Cougar Creek's Debris Flood Retention Structure Our Path to Risk Reduction

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ABSTRACT

The 2013 floods in Alberta were devastating for many communities. In Canmore, extreme rainfall led to debris floods and debris flows that damaged homes, businesses, and infrastructure. Flood protection works constructed to protect existing development suffered either extensive damage or complete loss. A particularly large debris flood on Cougar Creek eroded banks and caused extensive damage. We are fortunate the consequences were not far worse. In response to the devastation, the Town of Canmore began a program of hazard and risk assessment, option analysis and mitigation design, resulting in a unique to Alberta mitigation approach for Cougar Creek. To share our acquired learnings and to inform other communities of our experience, we present the work undertaken by the Town of Canmore over the last five years.

RÉSUMÉ

Les inondations albertaines de 2013 ont affecté plusieurs communautés. À Canmore, les pluies torrentielles ont créé des laves torrentielles et écoulements hyperconcentrés qui ont endommagé plusieurs maisons et infrastructures publiques. Les éléments structurels de protection contre les inondations qui étaient en place pour protéger les infrastructures existantes ont été sévèrement endommagés. L'écoulement hyperconcentré de Cougar Creek a érodé les berges du ruisseau et a causé d'énormes dommages qui étaient auparavant inimaginables. À la suite de ces évènements, la ville de Canmore a commencé un programme extensif d'évaluation des dangers et des risques, d'analyse des options de gestion de risque, et de la conception de structure de protection. Le résultat est une approche de gestion des risques de Cougar Creek unique en Alberta. Afin de partager notre cheminement et nos connaissances acquises, nous présentons l'approche que la ville de Canmore a utilisée durant les cinq dernières années.

1 INTRODUCTION

The Town of Canmore (Town) is situated in the Front Range of the Canadian Rockies in the Province of Alberta. The local mountains are a fold and thrust belt. They consist of more erosion resistant carbonates that were folded and thrust over more friable sandstones and shales. The Cougar Creek watershed is located in a region that was affected by phases of glaciation and de-glaciation during the last 11,700 years (BGC Engineering 2014a). The Bow River flows through the community along the valley bottom and is partially fed by a number steep creeks within the municipality.

Steep mountain creeks are typically subject to a spectrum of mass movement processes that range from clear water floods to debris floods to debris flows in order of increasing sediment concentration. There is a continuum between these processes in space and time with floods transitioning into debris floods and eventually debris flows through progressive sediment entrainment. Conversely dilution of a debris flow through partial sediment deposition and tributary injection of water can lead to a transition towards debris floods and eventually floods (BGC 2013).

A review of events of the last century on Cougar Creek indicates that large debris floods, that have affected the fan, have an approximate return period of 30-years. Smaller events, mostly confined to the channel, indicate an approximate 8-year return period (BCG 2013).

1.1 Hydroclimatic Event

The 2013 storm event has been analyzed by BGC Engineering (BGC) in their Hydroclimatic Analysis report

(BGC 2014b). The Kananaskis climate station has the longest data record in the region and has been used extensively to study the storm event. Record-breaking rainfall values were measured for the 1-day, 2-day and 3-day rainfall values. The return period for the storm has been estimated as ranging from 235 to 575-years.

The Hydroclimatic report also analyzes the snowmelt contribution specific to the Cougar Creek catchment, flow estimates on the Bow River, as well as trend analysis of rainfall events in the Canmore region.

1.2 Effects in Canmore

Most of the steep creeks within the Town were affected by the combination of the storm and snowmelt runoff. Three days of heavy rainfall saturated the soil and overwhelmed the storm drainage system. The sewer system was also overwhelmed due to high infiltration of water in the sewer lines. Cell tower, power and natural gas outages occurred in many areas of Town.

Stoneworks Creek heavily damaged its pre-existing flood protection works and avulsed towards existing development. Due to the low gradient of its fan, the debris flood transitioned to a flood before it reached the developed areas. The Canmore Hospital, apartment and residential buildings, and commercial developments were all affected by Stoneworks Creek.

Stone Creek was also active during the storm. A debris flow jumped its creek bank and damaged a condominium development.

Significant damage was sustained on the heavily developed Cougar Creek fan due to sediment deposition and bank erosion. According to BGC (2014a), the 2013

Cougar Creek debris flood is estimated to be approximately a 400-year return period.

A state of local emergency was declared early in the event to help manage the situation.

1.3 Short-Term Mitigation

Shortly after the event, the Town issued a Request for Proposal (RFP) for the design and construction of structural mitigation for steep creeks. Three consultants were selected and successfully delivered short-term mitigation projects on Stone Creek, Three-Sister Creek, Cougar Creek and Pigeon Creek. The projects focused on channel re-shaping and bank erosion reduction.

The Cougar Creek short-term mitigation project, designed to provide conveyance and erosion protection along a newly shaped channel on the Cougar Creek fan, consisted of excavating and widening the original channel, as well as armoring the banks with Articulated Concrete Mats (ACMs). Figure 1 shows the extent of the channel armored with ACMs, from the Wildland Park boundary, at the bottom of the photo, to the Trans-Canada Highway, at the top of the photo.



Figure 1. Articulated Concrete Mats along Cougar Creek

Moreover, a 40m wide and 6m tall Debris Net was installed at the fan apex (Figure 2). The net is designed to capture up to 20,000 cubic meters of sediment and debris during a flood event.



Figure 2. Debris Net at the fan apex of Cougar Creek

2 HAZARD AND RISK ASSESSMENTS

Following the flood event, the Town of Canmore sought to understand what had happened. We also needed to know how often such an event could occur, as well as the size range of potential events that could be possible.

The Town required specific expertise in steep creek flooding. A request was sent to industry to provide qualifications for experts geotechnical, in geomorphological, and hydrological fields. BGC Engineering was selected through this gualifications based process for their knowledgeable and experienced personnel, as well as the firm's experience with similar studies and assessments in British Columbia and throughout the world.

BGC was therefore engaged to analyze Canmore's steep creeks and first produce forensic reports. BGC was then tasked to analyze the hazard on Cougar Creek, followed by a complete risk assessment.

The Town retained Dr. Church and Dr. Morgenstern as specialist advisors to provide third party review of all technical reports. Dr. Church is one of the world's foremost experts in fluvial geomorphology and Dr. Morgenstern is an internationally recognized authority in the field of Geotechnical Engineering and risk assessments related to geohazards and dam safety. They have both been involved in the review of all assessments completed up to date on Canmore' steep creeks.

In order to keep residents informed, and to support the transition to a risk based approach for steep creeks, an intensive communication process was undertaken. This process involved community and council presentations, open houses, and community news letters.

2.1 Hazard Assessment

The main objectives of the hazard assessment of Cougar Creek were to establish the frequency-magnitude relationship of debris floods on Cougar Creek and to identify representative debris flood scenarios that could lead to damages and loss of life. These scenarios were modelled using a 2D flood model that allows for variable sediment concentrations and rheologies.

BGC's hazard report (BGC 2014a) indicates that two different hydrogeomorphic processes occur in the Cougar Creek watershed. The first one is debris floods where sediment increases in response to severe rainfall and increased bank erosion rates. The second process consists of debris floods triggered by hillslope processes (debris flows, slumps, ravels) feeding sediment to the main channel. Moreover, landslide dam outbreaks, from either tributary debris-flows or rock slides of variable size, are also contributing sediment and debris for return periods higher than 300-year.

The frequency-magnitude relationship for Cougar Creek was also analyzed in the hazard assessment. Two independent approaches were used for this analysis. The first approach relied on stratigraphy of several test trenches in the Cougar Creek fan, dendrochronology investigation, historical air phots measurements, and empirical formulae relating inundation area to debris volume. The second approach applied an empirical formula derived from a comprehensive Swiss dataset that correlates sediment transport volumes to runoff volumes. Both approaches were combined to produce the Cougar Creek debris flood frequency-magnitude relationship shown in Table 1.

Based on the relationship established, the 2013 debris flood at Cougar Creek was estimated to correspond to a 350-400-year return period.

Return Period (yrs)	Volume Estimat e (m ³)	Peak discharge Estimate (m ³ /s)	Dominant Hydro- Geomorphologica I Process
1-10	< 6,000	-	flooding
10-30	30,000	30	flooding/ debris floods
30-100	40,000	50	flooding/ debris floods
100-300	60,000	60	debris floods
300-1000	160,000	700	landslide dam outbreak floods
1000-3000	260,000	1000	landslide dam outbreak floods

Table 1. Frequency-magnitude relationship

BGC then modelled five Debris flood scenarios; they are the 10-30-year to 1000-3000-year return periods, as per Table 1 above. The main results from the modelling include:

- Debris flood for up to 30-year return periods are expected to be confined in the Cougar Creek channel. Avulsions are unlikely at Elk Run Blvd. and at Highway 1.
- Debris floods of higher return periods are more likely to block existing culverts, especially at Highway 1, Highway 1A and at the CP tracks.
- Avulsion is likely at Elk Run Blvd. for return periods exceeding 300 years. The eastern fan sector is more likely to be affected than the western fan.
- The short-term mitigation works are significantly reducing debris flood risk for flows up to a 30-year return period, and provide some risk reduction for flows up to 300 years. For higher flows, the short-term mitigation measures provide very little risk reduction.

The last deliverable of the hazard assessment consisted of the preparation of debris-flood hazard intensity maps for each modelled scenario. These intensity maps provide a measure of the destruction potential for a given debris flood scenario. The maps also form the basis to assess debris flood risk. As an example, Figure 3 shows the intensity map for the 100-300-year return period with a blocked culvert at Elk Run Blvd.

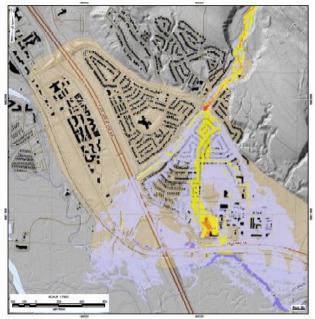


Figure 3. Debris flood scenario for 100-300-year return period. Elk Run Blvd. is blocked.

2.2 Risk Assessment

To assess the risks, four debris flood scenarios were analyzed, with a range of debris flood return periods from 30-100 to 1000-3000 year. The elements at risk considered on the scenarios included buildings, roads, utilities, critical facilities, and persons within the buildings. Two key elements, direct building damage and safety risk, were selected as the primary elements to focus on. Both of them can thoroughly be assessed and compared to risk tolerance standards.

- The risk assessment (BCG 2014c) found the following:
- The average annualized building damage cost is estimated at \$700,000. Actual direct damage costs to buildings, depending on the scenario analyzed, ranged from \$8 million to \$129 million.
- 190 parcels were identified where the estimated safety risk for individuals exceeded 1:10,000 probability of death per annum.
- The estimated group safety risk fell into the "unacceptable" range.

The safety risk standards used by BGC were based on international risk tolerance standards. They were adopted by the District of North Vancouver, British Columbia, in 2009. The Town of Canmore formally adopted these risk tolerance standards in the Municipal Development Plan (MDP) in 2016 (Canmore 2016a). Section 3.5 of the MDP provides details regarding the risk tolerance criteria adopted by the Town.

The result of the Cougar Creek risk assessment shows a high level of risk, much higher than other creeks in the Bow Valley and outside of the accepted threshold.

3 OPTIONS DEVELOPMENT AND ANALYSIS

To reduce risks discussed in section 2.2 above, mitigation options had to be developed and assessed, including the option to remove elements at risk (homes and people) from the fan. The previous class 2 rip rap armoring of past years was clearly not sufficient to prevent another event of such magnitude. More intensive structural mitigation was required to reduce the risks to acceptable levels.

The Town undertook an extensive process to select a qualified specialist consultant to develop the mitigation options. As described in Section 1.3 above, an RFP was issued for the design and construction of mitigation infrastructure. However, no proponents who submitted through the RFP process had enough experience in the design and construction of large scale debris-flood or debris retention structures. The search for a qualified specialist therefore required to be broadened to international specialists.

Europe has a long history of steep creek mitigation in the Alps. Austria in particular is home to a robust research and education program through its Institute of Mountain Risk Engineering at the University of Natural Resources and Life Sciences in Vienna (BOKU). Over \$400,000,000 are spent annually in Austria, a country of under 9,000,000 people, on research, and the design and construction of avalanche and steep creek mitigation. As a result of its long history of impacts from steep creek hazard, and through intensive effort, Austria is home to some of the worlds most advanced understanding in managing and mitigating steep creek hazards.

The Town retained Dr. Johannes Hubl, director of the BOKU Mountain Risk Institute as a specialist advisor for the first two years of the project. Dr. Hubl assisted the Town in our search for consulting expertise by recommending Austrian firms that have appropriate experience and are respected in this field. The Town requested a proposal from the recommended firms for the Cougar Creek long-term mitigation project. Alpinfra Engineering & consulting (Alpinfra) of Salzburg, Austria, ranked highest in the evaluation based on their project team's extensive experience dealing with similar hazards in the Alps. Alpinfra specializes in mitigating geotechnical hazards, including snow avalanches, rock falls, landslides, debris flows and debris floods.

3.1 Alpinfra Concepts

Alpinfra was retained by the Town and tasked with development of conceptual mitigation schemes. The concept design was guided by risk reduction targets instead of a fixed hazard return period. Alpinfra proposed three schemes to reduce group risk into ALARP and reduce the annual risk of individual loss of life for the 190 properties that exceeded the accepted threshold (Alpinfra, 2015).

The three options developed by Alpinfra are:

- Option A: a 30m high debris flood retention structure located at the site of the existing Debris Net. Option A is shown in Figure 4 below.



Figure 4. Rendering of Option A

 Option B: a 24m high debris flood retention structure located at the boundary of the Wildland Park and the Town of Canmore. Option B is shown in Figure 5 below.



Figure 5. Rendering of Option B

 A 11m high debris retention structure located at the boundary of the Wildland Park and the Town of Canmore. This option retains larger sediment and woody debris. Water is passed freely through an unrestricted outlet structure. Option C is shown in Figure 6 below.



Figure 6. Rendering of Option C

Once the locations of the options were determined, geotechnical investigations were performed to better understand the underground conditions of each proposed site. Significant engagement with stakeholders was undertaken as part of a formal process to evaluate options and communicate risk and risk reduction to the community. A number of land, environmental, cost, social, technical, and political concerns were raised in the meetings. The options were further refined based on the geotechnical investigation results and feedback received in meetings.

To select a preferred option, a formal option analysis process was undertaken by the Town.

3.2 Kepner-Tregoe Process

On the recommendation of our specialist advisor, Dr. Norbert Morgenstern, the project team retained Kepner Tregoe (KT) to facilitate the decision making process during a 2-day workshop. The methodology developed and tested by KT over 50 years provided a structured and effective process for selecting the preferred option. It is a methodology that is well respected in both private and public organizations.

The KT method is based on the premise that the end goal of any decision is to make the "best possible" choice. The goal is not to make the perfect choice, or the choice that has no risks, but to make the best choice possible. An important feature of the KT method is that it helps evaluate and mitigate the risks of the decision taken.

Prior to the 2-day workshop, the Town held a preparation workshop with KT. The goal was to understand the overall KT decision making process, to develop a decision statement, define basic assumptions, establish draft objectives and weightings, and determine what further information would be required prior to the option selection workshop.

A KT facilitator guided a large and varied group of stakeholders and project team members during the 2-day workshop. The overarching goal was to select the option that would be recommended to Town's council and the residents to appropriately reduce the risk on the Cougar Creek fan. Time was first dedicated to refine the draft objectives and their weights. Some objectives were added while others were re-worded, replaced or separated into two different objectives. The revised list of thirteen objectives, shown in Table 2, focused on ensuring acceptable safety and further balanced between social , economic and environmental objectives.

Table 2. Final objectives used in the selection process

Weight	Objective
10	Minimize damage to public and private property
10	Minimize potential for blocked evacuation routes
10	Maintain safe passage of goods and services on major transportation links including Trans- Canada Highway, Highway 1A and CP Rail.
9	Maximize protection of major utilities including power, gas, and communication
9	Minimize need for operation of heavy equipment involvement during flood event
9	Minimize impact on regional wildlife corridor
8	Minimize habitat fragmentation
7	Minimize annual maintenance costs including: Sediment removal, post-flood re-vegetation, infrastructure inspection
6	Minimize construction costs

4	Provide access to recreation and natural
	areas
3	Minimize impacts related to resident's view and sight lines
3	Minimize impact to park users' experience
3	Minimize construction duration with a goal of two or less construction seasons.

The three mitigation options were reviewed, discussed, compared and then scored for each defined objectives. Also, the option of not doing any further mitigation work was evaluated and compared to the proposed strategies. The four options were then ranked based on their score and the relative weight of each 13 objectives. The 30m high debris flood retention structure was selected as the recommended flood mitigation concept for Cougar Creek.

The risks associated with the project were identified in the final phase of the KT workshop. Political, community, safety, design, construction, permitting and maintenance risks were assessed. Most of the risks identified were common to all mitigation options. The risks identified during the session have been taken into account throughout the different phases of the project.

Following the KT decision process, two public open houses were held for the community, a newsletter was published and studies and reports were posted to the Town's website. A summary of the option analysis process is described in the Option Analysis Summary Report (Canmore, 2015)

4 STRUCTURE DESIGN PROCESS

Once the debris flood mitigation concept had been selected through the KT process, supplemental rounds of geotechnical investigation were performed and the detail design of the structure could commence.

4.1 Canadian Hydrotech

The Town awarded the design project to Canadian Hydrotech Corporation (CHT) in early 2015. CHT is composed of engineers and geoscientists that are highly specialized in flood mitigation structures and deep underground foundation and tunneling. It is a subsidiary of Alpinfra and Dr Sauers & Partners.

The detailed design was carried out in 2015 through the first half of 2016. Bi-weekly meetings were held between the Town and CHT for the duration of the project and the regulators were regularly updated. The Structure design, as well as several supporting documents, was ready for submission of the Environmental Impact Assessment and Dam Safety Review by mid-2016. The supporting documents consist of a comprehensive Design Report Structural and Geotechnical Analysis, Dam Breach and Inundation Analysis, Geotechnical Design Basis Memo, Seismic Hazard Assessment, Hydrological Assessments, Operation, Maintenance and Surveillance Manual, and an Emergency Preparedness and Response Plans.

4.2 Independent Reviews

Along with Dr. Johannes Hubl, two other specialist advisors were retained by the Town for third-party reviews during the Structure design. Both Dr. John Sobkowitz and Dr. Norbert Morgenstern have many years of experience in geotechnical investigation, dam design and dam safety review. Dr. Morgenstern is still involved in the Cougar Creek project to this day, advising the Town on an asneeded basis.

Reviews were undertaken approximately every four to six months with the specialist advisors and representative of CHT and the Town of Canmore. The design of the Structure was updated and modified based on the technical feedback received.

Northwest Hydraulic Consultants were also engaged to review the Hydrology Assessment and produce the Probable Maximum Precipitation and Probable Maximum Flood estimates.

5 PROJECT FUNDING

The project is estimated to cost \$48M and full funding has been acquired. Funding such a project can be very challenging. The Town has been working closely with the Province of Alberta to ensure that the project would be properly funded. The Town's commitment to understand current flood risks, through our studies and approaches, has played a key role in securing funding. Moreover, the updated bylaws and new policies, adopted since the flood, to limit increases in future risk on our alluvial fans, have also been essential in securing the required funding.

Moreover, we were able to justify with our funding partners a return period other than the standard 100-year currently used in Alberta. The business case for a higher return period protection was based on the risk assessment and the option analysis of Cougar Creek mitigation options. The selected mitigation option fared much better compared to do nothing (status quo) and the removal of all residential buildings in the highest hazard areas on the Cougar Creek fan.

5.1 Funding Sources

Funding sources include: Alberta Environment and Parks (AEP) through the older Flood Recovery and Erosion Control (FREC) Program (36%); Alberta Community Resiliency Program (ACRP) (23%); The Federal Government New Building Canada Fund (30%); the Town of Canmore (8%). Additionally, Alberta Transportation contributed funding for the Highway 1 culvert protection project completed in 2017 (3%).

6 PERMITTING PROCESS

The proposed structure is located in the Bow Valley Wildland Provincial Park where roads are not allowed. This issue was raised early in the project and the Town and AEP have been working collaboratively to find an appropriate solution. Some recent changes in regulations have facilitated the construction of access roads within the Wildland Park, which in turn makes the overall project possible.

Due to the height and significance of the project, an Environmental Impact Assessment (EIA) is required as well as a Dam Safety review. Furthermore, once the EIA is 'deemed complete' by the Province, the Natural Resources Conservation Board (NRCB) will make a formal decision as to whether the project is in the public interest, considering social, environmental and economic impacts.

6.1 Land Issues

The proposed structure is located in the Bow Valley Wildland Provincial Park where there are strict regulations regarding developments. A dam structure is a permissible development; however the project requires an access road, which was not permissible within the Wildland Park. AEP's preferred solution was therefore to sell a portion of land to the Town of Canmore. The parcel would have been large enough to accommodate the access road, the structure, and its appurtenant structures. The land sale process triggered public and aboriginal consultation that lasted several months.

While consultations were ongoing, AEP undertook a review of the regulations and proposed changes were brought forward to the Minister for approval. One of the changes is with respect to roads within a Wildland Park. The new regulations allow the Minister of AEP to approve construction and maintenance of an access road within a Wildland Provincial Park if it is in the interest of public safety. The Cougar Creek project, including the access road, supports public safety and is now permitted in Bow Valley Wildland Provincial Park.

AEP will issue a disposition to the Town of Canmore to support the construction and operation of the project. This solution is simpler and more effective.

6.2 Environmental Impact Assessment

An environmental impact assessment (EIA) is required for the Project since the Project is considered to be a dam greater than 15 m in height (mandatory activity in Schedule 1 of the Environmental Assessment Regulation established under the *Environmental Protection and Enhancement Act*).

The EIA process has three basic goals:

- a) Gather information The process ensures that enough information is provided by the Town of Canmore to inform the public and government agencies about the Town's understanding of the consequences of the project.
- b) Public involvement The process provides an opportunity for people who may be affected by a proposed activity to express any concerns and provide advice to the Town and government agencies.
- c) Support sustainable development The information provided during the process allows early consideration of the project's place in the overall plan for Alberta's environment and economy.

The Town also conducted Aboriginal Consultations as part of the EIA process. Treaty 7 First Nations were formally consulted and were given the opportunity to visit the project site. Some First Nations requested the right to hold a ceremony on the site before construction starts, as well as being able to gather plant material of significance or importance to them.

The EIA report was submitted to AEP in August 2016 (Canmore, 2016b). All environmental and socio-economic impacts assessed were found to have a range of effects from low and positive to low and negative with the exception of creek hydrology with a moderate and negative impact. However, all these effects are considered to be offset through significant reduction in risk to public safety.

6.3 NRCB Decision

The NRCB is an arms-length agency of the Government of Alberta. It was established under the Natural Resources Conservation Board Act (NRCBA) to review proposed nonenergy natural resource projects that require an EIA. The NRCB starts its formal public review process when AEP deems that the environmental impact assessment is complete.

Reviews consider the potential effect of proposed projects on the environment, the community and the economy. The reviews normally include the participation of community residents, interest groups, government ministries and municipal authorities, as well as applicants. The Board encourages affected Albertans to participate in public hearings and notifies potentially affected communities about the review by placing notices in local papers, in accordance with its rules of practice. All participants can question the evidence put forward by other participants.

Following the review period, the NRCB decides if the project is in the public interest. Any approval issued by the NRCB must be authorized by the Alberta cabinet and is in addition to licences, permits or approvals required by other acts, regulations or by-laws.

The Cougar Creek project is subject to review and approval by the NRCB. This process will start once the EIA is 'deemed complete'.

6.4 Water Act Submission and Dam Safety

In Alberta, water retaining structures are regulated by the Water Act (Alberta, 2000) and Part 6 of the Water (Ministerial) Regulation - Dam and Canal Safety (Alberta, 1998). To build any such structure, Water Act (WA) authorization is required and applications are referred to the Dam Safety branch of AEP for review if the structure is at least 2.5 meters high and has at least 30,000 cubic meters of reservoir capacity. The Cougar Creek project requires review by Dam Safety as it exceeds the established criteria.

The Town has submitted the Cougar Creek WA application package to AEP in September of 2016, following the requirements set-out in the safety guidelines (Alberta Environment, 1999). The package contained all required information for the Dam Safety review. The technical review is ongoing and focuses on the geotechnical, structural and hydrotechnical aspects of the project. A collaborative approach between AEP Dam Safety, an independent third-party reviewer, and the Town, is being used to ensure that the Structure is designed and built in a safe manner that is aligned with provincial, national and international guidelines and best practices. Since debris flood retention structures are new to Alberta, this collaborative approach is essential for the project's success. The design has undergone refinement and optimization based on feedback and input from the review process.

A final and updated Water Act package is to be submitted to AEP once the Structure's design is finalized. The updated WA package will be referred to specialist reviewers such as the Aboriginal Consultation Office, Fish & Wildlife branch and Dam Safety branch of AEP. Once the WA referral process is complete to the satisfaction of the Province, regulatory approvals to construct and operate the Cougar Creek debris flood retention structure will be provided.

7 CONCLUSION / SUMMARY

The floods of 2013 severely impacted the community of Canmore. We were fortunate to avoid loss of life. As a result of the impacts, Canmore has fundamentally changed the way steep creek hazards are assessed and has progressed to a risk based decision making process. This risk based process now informs each decision with respect to active and passive mitigation approaches for Cougar Creek, as well as all other creek hazard areas in our community.

Program success to date has come through involving appropriately educated and experienced individuals from academia, and consultancy. The involvement of Dr. Jakob of BGC Engineering, Dr. Church, Dr. Morgenstern, and Dr. Hubl has led to a more comprehensive quantification of our hazards, including a full recognition of the processes involved and a more complete understanding of the full potential for damage and destruction. Adoption of a risk based approach to hazard management has provided a stronger framework for decision making and new tools to help communicate with the community. This framework shifts discussion from fixed return period to community safety and sustainability. It also allows for more effective investment in mitigation and better policy decisions.

A risk based approach, in combination with the KT option analysis, enabled effective decision making in selecting a mitigation approach for Cougar Creek. Further, a risk based approach has led to success with obtaining funding for the debris flood retention structure. Risk based assessments provide powerful business cases for funding and grant application. Moreover, approval agencies can effectively demonstrate value for money while highlighting community safety risk.

While a risk based framework has been effective in shaping a path forward for Cougar Creek, it has also been significantly more difficult to implement than following a hazard based policy approach. The technical work is more complex and involved. The amount of information to communicate is significantly higher. There are political impacts due to perceived concerns with property values, and frequently with higher project costs. Policy changes make development more difficult in the Cougar Creek hazard areas with technically challenging assessments required and higher building costs. In some cases, development areas have been sterilized, or their uses heavily restricted. Lastly, there is some potential liability in deviating from standard provincial policy.

These challenges are offset by a greater understanding of our risks and in turn the ability to take steps to effectively ensure our community is safe and sustainable. The hard work up front reduces the risk of a much more difficult future where we contend with loss of life, as well as the societal cost and effort that the hundreds of millions of dollars in damage Cougar Creek can, and with enough time will, otherwise cause.

8 REFERENCES

- Alberta, 1998. Alberta Regulation 205/98, Water Act, Water (Ministerial) Regulation. Province of Alberta.
- Alberta, 2000. Water Act, Revised Statues of Alberta 2000 Chapter W-3. Province of Alberta
- Alberta Environment, 1999. Dam and Canal Safety Guidelines. Alberta Environment.
- Alpinfra, 2015. Mountain Creek Hazard Mitigation, Design of Mitigation Measures, Cougar Creek, Interim Report 03, Final Option Analysis. Alpinfra consulting + engineering gmbh. Salzburg, Austria.
- BGC Engineering Inc. 2013. Cougar Creek, 2013 Forensic Analysis and Short-term Debris Flood Mitigation, final. Report prepared for the Town of Canmore. Vancouver, British Columbia.
- BGC. 2014a. Town of Canmore, Cougar Creek Debris Flood Hazard Assessment - Final. Report prepared for the Town of Canmore. Vancouver, British Columbia.
- BGC. 2014b. Cougar Creek Forensic Analysis, Hydroclimatic Analysis of the June 2013 Storm – Final. Report prepared for the Town of Canmore. Vancouver, British Columbia.
- BGC. 2014c. Town of Canmore, Cougar Creek Debris Flood Risk Assessment – Final Revised. Report prepared for the Town of Canmore. Vancouver, British Columbia.
- Canmore, 2015. Cougar Creek Long-Term Mitigation, Option Analysis Summary Report, Canmore, Alberta.
- Canmore, 2016a. Canmore Municipal Development Plan. Bylaw 2016-03. Canmore, Alberta
- Canmore, 2016b. Cougar Creek Debris Flood Retention Structure Environmental Impact Assessment. Canmore, Alberta.