LANDSLIDE RISK ASSESSMENT
SOUTHERN REGION

SITE S3: COCHRANE

LEGAL LOCATION:	**LSD 6-34-25-04 W5M**
REFERENCE LOCATION ALONG HIGHWAY	1 km south of the bridge across the Bow river, immediately south of Cochrane
UTM COORDINATES:	**N 5672000** **E 676000** (NAD27) NTS Map Sheet 82 O/1 (Calgary)
AI FILE:	**H22:16**
AI PLAN & PROFILE:	
Date of Initial Observation:	August, 1991
Date of Last Inspection:	Inspected July, 2003 Instruments read May, 2003
Instruments Installed:	1991 - 3 Slope Inclinometers 1994 – 5 Slope Inclinometers (4 new SI's plus one replacement of previous installation)
Instruments Operational:	5 Slope Inclinometers
Risk Assessment:	PF(9) * CF(2) = **18** (Probability Factor increased from 7 to 9 in July 2003)
Last updated by:	AMEC, August 2003
Comments:	

Location

The site is located on Highway 22 about 1 km south of the bridge over the Bow River, immediately south of the Town of Cochrane. At this location the highway traverses up the south slope of the Bow River Valley.

General Description of Instability

The instability appears to be relatively shallow, however is affecting an area about 50 m by 50 m downslope of the highway. At this location the highway traverses a steep slope and the sliding may be a combination of natural movements and side cast fill placement. Movements of up to 20 mm per year have been recorded, however movements at various locations are sporadic (starting and stopping between successive SI readings). Movements are also likely exacerbated by surface water running from the highway ditch to the slide area.

Geologic Setting

The surficial soils generally consist of stiff, high plastic clay till. In most boreholes the till extended to depths beyond those investigated (about 20 to 30 m). Sandstone bedrock was encountered in two of the seven borehole locations at depths of 14 and 27 m.

Chronological Background

Table A1 provides the Chronological Background of the slide.

Past Investigations

AT has conducted borehole drilling and SI installation programs in 1991 and 1994.

Golder Associates performed annual inspections and semi-annual instrument readings from at least 1997 to 1999.

AMEC has performed annual inspections and semi-annual instrument readings since the spring of 2000.

Mitigative Measures Taken

No major mitigative measures undertaken to date.

Some redirection of surface water and regrading/lining of the road sideslope and ditch has been done. The ditch liner was repaired in the summer of 2000.

Monitoring Overview

All slope inclinometers installed at the site show various degrees of slide activity, generally at depths of less than 4 m. One slope inclinometer location has sheared off twice at a depth of 9 m. Two other slope inclinometer locations are no longer being read for unknown reasons. Rates of movements in the slope inclinometers appear to be sporadic, with different instruments showing movements at different times. This indicates varying degrees of slide activity, possibly induced by changing surface drainage patterns. Relatively little movement has been measured since the ditch liner was repaired in the summer of 2000.

Cracking along the north shoulder of the road was first noted in the May 2002 inspection, and appeared to be continuing when checked again in the July 2003 inspection. In addition, the shallow slope instability around the fenceline below the road appeared to have reactivated between the May 2002 and July 2003 inspections.

Table A1 –S3 – Cochrane- Chronological Background

YEAR	MONTH	DESCRIPTION
1991	August	Several successive slide scarps were noted down slope of the road, which traverses a steep valley slope.
	September	3 slope inclinometers installed
1994	September	5 slope inclinometers installed (one was to replace the previous SI-3)
1998	May	Instruments read by Golder Associates. About 10 mm of movement was noted along a shear plane at 3.5 m depth in one of the SI's. Remaining 4 SI's showed no movement since previous readings.
	June	Annual Inspection by Golder Associates. Road embankment appeared safe, however further movements expected in slide down slope of road. Modifications to ditch liner and replacement of sheared SI's recommended.
	September	Instruments read by Golder Associates. 5 to 15 mm of movement was noted along a shear plane at 3.5 m depth in 3 of the SI's. Remaining 2 SI's showed no movement since previous readings.
1999	May	Instruments read by Golder Associates. 10 to 15 mm of movement was noted along a shear plane at 3.5 m depth in two of the SI's. Remaining 3 SI's showed no movement since previous readings.
	June	Annual Inspection by Golder Associates. Road embankment appeared safe, however further movements expected in slide down slope of road. Modifications to ditch liner and replacement of sheared SI's recommended.
	September	Instruments read by Golder Associates. 15 to 30 mm of movement was noted along a shear plane at 3.5 m depth in 2 of the SI's. Remaining 3 SI's showed no movement since previous readings.
2000	May	Instrumentation read by AMEC. 4 to 10 mm of movement in 3 of the 5 operational SI's. Remaining 2 SI's showed no movement since previous readings.
	June	Annual Inspection by AMEC. Road embankment appeared safe, however further movements expected in slide down slope of road. Modifications to ditch liner and replacement of sheared SI's recommended.
	September	Instrumentation read by AMEC. No significant movement. Ditch liner had been repaired.
2001	May	Instrumentation read by AMEC. No significant movement in any SIs. Annual inspection by AMEC and AT personnel.
	October	Instrumentation read by AMEC. No significant movement.
2002	April	Instrumentation read by AMEC. No significant movement, aside from continued creep at 2.7 m depth in SI #4.
	May	Annual inspection by AMEC and AT personnel.
	November	Instrumentation read by AMEC. The rate of movement at 2.7 m depth in SI #4 over the summer of 2002 was lower than during previous intervals between readings. Approximately 15 to 20 mm of additional cumulative movement noted since April 2002 in the upper 3 m of SI #6. Creep movement had previously been noted in this zone. The rate of movement over the summer of 2002 is comparable to that from the summer of 2000. SI casing SI #7 snapped off at ground surface. This SI was read twice – first at depths referenced to the previous casing stickup and second with depths referenced to ground surface. Future SI readings will be taken with depths referenced to ground surface and compared to the second set of readings taken in November 2002.
2003	May	Instrumentation read by AMEC.

	July	Annual inspection by AMEC and AT personnel. Cracking in north shoulder of road appeared to be continuing, and the shallow sliding around the fenceline appeared to have reactivated since the May 2002 inspection.

S3 – Cochrane

The Cochrane site was visited on July 7, 2003. Photographs from this site visit are included in Appendix S3, along with a site plan, air photograph, and a detailed discussion of the visit. This discussion has also been submitted in separate unbound sheets for inclusion in Appendix B of the Cochrane binder. The following is a brief summary of the assessment.

The landslide downslope of the road has experienced movement since the May 2002 site visit, as evidenced by the deformation of the slope face below the fenceline and the stretching of the fenceline itself. The cracking in the north shoulder of the road was also seen to be continuing.

The Risk Level at the site was increased to 18 in order to reflect the renewed movement of the landslide below the road and the continued cracking in the north shoulder of the road. AMEC recommends that the annual assessments and semi-annual monitoring at this site be continued. Please refer to Appendix S3 for further discussion.

APPENDIX S3
Cochrane

1.0 Site Visit

The Annual Inspection site visit was conducted on July 7, 2003. At the time of the visit, the weather was clear and windy.

2.0 Significant Observations

The following observations, considered to be relevant to the stability of the slope were made:

- Cracking along the north shoulder of the road, adjacent to SI #4 and SI #2 (Photos 1 to 4).
- Further downslope movement in the slide mass on the slope face below the fence line north of the road, as evidenced by tension cracking and downslope pulling of the fenceline adjacent to the scarp of the movement and overall slight downdropping of the slide mass (Photos 5 to 7). The renewed slide movement appeared to extend well downslope (i.e. 10's of metres) of the fenceline.
- The repairs to the ditch liner along the downslope edge of the road that were made in the summer of 2000 continue to perform adequately, however it appeared that the relatively low gradient of the ditch and relatively high spots on the ditch floor, particularly between SI #2 and SI #4, may have been allowing some of the ditch flow to overtop the berm and flow downslope into the shallow sliding area below the fenceline.

3.0 Changes from Previous Visits

It appears that the cracking along the north shoulder of the road has become slightly worse since the May 2002 inspection. The crack adjacent to SI #4 appears to have widened slightly (Photos 1 and 2) and a new crack has developed adjacent to SI #2 (Photo 3). This cracking is likely a reflection of the ongoing movement measured in the uppermost 3 m of SI #2 and SI #4 (please refer to the Spring 2003 monitoring report for further discussion).

The previously-noted shallow slide mass on the slope face below the fenceline appears to have undergone further movement since the last inspection in May 2002, and has an overall appearance of greater activity than has been noted in previous annual inspections, as shown in Photos 5, 6 and 7. The scarp of this movement roughly coincides with the fenceline for a distance of approximately 25 to 30 m, with pronounced tension cracking and downdropping visible along the scarp.

The summer 2000 repairs to the ditch liner appear to still be performing adequately, however a closer inspection of the overall ditch gradient and relatively low berm height suggests that peak ditch flows may overtop the berm. The runoff would then flow downslope into the shallow sliding area below the fenceline. There is a subtle, shallow swale beginning to form on the slope face downslope of SI #3A and any surface drainage that enters this swale would also be directed into the shallow sliding area downslope of the fenceline. While there was no definitive evidence that some of the ditch flow is occasionally overtopping the berm and flowing into the sliding area, the visual evidence suggests that this could be occurring, and may have at least partially been the cause of the increased sliding below the fenceline in the past year.

4.0 Discussion

The recent instrument readings and site inspection have shown evidence of two types of slope movement at this site:

- Shallow movement in the upper 3 m of SI #2, SI #4 and SI #5 – the SI's adjacent to the north shoulder of the highway. This movement is likely the cause of the cracking observed on the north shoulder of the highway.

- Renewed movement of the shallow slide mass below the fenceline, based on visual observations of the slope condition. SI #6 and SI #7, located upslope of the fenceline, have not measured any recent downslope movement, therefore it is possible that the recent movement below the fenceline is a shallow reactivation only and has not affected the area above the fenceline.

The summer 2000 repairs to the ditch liner appear to have been successful in restoring the ditch to its current state of effectiveness, however based on the observations of the relatively low ditch gradient it would be desirable to increase the ditch capacity through this area.

The cracking of the pavement on the north shoulder of the road adjacent to SI #4 could possibly be related to the shallow creep in SI #4, however, these cracks also had the appearance of longitudinal cracking of the pavement structure. These cracks should be checked during future site visits in order to further assess if they are related to the slope movement.

It is likely that damage to the highway in the near future can continue to be minimized by continuing to carefully control the surface water runoff conditions, however the ongoing cracking of the north shoulder is a concern and the renewed slide movement downslope of the fenceline could continue and possibly retrogress closer to the highway.

AMEC understands that AT is preparing to start a Functional Planning Study on the possible twinning of Highway 22 through this area. Based on discussions on site, it is understood that AT will check if possible geotechnical remedial options for this site will be included in the scope of this Functional Planning Study.

5.0 Assessment

The reactivated slide movements at/downslope of the fenceline are likely associated with the numerous shallow landslides on the valley slope below the road. The apparent reactivation of this slide movement in the past year may have at least partially been triggered by increased and/or peak surface runoff from the highway. As noted in the previous annual assessment reports, it is not considered feasible to mitigate the slope instability on the entire valley slope below this site. The most effective strategy would be to continue the instrument monitoring and annual inspections of the slope condition and also increase the carrying capacity and further reduce the possibility of peak flows escaping from the ditch and entering the slide area below the fenceline. Future monitoring should pay particular attention to the cracking along the north shoulder of the road, and consider remedial options for this site (e.g. pile wall) only if slope movement directly affecting the road is detected. As noted above, it is also possible that the upcoming Functional Planning Study for Highway 22 may address the geotechnical issues at this site.

On the basis of the above assessment, the Probability Factor with respect to this slide should be increased from 7 to 9 in order to reflect the renewed slide activity at/below the fenceline and the ongoing cracking in the north shoulder of the road.

It is likely that in the short term continued movements of the current slide will not impact the highway. Given the shallow nature of the slide mechanism, potential impacts in the highway, should they occur, are expected to be relatively small and gradual. The cracking in the road surface noted above SI #2 and SI #4 may represent such impacts. Significant losses to the highway would not be expected to occur rapidly. On this basis, the Consequence Factor of 2 for this site should be maintained.

Based on the above, the Risk Level at this site is calculated as 18, which is an increase from the value of 14 calculated after the annual inspections in 2001 and 2002.

6.0 Recommendations

The monitoring programs currently in place should be continued.

Annual Assessments at this site should be continued.

The surface conditions of the road at this location should be carefully monitored by maintenance personnel. This would be in conjunction with slope indicator monitoring to provide as early detection of potential problems below the road as possible. Particular attention should be paid to the cracking noted adjacent to SI #4 with repeatable measurements recorded to track crack development over time.

The carrying capacity of the ditch along the north shoulder of the road should be increased. This will reduce the chance of peak flows overtopping the ditch and flowing into the slide area.