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INNOVATION

DEBRIS FLOW DANGER
PREDICTING THE UNPREDICTABLE

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THE DEVASTATION OF DEBRIS FLOWS AND THE DIFFICULTY PREDICTING THEM

BC's steep terrain coupled with an increase in fire-damaged slopes, are the perfect ingredients for destructive debris flows. Here are four perspectives on approaches to mitigate damage from this unpredictable foe.

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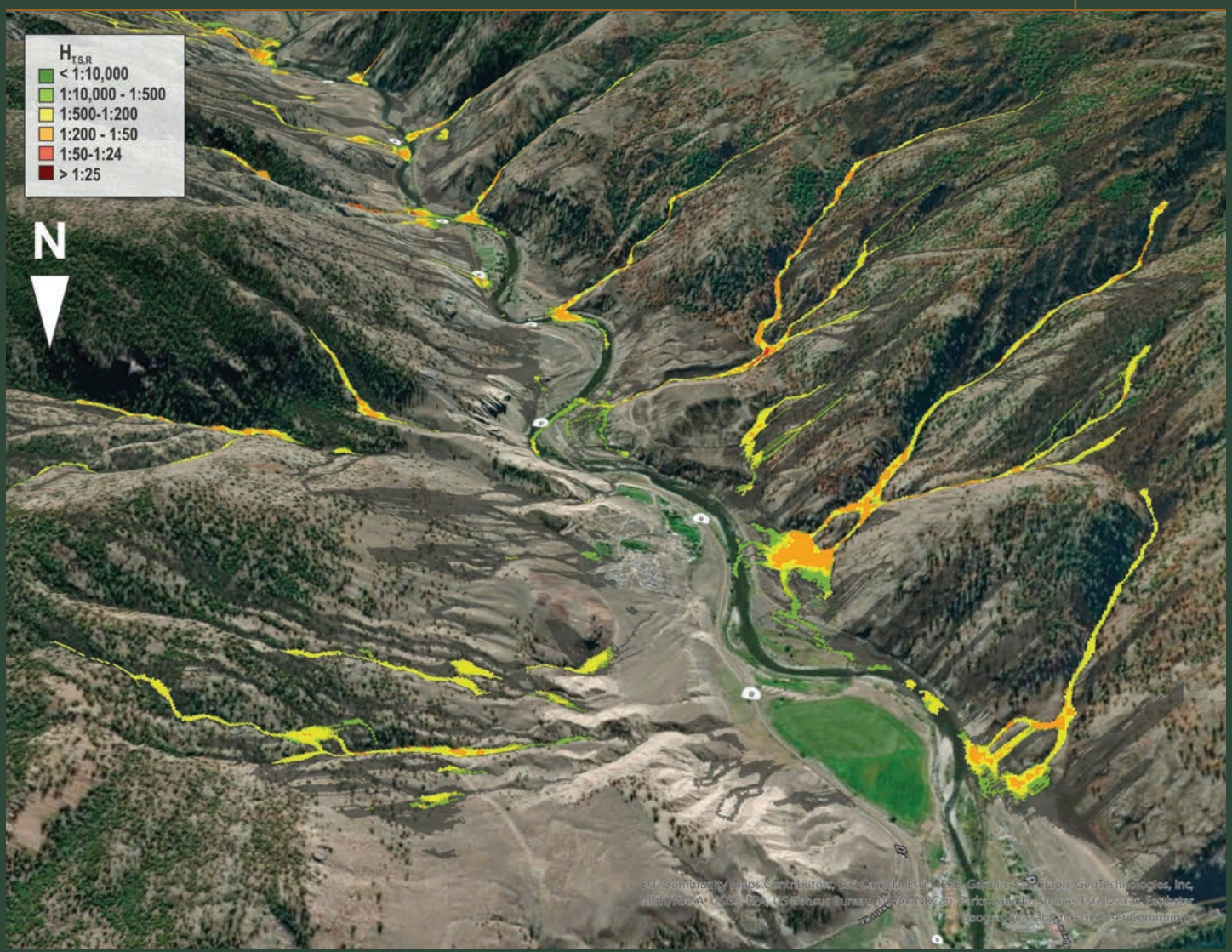

Triggered by intense rainfall, or possibly an earthquake, debris flows gain momentum from afar and strike with little warning. They tear through earth, collecting trees, rocks, mud, and any other debris in their dangerous erratic path.

BC's steep topography is particularly prone to damaging debris flows.

Predicting potential routes and developing solutions to prevent and protect against damage and loss of life is a costly and complicated challenge.

Debris flows "are among the largest growing deadly hazard," says Dr. Richard Guthrie, MSc, P.Geo. "As our population grows on the planet, more and more of us are occupying cities and communities that are adjacent to mountain hazards."

Guthrie has dedicated his career to protecting people from geological hazards. The geoscientist is on the cutting edge of modelling debris flows, calling this a "remarkable moment in history" where there is an ocean of data along with the tools to process it all.

As Vice President and Director of Geohazards and Geomorphology at Stantec, Guthrie has been working on a tool called DebrisFlow Predictor. He says the next six months will change the landscape for such tools.

LEFT: Dr. Richard Guthrie, MSc, P.Geo., and his team have developed the DebrisFlow Predictor, a tool to assist in assessing potential trajectories and damage of debris flow. Photo: Courtesy of Stantec. RIGHT: The danger of debris flow from Catiline Creek, shown in the centre of the photo, affects residents in Lillooet Lake Estates and Heather Jean Properties, 20 km east of Pemberton. Photo: CONTRIBUTED

Debris flow experts Dr. Richard Guthrie, MSc, P.Geo., at right, and Dr. Thad Wasklewicz, lead Stantec's geohazards practice. PHOTO: CONTRIBUTED

"We're at the cusp of a completely different understanding," he says. "Our understanding of what those events involve and where they occur is going to change. It is changing dynamically."

The tool Guthrie has been developing with a team of about 30 geoscientists based across several countries has already mapped about two million potential debris flows in Canada—more than three-quarters of them in BC. Until now, only the development team and universities have had access to DebrisFlow Predictor, but the software as a service will be widely available in early 2024.

"It's really important to think about debris flows as a hazard in both time and space," he says.

The probabilistic model can be run over and over to give a cumulative footprint of potential debris flows with a simulation that shows how they might come together in a big storm to create a cumulative effect massing into a bigger footprint.

The effects of climate change are also impacting debris flows, including record wildfires which multiply their likelihood.

"The immediate effect of intense burning on a slope is like spraying Teflon over the entire thing," says Guthrie.

Water accumulates gaining speed until there's enough weight that it breaks through the soil, causing a debris flow.

Guthrie says new research is showing that post-wildfire debris flows are much more likely—perhaps by hundreds of times.

That could have an impact on BC, which is experiencing a record-setting amount of scorched earth. So far in 2023, nearly 30,000 square kilometres have burned in wildfires. That's double the previous record set in 2018 of 13,500.

New predictive tools being developed will help professionals who are struggling to assess risk.

"There are people who are tackling it but it's not easy," Guthrie says. "There is a very high degree of interpretation and expertise involved. We want to give them the tools that will help."

GROWING NEED TO PROTECT AGAINST DEBRIS FLOWS

In the remote BC Central Coast community of Wuikinuxv (Wi-kin-oo) Nation, engineers faced challenging conditions rebuilding a debris barrier and wharf facility.

The community's wharf, which the locals rely heavily on, was badly damaged by debris flows that travelled down steep slopes into the lake and river, dumping large trees and other objects into the watershed.

To prevent damage from debris flow damaging the central wharf in the remote BC community of Wuikinuxv (Wi-kin-oo) Nation, engineers rebuilt a debris barrier and wharf facility.
Photo: Courtesy of Westmar

Lauren Hutchinson, MSc, P.Eng., a senior geotechnical engineer at BGC, worked with the community of Lillooet on assessing risk and proposing solutions from debris flow. PHOTO: CONTRIBUTED

Daniel Leonard, P.Eng., is Vice President at Westmar, which led the restoration. Westmar won an ACEC British Columbia 2023 award of excellence in the natural resource and habitat category for the project, which was completed late 2022.

He said a combination of more rain and less snow cover in recent years has led to larger objects more frequently in the water, including full trees.

Westmar was tasked with designing a structure that could withstand increasing barrages after a floating debris barrier built in 2006 was overwhelmed by logs, despite a redesign and refurbishment in 2011.

Leonard said there is no road access to the small village, and the community is serviced by a small airstrip or boat. Using an alternate wharf facility located farther from the village is not possible for many community members. Rather than rebuild further away, the decision was made to build a robust wall to protect the wharf located on the north bank of the Waanukv River.

After consultation with the community, Westmar and the project team designed, obtained environmental permitting, and constructed the barrier on a tight timeline and under challenging conditions.

The new barrier is almost 100 metres long and supported by steel pipe piles up to 23.5 meters long that were driven up to 12 meters into the riverbed. The barrier was designed to allow fish to swim under it.

"Putting in a wall is not necessarily a natural solution—that's something we continually struggle with; if we could make it work, we would much rather have a natural solution to use," says Leonard.

"But sometimes you're dealing with a constrained site, or when you look at all the trade-offs, building a mound out of rocks is going to have a worse effect on the river than putting in a wall like that."

Limited information added further difficulty. Experts on the team assessed river levels, debris characteristics, and what they thought the riverbed materials would comprise. They were confident they wouldn't encounter bedrock too shallow, but had a back-up plan and equipment at the ready, just in case.

"From an engineering perspective, it was quite challenging. We had very minimal geotechnical information to go on. We had to use our best judgment and use our limited information to come up with a solution," says Leonard. "The thing with these remote sites is that sometimes it's more expensive to go and do investigative work than to have a back-up solution in your back pocket when you go to site."

The design had to be completed within about a month to adhere to funding deadlines and a narrow fisheries window.

Once all the challenges were met, the community had a more durable and safer solution that also had low environmental impact.

LIVING WITH THE RISK OF DEBRIS FLOW

Some of those living in higher-risk areas don't have funds available to do a detailed assessment or build a barrier. Residents in Lillooet Lake Estates and neighbouring Heather Jean Properties have been living for years with the knowledge they are in the potential path of a debris flow.

Lauren Hutchinson, MSc, P.Eng., is a senior geotechnical engineer at BGC Engineering. She worked on assessing risk and proposing solutions for the community, located about 20 kilometres east of Pemberton.

"It's a really compelling story," she says. "It's a community that has been living with the risk of debris flows and trying to navigate their options. It's not a small task to be able to get the funds."

She says it takes a commitment of time and leadership within the community to forge partnerships and develop grant applications. Now, nearly a decade since the initial assessment, residents there are planning to move ahead with mitigation after receiving millions of dollars in grant funding and loans.

BGC became involved with the Lillooet Lake Estates when they were tasked with a detailed risk assessment following two debris flows, one in 2010 and another in 2013. The company released the Catiline Creek Debris Flow Hazard report in 2015.

"We identified the risk was substantially higher for many of the properties on the alluvial fan than would be considered tolerable in other jurisdictions," says Hutchinson.

In response, a number of property owners in the area were told it wasn't safe for them to live there due to debris flow danger. Notices were posted in the community. BGC has been working with engineering firm Kerr Wood Leidal on the preliminary design work at Lillooet Lake Estates and the detailed design.

BGC has also worked on projects connected to the series of debris flows in 2021 that damaged highways and bridges along key transportation and utilities corridors in BC, cutting off the Lower Mainland from the BC Interior.

"All around, locations where you're living in complex geographies with mountains, streams and waterways, there are risks," says Hutchinson. "The events of November 2021 have really brought this to the forefront. There's more of a focus on building our infrastructure to be resilient to the hazards we might face especially in a changing climate."

THE COMPLEXITIES IN INTERPRETING DEBRIS FLOW MODELS

Sophia Zubrycky, MSc, P.Eng., a geological engineer at BGC, is a leader in the field debris flow hazard and risk assessment. She uses field mapping, remote sensing, numerical modelling, and statistical analyses in her work, and she helps make models useable by calibrating them and interpreting the results.

Sophia Zubrycky, MSc, P.Eng., a geological engineer at BGC, is a leader in the field debris flow hazard and risk assessment.
PHOTO: CONTRIBUTED

"Risk assessments are not trivial," she says. "They're pretty complicated and there are lots of steps and assumptions."

Zubrycky says she looks through historical records, photos from the air, seeks oral histories, cores trees to examine scars, and—if there's budget—digs test pits into the fan to look for wood debris to radiocarbon date.

"We take all those pieces of information and we bring them together and try to put together a story of what are the possible sizes of events, and how often those may happen," she says.

Then they run the scenarios through a numerical model and simulate debris flows to see where they might hit.

"The models are only models," she adds. "There's a lot of engineering judgment and interpretation. We run these models to the best of our ability—sometimes we use multiple models and sometimes we look at those models and say, 'nope, don't believe it,' and we make our own maps. The models are just one tool in our big toolbox of decision making. Because models are systematic and repeatable, does not make them good and does not make for a good design."

Zubrycky says there's a lot of engineering judgment and creativity involved in design. A lot of engineers don't like that uncertainty, she says, but it makes for interesting work.

"There isn't a one-size-fits-all mitigation at any location. It's a bespoke design for every fan, as each one is unique like a snowflake," she says. "There's only a handful of debris flow mitigation structures in Canada. I may design something in my life as an engineer and I may never see it tested and never know if my design worked as I hoped. That makes it a unique engineering challenge." ◆

GUIDELINES AVAILABLE

The Engineers and Geoscientists BC professional practice guidelines, *Landslide Assessments in British Columbia*, was updated March 1, 2023, to address "adaptive management in a changing climate, and coping with rapid technological change in the digital era." New guidelines are being developed concerning mapping and assessing landslides: *Landslide Hazard and Risk Mapping Guidelines*.

The guidelines are available on the Engineers and Geoscientists BC website: *egbc.ca/Practice-Resources/Individual-Practice/Guidelines-Advisories*.