Thistle Landslide

Utah reroutes round mud mound

Very rapid large-scale engineering operations were called for in the United States when a Utah valley was drowned in April by ponding behind a massive landslide. Geologist Dr Tony Waltham of Trent Polytechnic civil engineering department reports what he found recently when he visited main contractor W W Clyde at the site.

Just downstream of the tiny village of Thistle the Spanish Fork River flows through the narrowest part of its valley, cutting through the last barrier of the Uinta and Wasatch Mountains. It provides a natural routeway, westwards to Salt Lake City and out to the Nevada deserts. So beside the river lie a major highway and the main transcontinental line of the Denver and Rio Grande Western Railroad. Small rockfalls were common along the valley; but the scale of the slope failure had caused no undue concern.

Last winter was exceptional. Record mountain snowpack melted very fast in a warm and wet early summer. Utah was declared a disaster area with flooding, dam erosion, mudslides and landslides almost throughout the state in April, May and June. On 14 April the mountainside north of Thistle started to move; deeply weathered clays flooring an entire tributary basin slumped down towards the main valley. Probably no thicker than 50 metres, the landslide mass was 2400m long and over 300m wide with the head scar 550m above the toe. Over 12M.m^3 of saturated soil and rock was on the move, and it did not stop for many weeks. Each day the sun melted more snow. Streams flowed from the snowfields into the moving slide material.

At night temperatures fell low enough to halt the melting. Between midnight and 2am it moved up to seven metres, whereas at midday the movement almost ceased. The 12 hour lag was the time taken for meltwater to reach the heart of the slide.

The landslide and dam seen from the new road on Billies Mountain, with the lake extending away to the left.

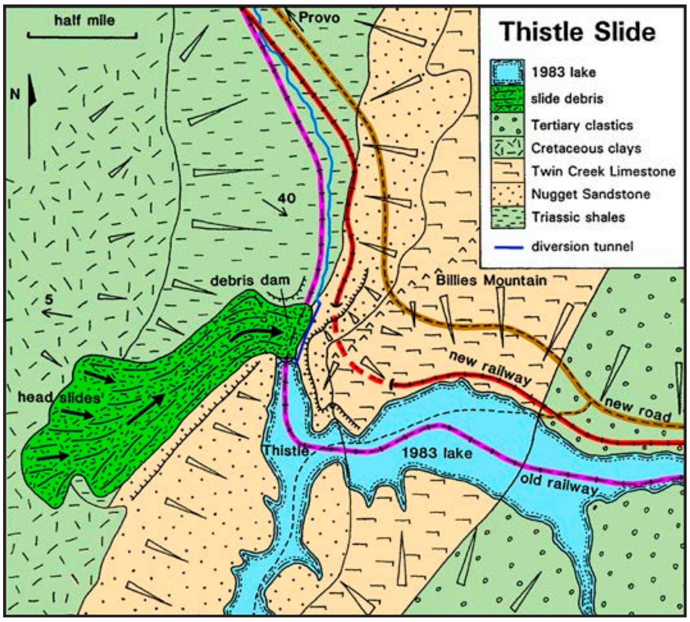
Road excavations east of the Billies Mountain cutting, with the new lake in the background and the new rail tracks along its shore.

The toe of the slide in the main valley floor was compressed against the sandstone spur of Billies Mountain directly opposite. It folded, sheared crumpled and lifted. Road and railway were lifted 15m before they were destroyed. When the slide movement stopped the valley floor was over 60m higher and the swollen main river was already starting to fill a lake to that depth on the upstream side. The village of Thistle was slowly drowned and eventually the lake backed up more than five kilometres in two feeder valleys.

The natural dam created by the slide is almost perfectly located in the narrowest section of the valley. Both walls are bedrock, though this is fractured and may be excessively permeable. The slide material is almost ideal watertight clay. It is still under compression from the main mass of the slide but may be heavily fissured towards the water face.

Prime concerns were for its overall stability and the threat of overtopping with erosion and a destructive downstream flood pulse. A major muck-shifting operation was therefore started in April. Work was instigated by the railroad company, which has since recovered costs from the state.

Material was moved from the heart of the slide and placed on the downstream face of the dam to give a 9° slope that is expected to be stable. The 300m-long crest of the dam was leveled, and raised at the eastern end.



Water from the new overflow pipe cascades down a bedrock spur, safely away from the front of the landslide dam.

Meanwhile an overflow tunnel 3.5m in diameter was cut in bedrock and extended with pipe so that the flow ran clear of the dam face. Lake level is now stabilized at tunnel level, 55m above the original valley floor. Concern for the dam stability continues and a low level tunnel is now being cut to allow complete drainage of the lake and inspection of the dam.

There is still debate about long term plans but it is quite likely that the lake will become a permanent feature of the landscape.

Both railway and road were very effectively cut by both the slide and lake. Both were vital routes that had to be quickly replaced.,

On the inside of the main valley bend, the spur of Billies Mountain rises 230m. Essentially a sandstone escarpment, dipping steeply southeast and capped by limestone this was the major obstacle for both road and rail.

The railroad company moved into action first. This was hardly surprising since regular coal trains on the line had their journey increased by the closure from 150km to an incredible 1700km. Work started in late April on a 940m-long tunnel through the spur at a level 11m above that of the new lake *(NCE* 19 May). At the same time four kilometres of new line had to climb over 60m on the downstream valley slide to reach the tunnel entrance. Another four kilometres track follows the edge of the new lake. The tunnel was favoured by excellent conditions in the sandstone and the outside earthworks proceeded smoothly, so that the first train covered the new route on 4 July. The first tunnel was only single track and a parallel tunnel for the second track is now under way.

The new road has to take a higher route because it is being built to four-lane standard throughout. The road climbs over 150m from the downstream side to reach a cutting more than 50m deep before a gentler descent towards the upper end of the lake. Scheduled for completion by 1 December the job was pushed through with a minimum of site investigation. Unfortunately problems have been revealed as the ground is opened.

Most of the earthworks have involved cutting benches into the valley sides in a variety of sedimentary rocks, mainly clays, siltstones and fairly friable sandstone. Cross-valleys have necessitated an impressive amount of cut and fill, though haul distances are mostly short. Difficulties have been caused by the steep slopes

The two limestone units exposed in the Billies Mountain road cutting; the strong upper bed forms a natural scarp, but the weak lower bed is having to be cut back and terraced.

but the sandstone at least is very effectively dozed over the edges of the drops on to site.

Excavation into the spur west of Diamond Fork revealed it to be a mass of ancient landslide debris that is totally unsorted and of doubtful stability. The cut was designed for a slope of 4 to 1, but has had to be modified to 1 in 1. With large boulders in the face even this may prove inadequate, but at present it cannot go back any further because of a power line just above.

The main sandstone unit forms a scarp face across the western slope of Billies Mountain. It is good competent material and the road traverses it on a ledge cut below a free face which is almost vertical and 20m high. This is perfectly stable except where it has revealed two crossing gullies each 15m deep and filled with alluvial sand and cobbles. Fill material has now been left at the same angle as the adjacent sandstone but at least some failure seems likely and the adequacy of the roadside rock trap may be questioned. The groundwater high of next spring should reveal the outcome.

The main cut through the crest of the spur is largely in the dipping limestone caprock. Design for the cut had called for the 50m faces to be very steep with only a single 6m bench. But it was found that whereas the upper unit is strong and massive, it overlies an impure, muddy and thin bedded limestone that is considerably less stable en masse. The cut in the upper limestone is therefore as planned, but the western face of the main cut in the lower limestone is cut back to include three benches each 10 metres wide. It was also hoped to use the limestone for road aggregate but debate is now ensuing over suitability of the material.

The alternative is rock brought in from quarries at Spanish Fork, 20km away. For the rail ballast, artificial aggregate was hauled 135km from the Kennecott copper smelter.

With work still continuing on the road earthworks, the second rail tunnel, and the lake drainage scheme, engineering consequences will make it a textbook example for the future.

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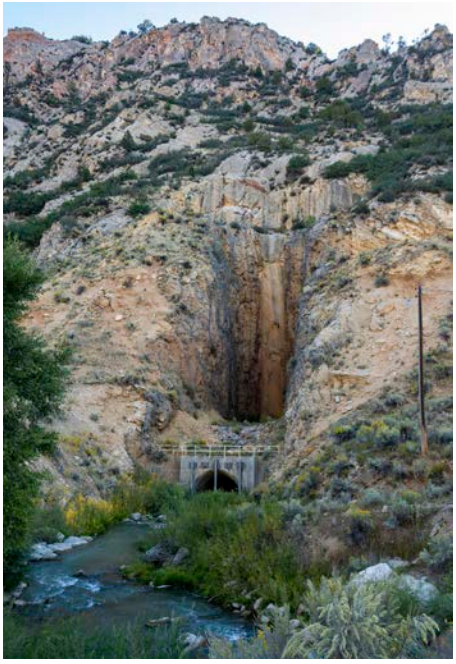
It has been reformatted for this e-version, but the text was scanned and is unchanged.

Postcript

The landslide dam retaining the new Thistle Lake was deemed unsafe in the long-term. It was therefore drained in 1984, before even the new road and the second railway tunnel had been opened. A low-level drainage tunnel was excavated through bedrock beside the landslide debris, through to the foot of a shaft sunk on the lakeshore. A short channel to the shaft was then deepened in stages so that the lake level progressively dropped, and the river now drains directly into the tunnel. Though damaged houses emerged from the retreating waters, the townsite of Thistle has not been re-established.



The notch in the hillside that was progressively blasted downwards to drain the lake into the shaft at the back.

The site as it appeared in 2017; the new road cutting is high on the left; the railway runs into its twin tunnel portals in the centre;the landslide debris lies in sunlight where it blocks the main valley on the right.