observations made during the site reconnaissance in 2000. Some minor cracking was noted in the pavement surface in this area with no significant differential height noted across the cracks. This cracking pattern is similar to that observed in 2000.

- A bump was noted for the first time in the roadway surface approximately 30 m uphill from the shallow dip. The pavement had not cracked at this location, however the surface dropped approximately 100 mm over a distance of approximately 3 m. This bump feature was not noted during the 2000 site reconnaissance. A traffic sign was in place warning of the uneven pavement surface.

- The graben feature first observed in 2000 on the upper side slope adjacent to the dip and bump features was inspected. The ground in this area appears more uneven than last year, indicating that some development of the graben feature may have occurred.

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- An older scarp feature was noted below (i.e. west) of the graben feature with a height of approximately 300 mm to 600 mm. There is no evidence of toe development from this scarp. This area of the slope was not inspected during the 2000 site reconnaissance, as there was no significant highway disturbance above this point at the time.

Other Areas

- The sinkhole first noted in 2000 on the side slope approximately half way down the slope, located between the two instability areas (approximately as shown on the site plan) is approximately 600 mm deep and 3 m in diameter. There was no evidence of seepage or piping discharge from areas below the sinkhole feature during the 2001 site reconnaissance. The sinkhole does not appear to have developed further since the 2000 site reconnaissance.

- The inactive scarp area noted in the lower portion of the slope during the 2000 site reconnaissance has not changed since then, and does not appear to be impacting the roadway at this time.

3. ASSESSMENT

As noted in the 2000 report, it is expected that the active slope instability has resulted from high pore water pressures in the slope generated from the natural groundwater regime, possibly combined with placement of embankment fill materials at the time of roadway construction and/or upgrading. The additional movement noted between the 2000 and 2001 site visits is likely related to the higher water level noted in the standpipe from that measured previously in 1998 (estimated to be about 2 m higher in 2001). The initial failure in the mid-hill area may have been triggered by the removal of soil at the toe of the slope for property development.

The flowing wells reported upslope of the roadway downhill from the active slide areas indicate that there is likely a confined aquifer in this area that may be providing high pore pressures to the failure plane, potentially from upslope and/or below the failure plane. Previous attempts at horizontal drain installation may not have been oriented properly to intercept this layer. The existing geotechnical information is insufficient to confirm the nature of the groundwater regime within this slope.

Due to the more active nature of the graben area and the scarp noted near the base of the slope noted during the 2001 site reconnaissance, the dip and bump feature located uphill from the mid-hill slide area may be a result of slope instability in this area. The mid-hill and uphill slides may also be connected as one larger instability feature.

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It is expected that, if no action is taken, the mid-hill and uphill (dip and bump) areas will continue to develop and cause further distress to the highway at these locations.

The scarp in the lower slope area still appears to be inactive and hence is not expected to impact the highway in the near future.

4. RISK LEVEL

A risk level of 36 is considered applicable to the active slide areas of this site, based on a Probability Factor of 9 (active with moderate steady rate of ongoing movement) and a Consequence Factor of 4. This is an increase from the risk level of 28 provided in our 2000 report, as a result of the additional distress noted. Other areas on the hill are considered to have a lower risk level.

5. RECOMMENDATIONS

5.1 General

Based on the visual observations made during the 2001 site reconnaissance, the distress to the roadway surface in the uphill area appears to have developed significantly since 2000. In addition, the mid-hill slide area has developed somewhat. There appears to be no significant distress to the roadway and side slope adjacent to the inactive scarp feature downhill from the mid-hill slide feature.

High groundwater levels appear to be the major cause of the instability at this site, however insufficient information is available on the source and distribution of the groundwater to allow detailed assessment of remedial measures. Additional study is therefore recommended to determine the nature of the groundwater regime for the overall slope.

Based on review of available information, the following options are tentatively considered for this site, pending the results of further investigation:

- Realignment of the roadway surface
- Toe berm construction, requiring land acquisition.
- A retaining structure at the toe of the slope may also be considered in lieu of land acquisition.
- Slope drainage measures such as horizontal wells and french drains. These may be considered in combination with the other options.

Slope drainage is not considered a viable option on its own due to the requirement for ongoing monitoring and maintenance to keep water levels down in the long term.

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These options are described in more detail below. Recommendations for further study are provided in Section 6.

5.2 Realignment

Consideration may be given to realignment of the highway upslope of its present location to move away from the problem areas. This may be combined with fill removal at the existing roadway location to achieve slope flattening, and dewatering to further enhance the stability of the area. Additional study is required to assess the feasibility of realignment, including geotechnical instrumentation, survey and preliminary assessment of vertical and horizontal alignments.

The feasibility study should also assess relocation away from this hill. However based on a preliminary review of aerial photography of the adjacent valley wall downstream (east) of the present alignment, an equal or better alternate route out of the valley is not evident from a geotechnical standpoint. A potential route exists to the west, up an existing ravine. However this route is likely too close to the existing west access to the town to be of benefit.

The construction cost to realign the highway upslope from its present location over a 650 m roadway length is estimated at $500,000 to $750,000. Control of groundwater during construction and permanent sub-drainage facilities will be required as part of the realignment. Land acquisition would also be required.

5.3 Toe Berm

5.3.1 Mid-Hill Slide Area

Consideration may be given to a toe berm below the mid-hill slide area, as previously recommended in the 2000 inspection report. However this approach does not address the instability noted in the uphill area. A berm in the order of 6 m high and 20 m wide along the length of the mid-hill disturbance (say 60 m) may be appropriate. A detailed design should be undertaken, including stability analyses using existing stratigraphic information and groundwater information obtained through further study. Control of water through the base of the berm would need to be incorporated into the design.

It is expected that the construction cost of a toe berm would be in the order of $100,000 to $150,000. Control of water from the base would be included in this amount, provided there is sufficient capacity in an existing sewer system near to the site to carry the anticipated flow. This available capacity would need to be assessed.

5.3.2 Overall Slope

Extension of the toe berm to the northwest (i.e. below the uphill slide area) would require consideration of the existing tower site and residences at the toe of the slope. Annexing the land would allow a full toe berm to be constructed. Alternatively, construction of a retaining structure at the toe of the slope may be considered to achieve the necessary slope flattening. A combination of a toe berm below the mid-hill slide and a retaining structure below the uphill slide may also be feasible. Additional study is required to confirm the feasibility of such options, and to gather sufficient information for design.

It is expected that the construction cost of the toe berm across the full base of the slope (approximately 250 m) would be in the order of $500,000 to $600,000 plus land acquisition costs. Control of water from below the toe berm would also be required, as for the mid-hill toe berm option described previously. If a retaining structure is required below the uphill slope, the construction cost may be in the order of $1,000,000.

6. FURTHER STUDY

6.1 Hydrogeological Study

High groundwater levels appear to be the driving mechanism for the slope instability at this site, hence an understanding of the groundwater regime for the overall slope is considered essential for the proper design and implementation of any effective mitigative measures to stabilize the slope. A hydrogeological study is therefore recommended, and should include the following:

- A preliminary hydrogeological assessment based on review of existing data, published hydrogeologic mapping and aerial photography review.
- Installation of nested piezometer groupings (i.e. with tips at different depths). The soils should be logged at each of the piezometer nest locations. A total of about six nests with three piezometers per nest are initially recommended, however this number should be reviewed after completion of the preliminary hydrogeological assessment.
- Monitoring of the water levels quarterly over a period of a year or more. Provision should be made to allow hydraulic conductivity testing in some of the piezometers.

The study should address the likely effect of groundwater on the slope movements and may be expanded to address the ditch icing if desired. If determined feasible, target zones for slope dewatering using horizontal drains would be identified.

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Further drilling may be required after completion of the study to confirm the extent of target zones for dewatering.

6.2 Slope Movement Monitoring

Geotechnical investigation (test hole drilling) is recommended in the uphill slide area, since no geotechnical information is presently available. Slope inclinometer (SI) installation is recommended to allow movement monitoring. Additional instrumentation is also recommended in the vicinity of the mid-hill slope failure. A total of seven SI's are recommended to monitor potential slope movements, as follows:

- Uphill Slide Area - one SI in the roadway (southwest shoulder), one SI on the down slope side of the graben feature below the roadway, and two SI's above (i.e. upslope of) the roadway.

- Mid-hill Slide Area –one SI in the roadway shoulder to replace the existing SI's that have likely sheared off since installation, and two SI's installed upslope of the highway.

The SI's upslope of the highway are required to assess the feasibility and requirements for the highway relocation option.

This work should be undertaken in conjunction with the groundwater study noted previously. SI readings should initially be taken quarterly to obtain information for design in a timely manner.

6.3 Topographic Survey

A topographic survey should be undertaken covering the entire side slope area to allow stability analysis and development of appropriate remedial design. This may be undertaken with orthographic techniques using existing aerial photography, and combined with land based survey methods to provide ground control and tie in specific features

6.4 Conceptual Design

Using the groundwater, slope movement and topographic survey information gathered, conceptual design for the various options could be undertaken. Additional remedial options may also be identified at this stage. The conceptual design would include stability analysis to assess the feasibility and effectiveness of the various remedial options for the site, including realignment options, preliminary volume calculations and preliminary construction cost estimation. The information gathered will allow AT to assess the most appropriate remedial solution.

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6.5 Potential Timeline

It is recommended that the groundwater study and instrumentation installation be initiated as soon as possible, such that the data gathering can commence in 2002. This will allow as much time as practical for shear to develop in the SI's prior to the conceptual design. After identification of the most appropriate remedial solution, detailed design may then commence during the winter/spring of 2002/2003. Construction could then follow in the summer/fall of 2003. It should be noted that delay in instrumentation installation may push remedial construction into 2004 or later.

7. CLOSURE

We trust this assessment and recommendations meet with your needs at this time. We would be pleased to discuss the requirements for further study and to provide a detailed scope and cost estimate for the work.

Yours very truly,
Thurber Engineering Ltd.
D. Papanicolas, P.Eng.
Review Principal

D.J. Law, P.Eng.
Project Engineer

attachments

cc: Mr. Roger Skirrow, P.Eng., Director of Geotechnical Services, AT