Worker survives excavator rollover

A utility hoe operator was pioneering a logging road along a steep slope. The area had been drilled and shot-blasted recently, and the road was being constructed through a prescribed ¾ bench endhaul section. The utility hoe operator was stripping the overburden (loose materials created by the blasting) and laying puncheon (small logs and branches) onto the sub-grade to establish a stable platform for the excavator. As the utility hoe operator was travelling back to grab more puncheon, the excavator broke through the previously laid puncheon and slid down a wet bank (40 percent slope). After sliding down 60 feet, the excavator toppled over a 30-foot bedrock bluff, landing upside down on a lower bench approximately 150 feet below the road. The utility hoe operator was pinned in the machine for approximately four hours. He suffered serious injuries.

Purpose of this report
The purpose of this online incident investigation report is to identify the causes and contributing factors of this incident to help prevent similar incidents and to support preventive actions by industry and WorkSafeBC. This online version is not the official WorkSafeBC report. It has been edited to remove personal identifying information and to focus on the main causes and underlying factors contributing to this incident.

Notice of Incident information
Number: 2005138190147
Outcome: Injury
Core activity: Logging road construction
Location: Northwestern BC
Date of incident: August 2005

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1 Factual Information

1.1 Employer and site planning

The company constructing the logging road at the time of the incident is a small business with fewer than 20 workers. This company (called "the employer" in this report) conducts business in logging road construction and maintenance. A forest product company (called "the licensee") holds the timber licence. All the planning and design of the logging road was conducted by the licensee.

The employer was constructing the logging road in a river valley along one of the inlets on the west coast of British Columbia. The method used was bench construction. (See the appendix for an explanation of bench construction.)

1.1.1 Pre-work planning

The licensee conducted pre-work surveys and planning and hired a geosciences company to conduct a geological study of the area. The geological study was conducted in March 2005 and the terrain stability field assessment report was completed in April 2005. According to this report, four sections of the road required full bench endhaul and one section required a ¾ bench endhaul. The slide occurred in the area of the road that required a ¾ bench endhaul.

The report calls for extra care while operating in this area to reduce impact and prevent injuries, and refers the operator to the licensee's standard operating procedures (see section 1.1.2).

1.1.2 The licensee's standard operating procedures

The three paragraphs below are from the licensee's standard operating procedures:

> The Guidelines for Working in Areas of "Questionable Stability" apply at all work sites. Beware of the terrain hazards (potentially unstable terrain, avalanche zones, etc.) in your work area, and be familiar with the Rain Shutdown Guidelines.
> . . .
>
> If work is being done in an area identified with a moderate to high likelihood of landslides, ensure workers' safety by always proceeding with caution. In areas like this, it is very important to identify unforeseen conditions and report them to your supervisor. Always follow all special construction techniques as described in a terrain report.
> . . .
>
> In rockwork, select blasting techniques to minimize disturbance to known forest resources. This will minimize fly rock and will reduce the potential for landslides or slope instability.

1.2 Sequence of events

1.2.1 The day before the incident

On the day before the incident, a heading hoe operator was working at the incident site pioneering the road. He was aware that the terrain stability report called for a ¾ bench endhaul. He noticed that the centre marker of the road was too far left down the slope (see Photo 1). He decided to move to the right and started cutting into the hill. He noticed that the ground was soft and slippery. He knew that there was a seepage bowl in the area, where the water was seeping through the ground and flowing on top of the solid rock. This resulted in a layer of water between the soil and solid rock, causing instability.

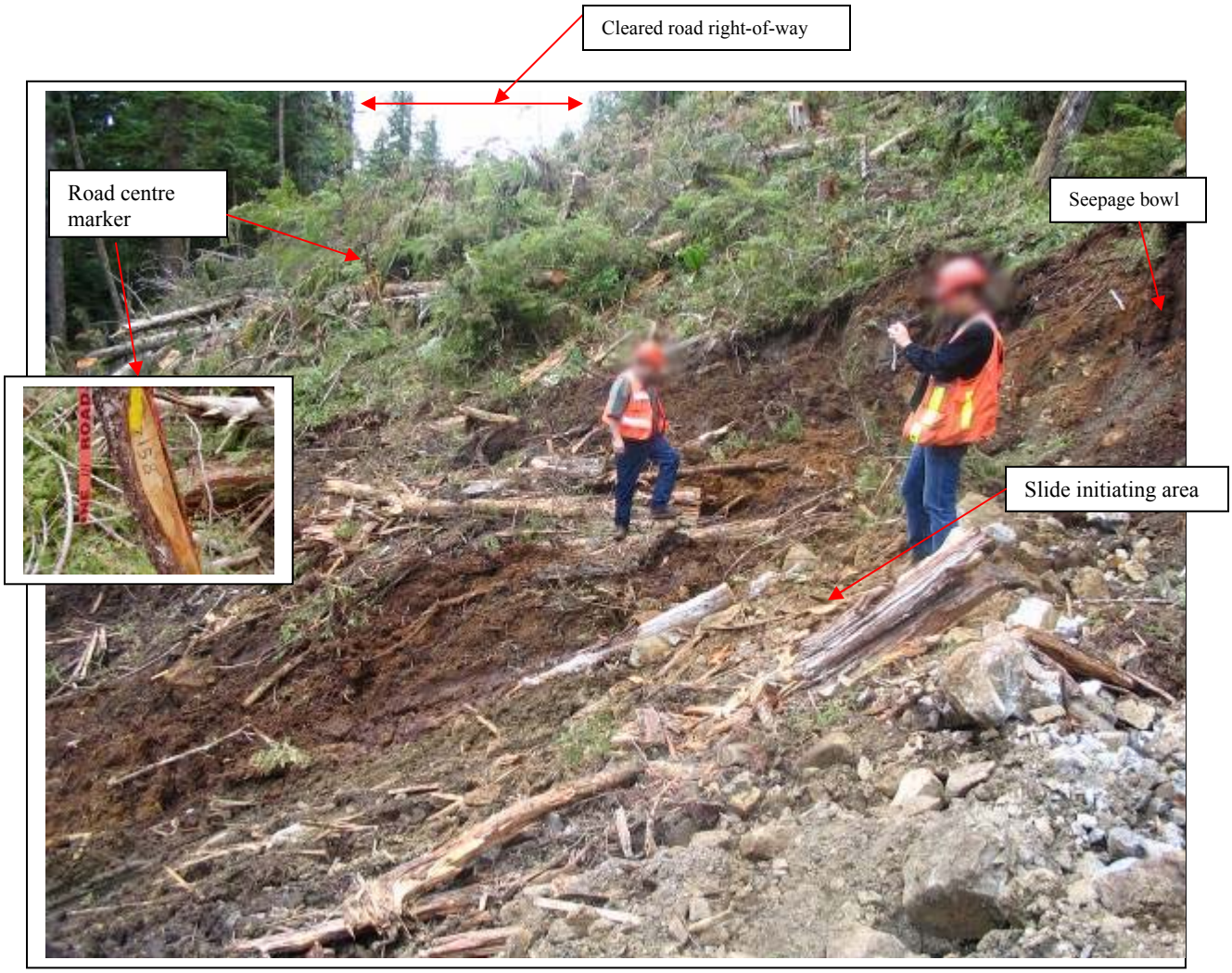

Photo 1: This photo taken after the incident shows the location of road centre marker.

This was the heading hoe operator's last day in camp, so later that day, the employer's supervisor and general manager discussed the personnel for the next day. There was another heading hoe operator scheduled to work the next day but at the last minute he was no longer available. It was decided that the utility hoe operator (the worker who was later injured in the incident) would work as a heading hoe operator on the following morning. The charge hand (who also worked as a heading hoe operator) would take over in the afternoon when he returned to camp. The heading hoe operator who had worked at the

site the day before the incident told the utility hoe operator to be careful because it was "bad area." (See the appendix for an explanation of the jobs of heading hoe operator and utility hoe operator, as generally used in the industry.)

1.2.2 The day of the incident

A crew of two workers—the utility hoe operator and the driller/blaster—arrived at the work site at approximately 0700 hours. The utility hoe operator began working on the spur road where the heading hoe operator had left off the day before. The driller/blaster prepared for blasting at the heading.

At approximately 1000 hours, the driller/blaster set off a blast. The utility hoe operator moved in to the heading and began to remove the overburden (loose materials created by the blasting) and to prepare the area for the next shot.

At approximately 1025 hours, the utility hoe operator travelled back and forth to pick up puncheon (small logs, branches, brush, etc.) to prepare a platform for the excavator. A few minutes later, as the utility hoe operator travelled back to get more puncheon, the excavator broke through the previously laid puncheon and slid down along a wet bank with a slope of approximately 40 percent. After sliding down the slope approximately 60 feet, the excavator toppled over an approximately 30-foot bedrock bluff, landing upside down on a lower bench approximately 150 feet below the road (see Photo 2).

Photo 2: The excavator slid down a steep muddy slope and over a bluff.

The driller/blaster saw the excavator slide down the slope and announced the incident over the radio. He noticed flames and smoke coming from the excavator and proceeded down the hill with fire extinguishers. The mechanic working nearby heard the slide occur and attempted to contact the utility hoe operator on the radio. He headed to the site and saw the driller/blaster attempting to extinguish the

fire. The mechanic gathered more fire extinguishers and went down to the excavator. Together the mechanic and driller/blaster extinguished the fire. They noticed that the utility hoe operator was conscious but trapped upside down in the machine cab.

The supervisor, who was in the crew boat, heard the incident and arranged for a helicopter. Additional crew members arrived at the scene and attempted to extricate the utility hoe operator. Due to the fuel and fumes in the area, the rescue crew requested a local fire department to respond with the "jaws of life." At approximately 1400 hours, the utility hoe operator was extricated from the excavator and transferred to hospital with serious injuries.

1.3 Weather conditions

The employer's record indicated the following amounts of moderate rain in the days leading up to the incident.

Date	Rainfall	Weather Conditions
7 days before incident	0 mm	Sunny
6 days before incident	0 mm	Sunny
5 days before incident	0 mm	Light rain in the afternoon
4 days before incident	68 mm	Raining
3 days before incident	39 mm	Raining
2 days before incident	51 mm	Raining
1 day before incident	6 mm	Rain in morning, sunny in afternoon
Day of incident	0 mm	Sunny

The licensee requires road construction to be shut down if the following rainfall limits are reached.

Time period	Measured rainfall and snowmelt limit
12 hours	75 mm
24 hours	100 mm
48 hours	150 mm
72 hours	200 mm

The rainfall in the preceding days had not reached these limits.

1.4 Equipment

The excavator involved in the incident was a turntable-type machine. It was equipped with a road builder package, which included operator protective structures (OPS), a thumb, catwalks, house guards (reinforced cab), rock guards, belly pans, and a counterweight fuel tank. The gross vehicle weight is estimated at 117,000 pounds.

A road builder package provides protection for the operator (the OPS), as required by the Occupational Health and Safety Regulation, and usually includes additional protection for the machine. (See the appendix for a description of the OPS requirements for the turntable-style excavator.) During the incident, the OPS collapsed, trapping the utility hoe operator.

1.4.1 Inspection of operator protective structures after the incident

The OPS were examined by a WorkSafeBC engineer after the incident. The cab, cab guard, and window guarding of an excavator provide a protective structure against falling objects, as required by WorkSafeBC's G602 standard (see OPS in the appendix). There is no requirement specifically for *rollover* protective structures for turntable-type machines. However, the required flying object protective structures (FOPS) will provide some protection to the operator in the event of a rollover.

The engineer's report states:

> The G602 FOPS was 42 inches wide, 60 inches long and 60 inches high. The roof, composed of 3½ x 3½ x ⅛ inch wall square tubing in a perimeter frame with 3½ x 3½ inch square tubing cross members and a steel plate skin, was slightly distorted.
>
> The FOPS roof and front supporting legs were still attached to the machine. The weld connection between the roof and front posts held. Parent metal tore and there was post deformation. The 2 rear left side legs had torn primarily in the welds at the roof connection. Approximately half of the welds failed in both of these connections. The rear right leg also tore close to the attachment to the roof. Here the failure was primarily [of] parent metal. There was no evidence of gussets for the rear connections. The 3 rear posts were missing as they had been removed in the extraction of the worker. The weld area showed the 2 left side rear posts were 3½ x 3½ x ¼ wall square tubing.
>
> The front window guard, consisting of 3½ x 3½ x ¼ square tubing post frame and ¾ inch round stock welded to the inside of the tubing, was bent towards the boom and somewhat to the rear. The knee welds in the posts approximately ⅓ of the way from the bottom opened from the rear. There was no tearing of parent metal in these welds, suggesting lack of penetration. The posts were only slightly distorted.
>
> The G602 structure had pinned connections where mounted to the machine. The pinned connections appeared intact. Each of the front posts had one gusset where they were welded to the roof. The cab had experienced substantial longitudinal loads and was "flattened" in the rearwards direction.

1.5 Worker

At the time of the incident, the injured worker was employed as a utility hoe operator. He had been with the employer for approximately 25 years, first in the logging industry, where he had a variety of jobs. Several years ago, he was transferred to the road construction crew and began swamping (as a helper) with the driller/blaster.

1.5.1 Training and experience as a hoe operator

The utility hoe operator learned how to operate a backhoe (excavator) when he was in logging. After transferring to the road crew, he would operate the backhoe whenever no other operator was available. He learned how to operate the backhoe on the job under the direction of the road charge hand. Most of his on-the-job training has been on level or low-slope road construction. He had very limited experience as a heading hoe operator. The day of the incident was his first day working as a heading hoe operator on a steep slope (40–70 percent).

The utility hoe operator was known to be a very good hoe operator who was confident and conscientious. However, he did not have the experience on steep slopes that would be expected of a heading hoe operator.

1.5.2 Work schedule and hours of work

The utility hoe operator was working on a schedule of 15 days in and 6 days out. During work days, he would stay at the camp provided by the employer. His work day lasted approximately from 0700 hours to 1700 hours. On the day of the incident, the utility hoe operator was on his sixth day in camp.

2 Analysis

2.1 What is the logging road construction process?

The very first phase of road construction is planning and design. During this phase, the area is surveyed and assessed for terrain stability and reports are prepared. A road engineer sets up the markers to clear right-of-way. In this case, the licensee contracted with a geosciences company to conduct the terrain stability assessment. A geotechnician and a road engineer planned and prepared the reports, and road centre markers were set for the road block where the incident occurred.

Construction of the road was contracted to the employer. During the construction phase, the planning and design decisions that had been made earlier are carried out on the ground to achieve the desired road standard in a way that is efficient and effective, and results in minimal impact to the environment. Each phase of the road construction is conducted according to the designed plans.

Plans and designs may need to be modified during construction as changing conditions are encountered in the field. Experienced administrators and equipment operators can accomplish minor changes to the proposed work in the field; substantial changes in road design, however, are made only by qualified personnel and through the proper procedures and approval processes.

2.2 What did the plan call for at the incident site?

The pre-work map calls for a ¾ bench endhaul at the incident site.

2.2.1 What is a bench cut?

Bench construction is also known as balanced cut and fill construction. What this means is that a portion of the road will be cut into the hillside and the rest of the road will be built with filling or side casting (see Figure 1). The incident site called for ¾ bench endhaul, which means that ¾ of the road would be cut into the hill and ¼ would be built with filling or side casting, and the extra materials would be hauled away with trucks.

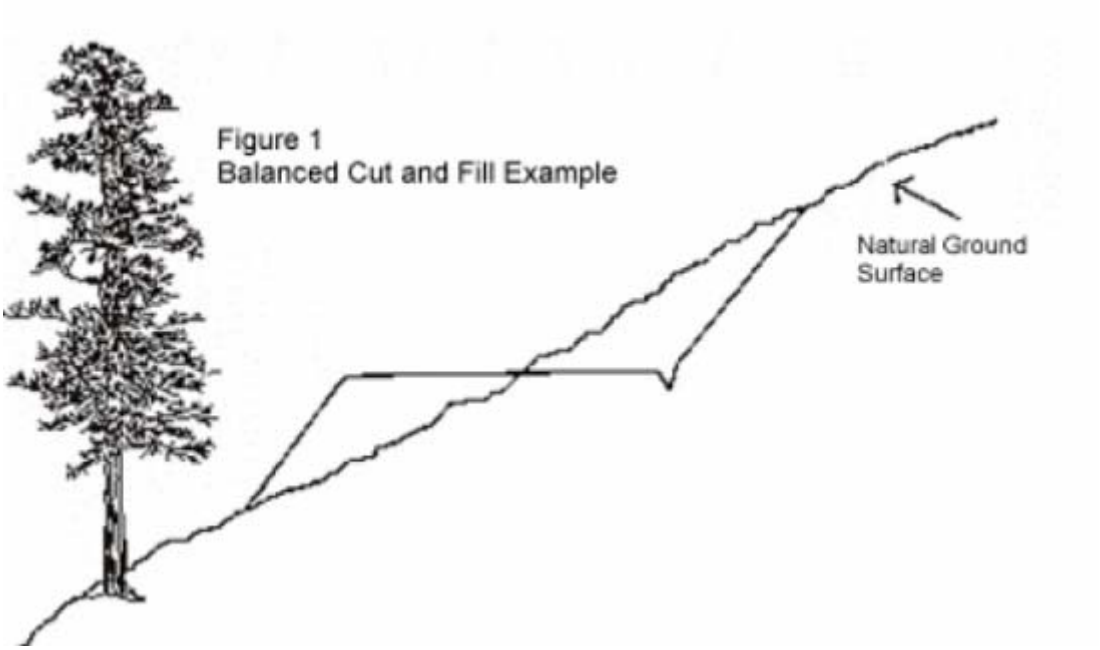

Figure 1: Bench construction, or balanced cut and fill. Source: *Forest Roads Manual,* Section 4. Oregon Department of Forestry. Used with permission.

2.2.2 Was ¾ bench the right decision for this part of the road?

In bench construction, some of the waste materials move down the slope below the road bed and cannot be adequately compacted. For this reason, this method is not suitable on steep slopes (over 55 percent) and moderate slopes (40–55 percent) that are near streams where uncompacted materials could become saturated with water.

According to the terrain report, the slope at the incident site was 40–70 percent. Furthermore, there was a seepage bowl in the area. This was mentioned in the terrain report. This phase of the road should have been full bench endhaul, with the full width of the road cut into the hill and all the extra material from the cut hauled away.

2.3 Were the operators following the instructions and standard operating procedures?

The heading hoe operator who worked at the site the day before the incident stated that he was following the map and was aware of the seepage bowl in the area. He had noticed that the road centre marker was way off to the left, and had he followed the marker they would have ended up with a dip in the road. Furthermore, he could feel with the bucket that the ground was very soft, which he described as "black mud on slippery rock." For these reasons he proceeded to cut into the hill and moved to the right. He knew that the area was unsafe, and on the day before the incident, he told the utility hoe operator that the area was bad and that he should stay into the hill and keep cutting.

The utility hoe operator did not review the map and the guidelines on the day of the incident. He was not aware of the fact that this phase of the road called for ¾ bench endhaul. Furthermore, he was not aware of the seepage bowl and the black mud on top of slippery rock. He was asked by his supervisor if he felt okay to conduct heading work until the charge hand arrived at the site.

The utility hoe operator stated that he was just following where the heading hoe operator had left off. He had noticed that the heading hoe operator had started to cut into the hill so he was following along. The heading hoe operator was right with his assessment of the area to be a "bad area."

2.4 Did the utility hoe operator have adequate experience to pioneer road at steep slopes?

The utility hoe operator had adequate training and experience to operate an excavator on level or low-slope areas, but he did not have adequate training and experience in conducting heading work. Experienced heading hoe operators had full confidence in him but did not feel that he was ready to conduct heading hoe work on steep slopes.

2.4.1 Why was the utility hoe operator asked to conduct heading hoe work on the day of the incident?

The employer had workers scheduled to ensure that a qualified heading hoe operator would conduct the heading work. However, the heading hoe operator who was supposed to be working at the time of the incident was suddenly no longer available. The supervisor knew that the charge hand was returning to the camp at 1100 hours on the day of the incident, and the supervisor asked the utility hoe operator to conduct the pioneering work in the morning. The supervisor made the wrong decision in allowing the utility hoe operator to conduct road pioneering work.

2.5 Why did the slide occur?

The road phase where the utility hoe operator was working had soft materials on top of slippery bedrock. Due to the seepage bowl, water was draining down the hill under the soft mud on top of the bedrock. This created an unsafe condition for the excavator, which weighs approximately 117,000 pounds. Furthermore, the crew conducted a heading shot in the area and the vibrations may have made the material unstable. The utility hoe operator was moving back and forth in the area and was setting up puncheon to build a new pad for the excavator. The back-and-forth movement of the excavator may also

have made the materials unstable. Previous rainfall, although it did not exceed the rainfall shutdown limits, may have added to the saturation of the materials in the area that failed.

2.5.1 Would an experienced heading hoe operator have prevented the slide?

It is very difficult to decide whether an experienced operator would have done anything differently that could have prevented the slide. After discussing the incident with experienced heading hoe operators, however, the WorkSafeBC lead investigator concluded that an experienced operator would have been aware of the soft muddy materials on top of slippery bedrock and either would have made adjustment to stay away from the low side or would have contacted the supervisor to assess the situation. Furthermore, experienced operators informed the lead investigator that after the machine began to slide down, they would have turned the bucket to the high side to slow or stop the machine from sliding. It is impossible to predict, however, whether that would have stopped the machine from sliding down in this situation.

2.6 Discrepancy in road station markers in the field and on the map

There was a discrepancy between the road stations marked in the field and the pre-work maps and paperwork, but this did not cause any confusion for the heading hoe operator the previous day; he was using the spur as his indicator and was fully aware of his location on the road. The utility hoe operator did not refer to the pre-work map and paperwork, however, and was only following the work begun by the heading hoe operator. After discussion with the utility hoe operator, the lead investigator concluded that even if the utility hoe operator had referred to the map and paper work, he would not have made any changes to his work.

2.7 Why did the operator protective structures fail?

This excavator model's bare operating weight is between 90,000 and 100,000 pounds. As equipped and with the road builder package, the machine involved in the incident had an actual weight estimated to be 117,000 pounds.

The WorkSafeBC engineer stated that for excavators in the 60,000–110,000 pound operating weight category, we would normally expect OPS with 4 x 4 x ⅜ inch square tubing with the joint between the legs and roof being gusseted. This would meet the requirement of the WCB Standard G602. However, the OPS on this machine was gusseted only at the joint between the roof and two front legs. Some of the welds on the OPS were inadequate in that the welds rather than the parent material failed. The actual section size and wall thickness of the legs were less than what WorkSafeBC engineering has suggested for this type of application (see section 1.4.1).

Turntable-type machines are not required to have OPS designed to withstand rollovers. However, well-built OPS—although designed for protection against falling and flying objects—have been found to generally provide protection in one 360° rollover.

The weld failures in the operator protective structure and limited deformation of the front legs suggest substandard construction as well as questionable design contributed to the failure. The WorkSafeBC engineer has suggested, and the lead investigator concurs, that the OPS on this machine did not meet the requirements in the following ways (see Photo 3):

- It lacked the gussets between all the legs and the roof section.
- The welds were inadequate in that the welds opened instead of the parent metal being torn.
- Unless certified as adequate, the supporting legs were not of sufficient size for an excavator of this capacity.

Photo 3: The operator protective structures did not meet requirements.

After reviewing all the available data with the WorkSafeBC engineer, we are unable to conclude that OPS fully meeting WorkSafeBC requirements would have stood up in this rollover. It can be concluded, however, that OPS fully meeting WorkSafeBC requirements would have absorbed considerably more energy before failing and would have been significantly more likely to have provided more survival space for the operator (see Photo 4).

Photo 4: The crushed cab.

The WorkSafeBC engineer's report also commented on the possibility of a future standard for a rollover operator protective structure (ROPS):

> Turntable type machines are at present excluded in North American and European rollover protective structure standards. However, the international standards organization has produced a draft international standard for ROPS on turntable based forestry machines. The standard I anticipate will be completed and published within 2–3 years. At that time certified rollover protective structures will be available for most turntable based forestry machines. Between now and then we will be relying on well built operator protective structures meeting WCB requirements for limited rollover protection on these machines.

3 Conclusions

3.1 Findings as to causes

3.1.1 Unstable muddy materials on top of smooth bedrock

At the incident site, there were sandy/soft muddy materials on top of smooth bedrock that had been made slippery with water draining down the hill.

3.1.2 Inadequate experience of utility hoe operator

The utility hoe operator did not have adequate experience and training to work as a heading hoe operator. He was unable to recognize that he was working on top of very soft muddy materials lying on top of slippery bedrock. He was also unaware of the seepage bowl.

3.1.3 Lack of instructions and information to the utility hoe operator

The utility hoe operator was asked by the supervisor if he felt okay to work as heading hoe operator in the morning; the supervisor, however, did not review the pre-work map and paperwork with him. The heading hoe operator from the previous day mentioned to the utility hoe operator to be careful because it was a bad area, but no further instructions were given to him.

3.2 Findings as to underlying factors

3.2.1 Poor planning and design for this phase of the road

The slopes in the area were 40–70 percent and there was a seepage bowl in the area. The road engineer and geotechnician should have conducted more field tests to determine the soil conditions in this area. The road marker was not set properly, which led the heading hoe operator to make a judgment call and start moving to the right without discussing this with the appropriate personnel. Because the heading hoe

operator had made the adjustments to the road construction by moving in to the right, the utility hoe operator followed without questioning and/or concerns.

3.2.2 Charge hand was not contacted

The supervisor contacted the general manager and asked him whether the utility hoe operator could be used as a heading hoe operator in the morning, but the charge hand was not contacted for his input. The charge hand would have known that the utility hoe operator did not have the necessary experience working on steep slopes.

3.3 Other findings

3.3.1 Operator protective structures collapsed

The operator protective structures on this machine did not meet the minimum requirements and failed. OPS fully meeting WorkSafeBC requirements would have absorbed considerably more energy before failing and would have been significantly more likely to have provided more survival space for the operator.

4 Orders Issued after the Investigation

WorkSafeBC issued two orders after the investigation. An order requires an employer to take steps to comply with the *Workers Compensation Act* or Occupational Health and Safety Regulation, to take measures to protect worker health and safety, or to fix a hazardous condition. An order is not intended to identify fault on the part of the employer but to ensure that unsafe conditions are identified and corrected and that the employer complies with the Act and the Regulation. An employer may ask the Review Division to review an order; the Review Division may confirm, vary, or cancel an order.

In addition to issuing orders, WorkSafeBC may recommend proceeding with an administrative penalty against an employer. In order to protect the privacy of individuals, this report does not give details of any penalty proceeding arising from this incident as that would identify the employer. Penalties are fines for health and safety violations of the *Workers Compensation Act* and/or the Occupational Health and Safety Regulation. For information on when penalties are considered and how the amount of the penalty is calculated, see the penalty FAQs on WorkSafeBC.com. Companies that have been penalized are also listed on the web site.

4.1 Order to the logging road construction company

This section summarizes an order to the logging road construction company, the employer of the injured worker. The investigation found that this employer was in contravention of the *Workers Compensation Act*, section 115(1)(a)(i), which states that an employer must ensure the health and safety of all workers working for that employer.

Without delay, the employer was ordered to ensure the health and safety of its workers, including but not limited to the following:

- Ensure that its workers are made aware of all known and reasonably foreseeable health or safety hazards to which they are likely to be exposed by their work.
- Ensure that all road construction work is conducted in accordance with the written instructions of a professional engineer when required.
- Provide its workers with adequate instruction training and supervision necessary to ensure health and safety of those workers in carrying out their work duties.
- Ensure that mobile equipment operator protective structures (OPS) meet the minimum requirements of the Occupational Health and Safety Regulation.

4.2 Order to the licensee

This section summarizes an order to the licensee, the forest product company holding the timber licence. The investigation found that this employer was in contravention of the *Workers Compensation Act*, section 115(1)(a)(ii), which states that an employer must ensure the health and safety of any other workers present at a workplace at which that employer's work is being carried out.

Without delay, the employer was ordered to ensure the health and safety of other workers working at a workplace where this employer's work is being carried out:

- Ensure all road construction work and/or excavation work is conducted under the direction of a professional engineer when required by the Occupational Health and Safety Regulation.

5 Health and Safety Action Taken

In addition to the specific actions below, employers, workers, or others in industry may have taken measures to prevent a recurrence of this type of incident. Employers are expected to comply with any orders issued. At WorkSafeBC, the Lessons Learned committee examines recommendations from incident investigations to see what can be done to prevent similar incidents.

5.1 Reassessment of the area by geotechnician

The site was reassessed by the geotechnician and instructions were provided to ensure that the work was carried out by experienced operators and that extra precaution would be taken through a 65-metre-long section where a similar seepage bowl existed.

5.2 WorkSafeBC

WorkSafeBC produced a slide show on this incident:
http://www2.worksafebc.com/publications/multimedia/slideshows.asp?reportid=34159

Appendix: Definitions

Bench: A cut made into the side of the hill to construct the road. Bench construction is also known as balanced cut and fill construction. A portion of the road is cut into the hillside and the rest of the road is built with materials from the cut (called filling or side casting). With a ¾ bench endhaul, three-quarters of the road is cut into the hill and one-quarter is built with filling or side casting, and the extra materials (endhaul) are hauled away with trucks. A full bench endhaul is built with the full width of the road cut into the hill and all the extra material from the cut hauled away.

Endhaul: The material that is hauled out by trucks after a bench is constructed.

Heading hoe operator: A heading hoe operator pioneers the road. A heading hoe operator has extensive experience as an excavator operator on steep slopes under the direct supervision of a trained supervisor.

Operator protective structures (OPS) for excavators: WorkSafeBC has a guideline and standards that describe the required OPS for hydraulic excavators pioneering on steep side slopes. See OHS Guideline G16.21, available on WorkSafeBC.com. This guideline includes links to the four relevant WCB Standards that apply to excavators used for road building on steep slopes:

- WCB Standard G602 covers cab structure
- WCB Standard G603 covers window guards
- WCB Standard G608 covers the heavy duty roof structures
- WCB Standard G604 covers an alternative window guard on the boom side

Utility hoe operator: A utility hoe operator operates an excavator on level ground and/or small slopes. A utility hoe operator can load trucks.