WFff 816 002

October 5, 2020

<Name>
<Address>
<City> <Province> <PC>

Dear <Name>:

Re: Cold Spring Creek Debris Flow Mitigation Project - New Hazard Assessment

The Cold Spring Creek project was identified as a priority by the Board during its 2020 Strategic Planning process late last year. In March, the RDEK was awarded $750,000 through the Union of BC Municipalities Community Emergency Preparedness Fund Structural Flood Mitigation Program. An additional $150,000 was allocated from the Fairmont Flood and Landslide Service Area reserves to bring the project total to $900,000. The engineering contract was awarded to McElhanney on May 29, 2020.

McElhanney partnered with BGC Engineering (BGC) to update the hazard assessment for Cold Spring Creek. BGC assessed the watershed this summer and the report has just been received by the RDEK. The assessment considers the historical evidence of debris flood (large volume of water with gravel, cobbles and boulders) and debris flow (higher concentration of gravel, cobbles, boulders and similar to wet concrete) activity and provides updated modeling that projects that the hazard is substantially higher than previously understood. As a result, the RDEK has taken immediate action to widen the scope of the Cold Spring Creek project and will be working with BGC, McElhanney and the community to clarify the risks, share risk reduction recommendations and identify mitigation measures to reduce the hazard.

We are in the midst of planning a community meeting and will post the meeting details on the Fairmont Hot Springs Debris Flow Mitigation project page at: ***engage.rdek.bc.ca/debris,*** via our email groups and on our website calendar once they have been confirmed.

The Executive and Technical Summary of the hazard assessment are included in this package. The full report can be found on the project page in the Documents section under Reports.

The RDEK will be prioritizing debris flow mitigation in the first phase of the project, which is now expected to involve multiple phases. The consultants have completed a conceptual design for a debris flow containment net and the total cost for this phase is estimated to be $1.375 million. On Friday, October 2, the RDEK Board approved $275,000 in new Community Works funding and the re-allocation of $200,000 that was previously approved for the Swansea Road watermain project. These Board decisions ensure funding is in place for Phase 1.

With estimated costs of $11 million for future phases of the project, the RDEK will be seeking out additional provincial and federal funding sources and will be engaging with the property owners within the Fairmont Flood and Landslide Service Area regarding the need for future borrowing and increased taxation to help fund the Cold Spring Creek project and maintenance of the constructed mitigations works on both Cold Spring and Fairmont Creeks.

We are reaching out to you today to ensure as a property owner, you are aware of the updated assessment, its illustrated hazards, and that the scope of Phase 1 of the project has been expanded. If you are not already on the RDEK's email list, we encourage you to sign up to get the upcoming meeting notification and ongoing project updates by clicking on the "Sign up for Community Email Updates" on *www.rdek.bc.ca*. The project page *engage.rdek.bc.ca/debris* will also always have the most updated information. There will be up to three project updates direct-mailed; however, regular and ongoing updates will be provided on both the project page and via email.

If you have questions about the Cold Spring Creek project, you can contact RDEK Engineering Technician Kara Zandbergen at kzandbergen@rdek.bc.ca or 250-489-2791 or 1-888-478-7335 (BC/AB only). Electoral Area F Director Susan Clovechok is another contact and she can be reached at 250-270-9314

Sincerely,

Brian Funke
Engineering Services Manager

Enclosure

SUMMARY

Debris-flow hazards and associated risks at Cold Spring Creek are substantially higher than previously understood.

The community of Fairmont Hot Springs is located on two fans that partially overlap: Cold Spring Creek and Fairmont Creek. A fan is a landform that develops at the location where a creek leaves the confines on the watershed and starts to spill water and sediment over its banks. These fans have developed over the course of some 10,000 years primarily by processes called debris floods and debris flows. Both are more destructive than normal floods. Debris flows can be life threatening in particular, and some 100 people in BC have lost their lives through debris flows. Worldwide, this number is much higher with over 78,000 fatalities resulting from debris flows between 1950 and 2011 (Dowling & Santi, 2014).

Most of the present community of Fairmont Hot Springs has been developed since 1975. This short habitation period means that, unlike for old villages and towns in the European Alps or Japan, there are few historical records of destructive debris flow or debris flood events. The July 2012 event on Fairmont Creek, however, gives a sense of how powerful such events can be. The lack of known extreme events in the historic record on Cold Spring Creek can give the perception to residents and regulators that the problem is manageable as only nuisance property flooding is expected. This is a severe and consequential misconception.

Debris floods are characterized by abnormally high rates of sediment movement with boulders, logs and other debris being transported downstream. Debris floods can clog culverts and bridges, jump out of the confines of the channel and erode its banks or road fills. Damage to buildings during debris floods can occur through bank undercutting and flooding, sometimes up to 30 cm deep on fans and deeper in depressions. BGC Engineering Inc. (BGC) concludes that such events have and will occur with annual likelihood of occurrence of 1 to 30% on Cold Spring Creek. The lower the annual likelihood of debris flood occurrence, the larger and more destructive the event will be. The latest (May 31, 2020) debris flood had an estimated return period of 5 to 10 years. Even at a 1% annual likelihood of occurrence, there is still about a 64% likelihood that it will occur in a person's lifetime (80 years).

Debris flows occur at a lower annual probability (< 1% likelihood). Debris flows are a landslide process and they are typically even more destructive than debris floods (see Figure E-1.). The forces associated with a wall of mud and boulders over 2 m (6 feet) in diameter, which can be found on Cold Spring Creek fan, is such that they can fully destroy homes, and people inside homes can and have died in the past in BC. Debris flows often come without warning. They can be triggered by intense rain, or a landslide damming the creek upstream of the community of Fairmont Hot Springs and then bursting the landslide dam. According to BGC's assessment and numerical debris flow modeling, should a debris flow occur on Cold Spring Creek there is a substantial chance that people will die and be injured. Figure E-1 provides an example of the kind of damage that can be expected given the flow depths and flow velocities modeled at Cold Spring Creek. Note that in the direct path of a debris flow, damage can be even more severe.

Figure E-1-1. Home damaged by debris flow at Montecito, California in January of 2018. Photo by USGS (public domain), https://www.usgs.gov/media/images/ls-post-fire-debris-flow. This type of destruction is entirely possible and even likely at Cold Spring Creek in the future.

Various effects of climate change are very likely to worsen the situation by creating more and potentially larger debris floods and debris flows in the future. The world has now entered temperatures not seen for 3 million years, long before humans existed. Three principle factors conspire: One is that in a warming climate more moisture can be held in the air and with more available energy, air masses are becoming more unstable. This means more frequent extreme rainfalls and higher intensity rainfalls, even when the total annual rainfall may be unchanged or even be reduced. In addition, in a rapidly warming world the trees in the Cold Spring Creek watershed will increasingly be stressed through drought and beetle infestation. That, in combination with a century of fire suppression has created substantial fuel loads, which means more, hotter and more severe wildfires. Debris flows can become particularly destructive after wildfires as the important buffer of trees and duff layer reestablishes. Finally, the upper watershed of Cold Spring Creek is likely underlain by permafrost which is continually frozen ground which thaws only surficially by a metre of so and then refreezes in the winter. In permafrost terrain, whenever water ingresses into rock cracks or soil voids it freezes and holds rock or soil together like glue. With a rapidly warming world, this “glue” disappears, and one can expect an increase in rockfall and other landsliding in the upper watershed. This process feeds the channel system with debris that is then ready for transport to the fan where people live.

In collaboration with McElhanney Ltd. and the Regional District of East Kootenay, a mitigation strategy is being developed to use available funds to reduce the risk of debris flows as much as possible at Cold Spring Creek. However, a residual risk will prevail as total risk reduction would be cost-prohibitive. Such risk could be further managed by provision of a real-time warning system and/or restrictive covenants for future developments on the fan of Cold Spring Creek.

TECHNICAL SUMMARY

This report and its appendices provide a hydrogeomorphic hazard assessment of Cold Spring Creek, BC. This creek has been studied before by Clark Geoscience and Tetra Tech EBA. The present report is an update of their analysis and has included some of their data.

This report provides some geomorphological and hydrological background and details the analytical techniques applied to create scenario and composite hazard rating maps for the Cold Spring Creek fan. This work could be used as the foundation for future quantitative risk assessments which estimates the probability of loss of life of individuals and groups.

The present hazard assessment is intended to directly inform mitigation works on that creek that for which McElhanney Ltd. and BGC Engineering Inc. (BGC) authored a proposal on May 19, 2020.

To assess the hazards at Cold Spring Creek, multiple hazard scenarios were developed for specific event return period classes (3 to 10, 10 to 30, 30 to 100, 100 to 300, 300 to 1000 and 1000 to 3000 years). BGC differentiated between debris floods which are believed to be the key hydro-geomorphic hazard for return periods up to 100 years and debris flows, which are believed to be the dominant hydro-geomorphic hazard for return periods in excess of 100 years.

A variety of field and desktop analytical techniques were combined to achieve a credible frequency-magnitude relationship for debris flows. This includes consideration of climate change, a highly complex topic. Complex because of the different layers of climate change impact: These include predicted increases in both the frequency and magnitude of rare short-duration rainfall events (high confidence) as well as more and more severe wildfires (high confidence) and permafrost degradation and higher frequency of rock falls (moderate confidence).

Debris-flood and debris-flow frequency-magnitude relationships were developed through a model ensemble in which BGC compared different approaches relating to a regional frequency-magnitude approach, dendrochronological investigation, radiocarbon dating from organic materials found in test trenches, stratigraphic analysis of test trenches and natural exposures and a post-fire debris-flow magnitude analysis (shown in Table E-1), and summarized graphically in Figure E-2.

Table E-1. Final frequency-magnitude numbers for debris floods and debris flows on Cold Spring Creek using a model ensemble.

Return Period (years)	Process	Debris Volume Best Estimate (m^3)	Peak Discharge (m^3/s)
3 to 10	Debris Flood	4,400	2.4
10 to 30	Debris Flood	4,800	3.8
30 to 100	Debris Flood	5,200	5.2
100 to 300	Debris Flow	63,500	210
300 to 1000	Debris Flow	76,000	260
1000 to 3000	Debris Flow	96,000	320

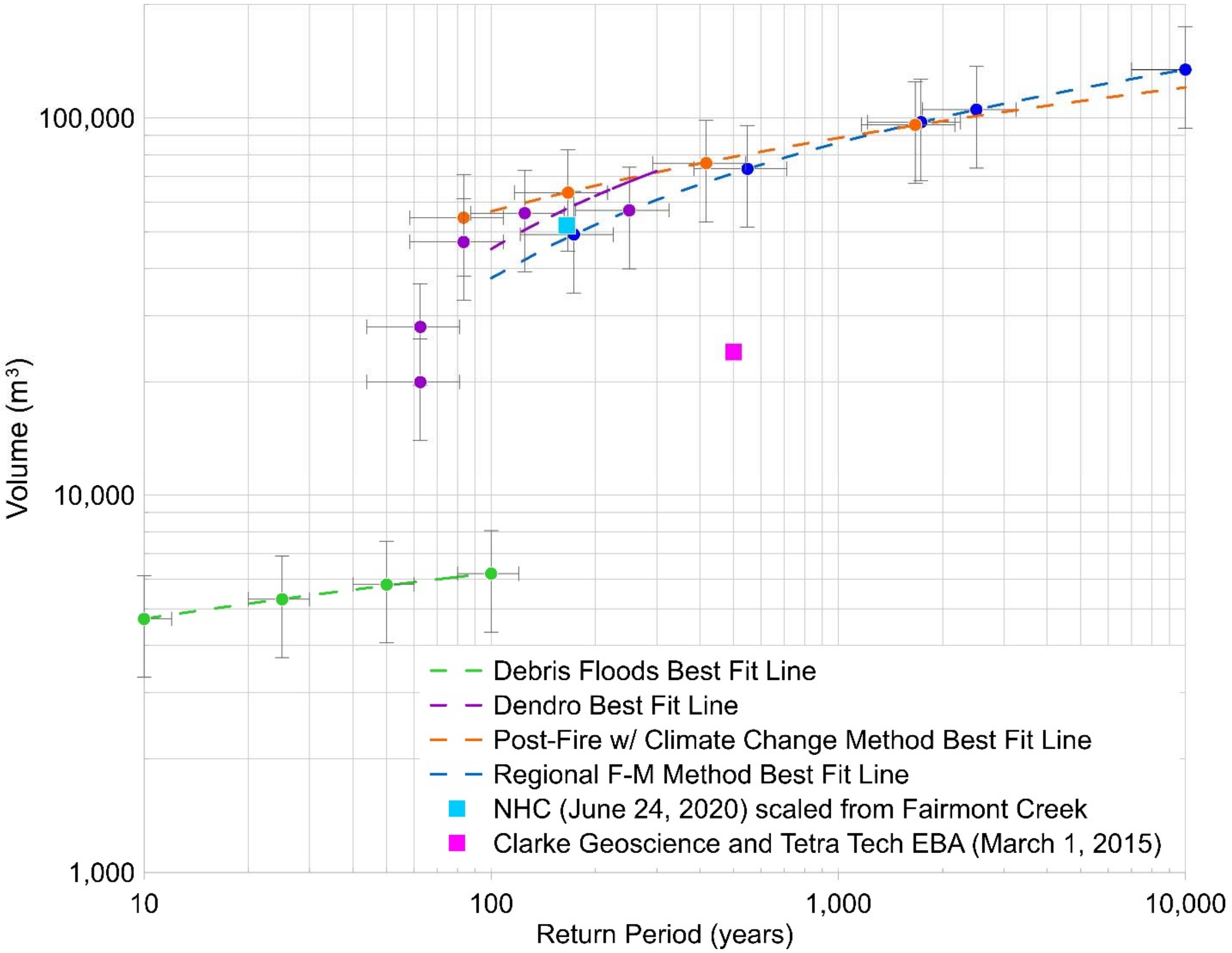

Figure E-1-2. **The frequency-volume methods considered reasonable for Cold Spring Creek. Best fit lines are trimmed at the 100-year return period as BGC considers debris flows below that return period are unlikely. The figure also shows the Clarke Geoscience and Tetra Tech EBA (March 1, 2015) F-M estimate as well as the recently updated (NHC, June 24, 2020) estimate for Fairmont Creek adjusted by watershed area. Error bars are based on judgement.**

A two-dimensional hydrodynamic model (FLO-2D) was employed to simulate debris-flood and debris-flow hazard scenarios on the fan. Bank erosion was not modeled as there are no properties in the immediate vicinity of the creek and because debris flows are the dominant (i.e., more destructive hazard at Cold Spring Creek). Debris flows tend to deposit, rather than scour, on fans such as Cold Spring Creek. Should a major channel avulsion occur, however, bank erosion is possible but difficult to predict given that the flow path of a future avulsion is highly uncertain and is influence by existing homes and infrastructure. Table E-2. provides key observations derived from the numerical modelling.

Table E-2. Key findings from numerical modeling of Cold Spring Creek debris floods and debris flows.

Process	Key Observations
Debris-flood inundation (return periods from 3 to 100 years)	• Debris floods are believed to avulse from the channel downstream of the water reservoir for return periods in excess of approximately 3 years. • Avulsions are likely to occur at all road crossings with avulsion probability increasing with return period. • The channel at return periods in excess of 30 years is likely to entirely fill with sediment and cause ubiquitous overflow on the southern fan, mostly south of Fairmont Resort Road • Access to the resort community from the south will largely be severed for most return periods modeled • Debris floods, while causing significant property damage are unlikely to lead to loss of life, though infrastructure damage can be in the millions of dollars for high return period debris floods
Debris flow inundation (FLO 2D model results from 100 to 3000-year return periods)	• All modeled debris flows will fill the water reservoir within minutes and then continue their path downstream • All modeled debris flows are very likely to avulse from the existing channel under current fan configuration towards the central portions of the fan north of the Fairmont Resort Road. • All modeled debris flows will cover portions of the upper and mid fan portions with flow velocities between 3 and 5 m/s and flow depths between 0.5 and 3 m. • The impact forces for all modeled debris flows will be of sufficient magnitude to results in property damage ranging from nuisance flooding away from the flow paths and in the distal fan portions to total building destruction along the main flow paths. • Though not quantified as part of this report, the potential of life loss on Cold Spring Creek fan is considered high to very high. If compared to risk tolerance thresholds adopted, for example for the District of North Vancouver, or the Town of Canmore life loss risk is likely unacceptable for numerous properties.
Auxiliary Hazards	• Most (if not all) properties on Cold Spring Creek fan heat with propane gas. Large gas tanks are omnipresent on the fan. Boulder impact to gas tanks is possible during debris flows and could lead to leakage and possible ignition of the highly flammable gas. Such explosions could substantially increase overall life loss and economic risk. While BGC did not inventory buried linear infrastructure, severe damage can be expected.

The numerical modelling demonstrates that the key hazards and associated risks stem from debris flows. Those could result in widespread fan inundation, particularly on the upper and central fan and affect multiple properties with possibly severe consequences.

Model results are cartographically expressed in two ways: The individual hazard scenarios and a composite hazard rating map. The individual hazard scenarios (defined by return period and avulsion scenarios) are captured by showing the impact force which combines flow velocity, flow depth and material density. Impact force is an index of destructiveness of an event and is suited for debris floods and debris flows alike. The individual hazard scenario maps are useful for hazard assessments of individual properties as part of the building permit process as well as to guide emergency response.

The composite hazard rating map combines all hazard scenarios into one map and incorporates the respective debris flood and debris flow frequencies. It provides a sense of the areas that could possibly be impacted by future events up to the highest modelled return period. The composite hazard rating map can serve to guide subdivision and other development permit approvals. It requires discussions and regulatory decisions on which of the hazard ratings is attributed to specific land use prescriptions, covenants, bylaws or other limiting clauses for both existing and proposed development. The categories range from low to very high hazard and are classified via the impact force intensity. The composite hazard rating map shows that the majority of the mid to proximal fan (everything upstream of Highway 93/95) is subject to high and very high hazards. The lower fan downstream of Highway 3A is subject to very high (near the outlet of Cold Spring Creek) to low hazards.

Some uncertainties persist in this study. As with all hazard assessments and corresponding maps, they constitute a snapshot in time. Re-assessment and/or re-modelling may be warranted due to significant alterations of the fan surface topography or infrastructure, such as future fan developments, debris flows, formation of landslides in the watershed, culvert re-design or alteration to any fan infrastructure. BGC’s analysis does not include breaches of the constructed water reservoir. Furthermore, the assumptions made on climate changes will likely need to be updated occasionally as scientific understanding evolves.

All hazards contain some component of chaotic behaviour, meaning that it is not possible to adequately model every possible scenario or outcome. For example, unforeseen log jams may alter flow directions and create avulsions into areas not specifically considered in the individual hazard scenarios. Sediment deposition patterns cannot be predicted exactly and are expected to be somewhat random as buildings (sheared off their foundations or remaining in place), log jams and sequential stalled debris lobes can deflect sediment in various directions. Finally, debris-flow behaviour is affected by the triggering storm intensity and duration as well as tributary landslides or debris flows in the watershed.

Despite these limitations and uncertainties, a credible hazard assessment has been achieved on which land use decisions and mitigation strategies can be based.