RDEK Elk River Priority Flood and Erosion Mitigation Sites

Conceptual Design Report

May 2016

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Prepared by:

On behalf of our Project Team, the authors trust that this document provides adequate information to describe the conceptual designs for erosion and flood protection at select sites along the Elk River. These sites have been identified as priorities following a review of information provided by the Regional District of East Kootenay, during public consultation through the development of the Elk River Flood Strategy, and letters from members of the public. Please do not hesitate to contact us with any inquiries about this document.

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We appreciate the reviews of this report provided by Christina Hopkins, E.I.T. (Urban Systems Ltd.); Jeff Rice, MSc, P.Eng. (Urban Systems Ltd.); Stella Swanson, Ph.D. Aquatic Biologist (Elk River Watershed Alliance); Lee-Anne Walker, MA Environment & Management (Elk River Watershed Alliance), and Jim Miller P.Eng (retired) (Elk River Watershed Alliance); and, Bruce Elson, P. Eng (retired) (Elk River Watershed Alliance).

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1 Introduction

Concept design development was completed as a component of the larger Elk River Flood Strategy (Flood Strategy) (Walker *et al.* 2016). The Flood Strategy is being prepared to provide municipal, regional, and provincial government as well as the public with information, data analysis, and potential solutions for minimizing the effects of flooding in the Elk River watershed. The Flood Strategy is a broadly-based study, that included: an analysis of the causes of flooding in the Elk River watershed, a historical review of the effects of flooding on community, a literature review of the effects of flooding on fish and wildlife, identification of associated mitigation options that improve habitat, analyses to ascertain future flooding in the Elk Valley (using hydrological and hydraulic modelling, and future climate change projections), and measures available to help mitigate against future flood risk.

Flooding is a natural process that has many beneficial aspects in regards to floodplain development, riparian forest ecology and instream aquatic habitat. Flooding can also have adverse effects on communities and infrastructure. In riverine environments, flooding can result from overtopping river banks or from raised shallow groundwater elevations that create ponding on the ground surface. Flooding is also typically associated with larger volumes of water and higher stream velocities that result in higher rates of erosion, which is the process of mobilizing and transporting material. It is important to distinguish erosion from flooding, particularly in the context of assessing the mitigation options described herein. Some sites discussed in the following sections are specifically erosion issues and not flooding.

Rivers are not stationary in time or space, and often change course. The erodible corridor is the lateral zone of which a stream needs to freely erode and deposit sediment (Piégay et al. 1997; Kondolf 2011). The erodible corridor concept efficiently incorporates both flood and erosion processes into one spatial domain, and can broadly be recognized as the active portion of a river valley or floodplain (Piégay et al. 2005). In the context of the Elk Valley, the erodible corridor, likely extends from valley wall to valley wall (the valley bottom). Note, this functional definition of the floodplain is not analogous with the 1:200 floodplain used for floodplain mapping described by the Ministry of Forests Lands and Natural Resource Operations. Previous work mapped land use within the valley bottom, and demonstrated that areas of dense development exist; however, these areas are localized and much of the Elk River valley bottom is considered to be in good condition (McPherson et al. 2013). Nevertheless, there is infrastructure within reach of the Elk River, and options to help mitigate flood risk to this infrastructure are being evaluated in this report.

The concept design component of the Flood Strategy was an exercise requested by the Regional District of East Kootenay (RDEK), where Lotic Environmental Ltd and MacDonald Hydrology were asked to provide potential flood mitigation options at flood risk sites along the Elk River. The conceptual design process drew on the larger body of information provided by the Elk River Alliance in the Flood Strategy document and incorporated design elements to maintain and promote ecosystem values and function where possible. However, it is important to recognize that structural flood and erosion mitigation techniques[1] inherently interfere with natural channel process and have the ability to impair the river ecosystem (riparian values included). We argue that the only flood mitigation strategies that can be employed without impairing the river ecosystem are non-structural: (1) avoiding development in the floodplain (policy); and (2) relocating existing development (land acquisition). As soon as development occurs within the floodplain, there is potential for interaction between the river and infrastructure resulting in higher risk of property loss and damage due to flooding and erosion. Limiting development within the floodplain or moving out of the floodplain should therefore, be considered the ultimate strategy to avoid these issues and maintain river ecosystem function.

[1] Structural techniques are more traditional approaches such as diking or riprap bank armouring. These do not include policy-type techniques such as “avoiding development in the floodplain” and “relocating existing development”.

While non-structural solutions to reducing the constraints on the river system should be considered when evaluating the concepts presented within this document, much of the existing development will be difficult to relocate, and without policy change, regulatory agencies will continue to permit development within the floodplain. Land acquisition is also a complex solution for an agency like the RDEK to consider. As such, these non-structural options were not included as a mitigative option in this report. Concepts have been limited to structural protection at this time. We do encourage that policy change and land acquisition remain in discussions as realistic and effective options that have been employed elsewhere in the world.

Protecting against flood and erosion almost always means interfering with natural fluvial processes and thus has the potential to adversely affect the river ecosystem, independent of the use of traditional engineering techniques (e.g., rip rap) or bioengineering options considered by some to provide more ecosystem value (e.g., rootwads). Therefore, careful consideration should be given when evaluating these techniques as viable options, with non-structural solutions being the most preferred. Where structural solutions are necessary, impacts of the projects can be reduced by incorporating bioengineering techniques into traditional designs. Where feasible, we have incorporated design elements to reduce the amount of interference with fluvial processes and to enhance fish and wildlife habitat values. A final consideration was to ensure designs would not create recreational hazards on the river. Specifically, no large woody debris structures have been proposed given the high use by boaters, tubers, and other recreationalists.

2 Methods

There are several properties in the RDEK, situated in the Elk River floodplain with potential flood and/or erosion issues. The term “priority sites” is used in this report to describe areas currently considered to be at higher risk of property loss or damage as a result of flooding and bank erosion. Priority sites were identified as sites: (1) known to have historic flooding/erosion issues; known to have flooding/erosion issues in the recent flood events; (3) brought to the RDEK attention by members of the public as having flood and/or erosion risk; and (4) identified during the extensive Flood Strategy public input process from May 2015-April 2016. Sites meeting these criteria were reviewed by the consulting team of Lotic Environmental Ltd and MacDonald Hydrology Ltd. Concept designs and associated cost-estimates were developed to further prioritize the sites, identify additional study requirements, and seek provincial funding. This list is not considered to be exhaustive. However, it is considered accurate that this report lists key areas of interest for the RDEK to consider in flood and erosion mitigation planning.

In November 2015, a professional team conducted field reviews of these sites, to identify potential flood mitigation solutions. It is important to note that these mitigation measures will only address erosion and/or overland flooding issues, not issues relating to subsurface water rising from the ground (i.e., basement flooding). The team was comprised of RDEK Engineering Technician (Kara Zandbergen), Lotic Environmental Aquatic Biologists (Mike Robinson MSc, RPBio and Sherri McPherson BSc. RPBio), and Macdonald Hydrology Hydrologist (Ryan MacDonald, PhD). The RDEK and the Elk River Alliance requested that mitigation options be developed to the conceptual design stage for each site.

Overall, eight sites were identified as priorities for conceptual design development (Figure 1):

- Whispering Winds Trailer Park
- Hosmer exfiltration ponds
- Lower Hosmer town site
- Hosmer bridge dike
- Elk River near Mt. McLean Street
- Elk River at Vanlerberg Road
- Elk River at Hill Road
- Elk River at Thompson Road

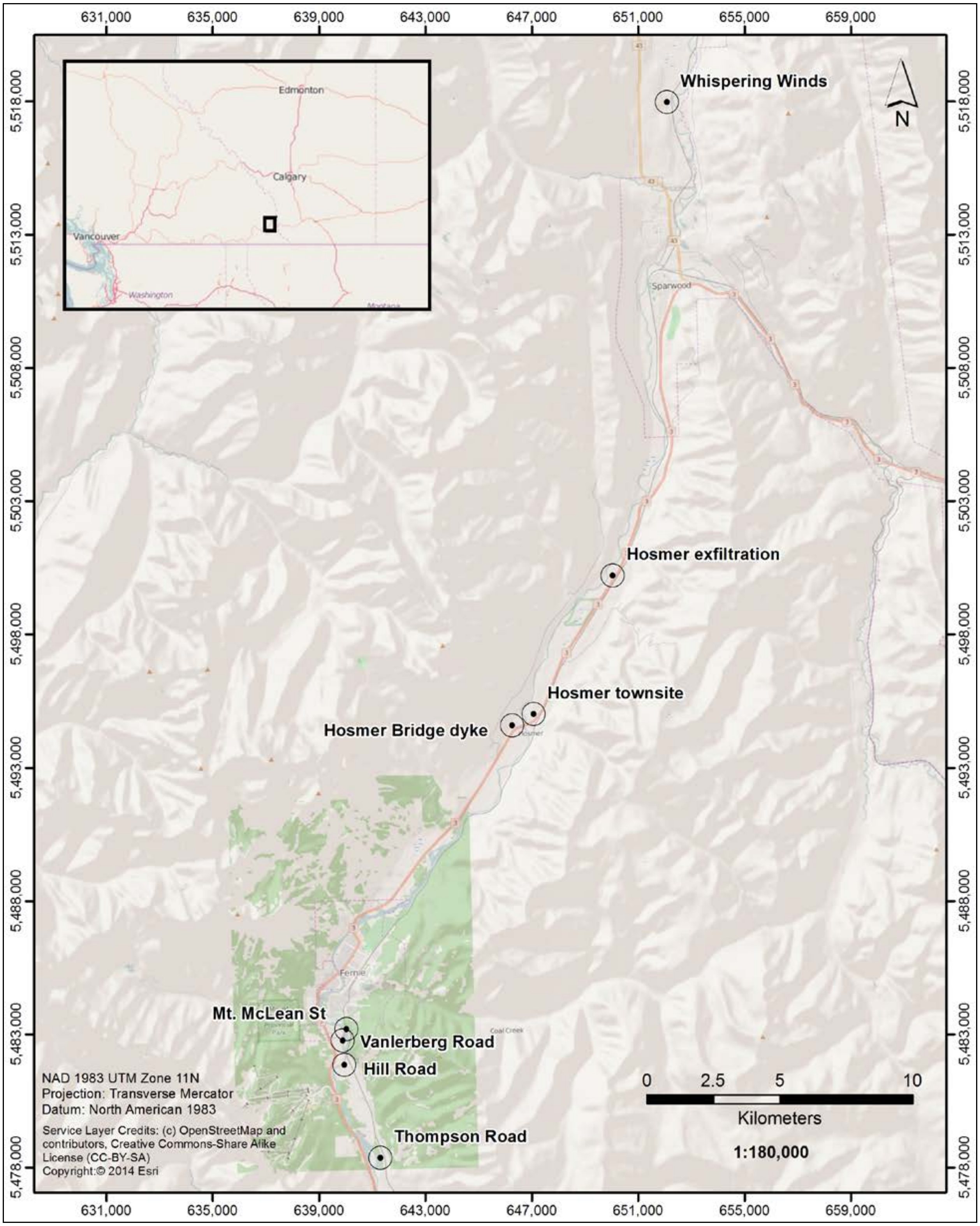

Figure 1. Overview site location map.

Conceptual designs were prepared using available information. This included the observations made during the site visits, and other available information obtained through a desktop review, including: land ownership and floodplain mapping, site level topographic features, and hydraulic modelling results from the Flood Strategy. Additional information such as topographic surveys, geotechnical investigations and detailed site-specific hydraulic modelling, to confirm flood level and flow velocity predictions would come in subsequent phases.

The conceptual designs include the following:

1) Project description
2) Proposed treatments and design assumptions
3) Plan form figures
4) Cost estimate, including: engineering assessment, environmental assessment, land acquisition cost (where required), construction cost, and contingency
5) Data requirements

Conceptual design drawings are provided in Appendix 1. Typical drawings and details of treatment options (McPherson and Robinson 2013) are provided in Appendix 2.

The level of understanding that currently exists for these priority sites is limited. Much work is required to advance any of these sites to a preliminary design stage. In particular but not limited to, significant changes in river conditions resulting from any of the potential improvements investigated here have not been fully assessed hydrologically, hydraulically and/or geomorphologically. This report refers to a hydraulic model developed for the larger Elk River Flood Strategy (Walker *et al.* 2016). This model was developed to be a flood visualization tools for discussion purposes. It is uncalibrated, but does have some validation of results based on the photos from the 2013 event. Significant effort will be needed to further develop these concepts towards constructible designs. The level of effort varies by site from the more basic erosion protection type projects to more complex projects, particularly for the most significant site at Hosmer.

While the RDEK is not responsible for developing flood protection levels, it will be necessary to decide what design criteria (e.g., the current standard in BC versus some other emerging standard) will be used so that residents are aware of the level of protection provided by the design. This report discusses sites that were, in some cases, brought to the attention of the RDEK and Elk River Alliance by citizens. Typically the 1-in-200 year flood event is used to design structural flood/erosion protection measures. However, the 2013 event was notably larger than the 1-in-200 year flood event. This report presents information relative to both of these flow events.

2.1 Cost estimates

Cost estimates were prepared based on the BC Ministry of Transportation and Infrastructure's *Project Cost Estimating Guidelines* (MOTI 2013). Cost estimates in this report are prepared at the "Conceptual" level. As defined by MOTI (2013) these costs are prepared at the most preliminary stages when 0-2% of project development has occurred. These costs are generally considered to be accurate to +/-35% of the actual project costs and will be refined as additional information is collected and the projects become better defined. A 20% contingency was applied at the request of the RDEK

Conceptual cost estimates included the following components:

- **Construction:** Construction costs were largely based on previous projects completed in the East Kootenay region. Unit prices for equipment operation and materials (e.g., rip rap) were also obtained from local sources in the region. Construction included a set cost for mobilization/demobilization that was 10% of the construction costs.
- **Engineering:** Engineering services will be required for hydraulic modeling used to identify design criteria such as dike elevations, riprap sizing, elevations for bank protections, and culvert sizing, as applicable to each project. Engineering services will also be required for all designs and construction inspections. Engineering costs were assumed to be 20% of construction costs.
- **Environmental:** Environmental requirements include an initial environmental site assessment that will be required by the RDEK. Environmental Site Assessments are required by the RDEK for any work occurring within an Environmentally Sensitive Area. We assume all instream work and work within the riparian area to be within environmentally sensitive. Environmental costs also include time required to obtain the necessary permits. Permitting will likely be required at the Provincial level (*Water Sustainability Act*) and the federal level (*Fisheries Act*). Permitting also requires adequate review and consultation with local First Nation's governments. Note, this list of permits is not considered to be inclusive. It is the responsibility of the RDEK as the project owners to ensure all permitting and approval requirements are met. Permitting costs were not included in the following site-specific cost estimates.
- **Project management:** Project management covers costs incurred by the consultants and contractors involved on the project. These costs were assumed to be 5% of the total project costs, before the contingency was applied.
- **Contingency:** Through discussion with the project team and the RDEK, a 20% contingency was considered appropriate at this conceptual estimate level. The contingency was placed on the total project costs. Contingencies will be further refined as the projects become better defined.

Subsequent phases will require the collection of additional information prior to construction. This will include completion of an environmental site assessment, land acquisition analysis (where applicable), engineering/geotechnical assessment, engineered drawings (indicating elevations and configuration etc.), and maintenance costing. Unless specifically stated, costs to complete these activities have been included herein.

3 Whispering Winds Trailer Park

3.1 Existing condition

Whispering Winds Trailer park is located approximately 5 km north of Sparwood, BC on the Lower Elk Valley Road. This site was brought to the attention of the RDEK following the 2013 flood. This site was assessed by reviewing aerial photos collected by the RDEK on an overview flight during the June 2013 flood event.

Whispering Winds is located on the west floodplain of the Elk River and is separated by the Elk River by the CP Rail line. Review of air photos found that the area in between the trailer park and the CP Rail line was flooded. However, most of the trailers were outside of flooded areas. Given the magnitude of the 2013 flood and the fact that much of the trailer park was not flooded, this site is considered lower priority relative to the other sites listed in this report. Furthermore, having the CP Rail line in between the trailer park and the Elk River provides protection against other flood related threats, such as bank erosion.

While from this review it does not appear that any flood mitigation here is urgent, it must be noted that the trailer court is mapped within the province's Flood Hazard area. This means that a risk of flooding does exist for the Whispering Winds trailer park. If additional investigations were of interest, then the RDEK could work to more accurately identify the source of flood waters threatening the trailer park. For example, several side channels exist upstream of the trailer court where the CP Rail line is on the opposite (i.e., east) side of the river. These channels present flow paths that could convey Elk River flood water along the west side of the CP Rail line. This water appears to have backed up behind the rail line during the 2013 flood and caused water to flood near the trailer court. A combined approach of a dike protecting Whispering Winds and improved flow under the tracks may reduce ponding and reduce the flood risk for Whispering Winds. Additional investigation can be completed if the RDEK elevates the priority of this site.

Figure 2. Whispering Winds Trailer Park during June 2013 flooding (Source: RDEK).

4 Hosmer Exfiltration Ponds

4.1 Existing condition

The Hosmer Exfiltration Ponds (the Ponds) are located approximately 11.5 km south of Sparwood. They have been constructed between the Elk River and Highway 3 near a meander bend to the west. There are two ponds within a small fenced off area. The system is primarily used as a septic dump.

This site was placed on the priority list as an “area that was brought to the RDEK attention as having flood and/or erosion risk”. The objective for this site is to reduced flood risk to the Hosmer Exfiltration Ponds.

The Ponds are located 300 m from the Elk River and are considered to be within the erodible corridor of the Elk River. This site is also within the riparian zone of the Elk River. Combined, the ponds plus the access road have a footprint of approximately 0.4 ha. While not considered to be at immediate risk, the Ponds are located such that future channel movement may put them at risk of being flooded and/or eroded by the Elk River.

The RDEK conducts routine groundwater monitoring at this site (Ecologic 2015). Monitoring found that conductivity, chloride, and nitrates were higher downgradient of the ponds. This suggests that some groundwater contamination may be occurring. However, dissolved metals met working provincial water quality guidelines (Ecologic 2015). Further investigation prior to site decommissioning will be required.

Figure 3. Hosmer Exfiltration Ponds site photo.

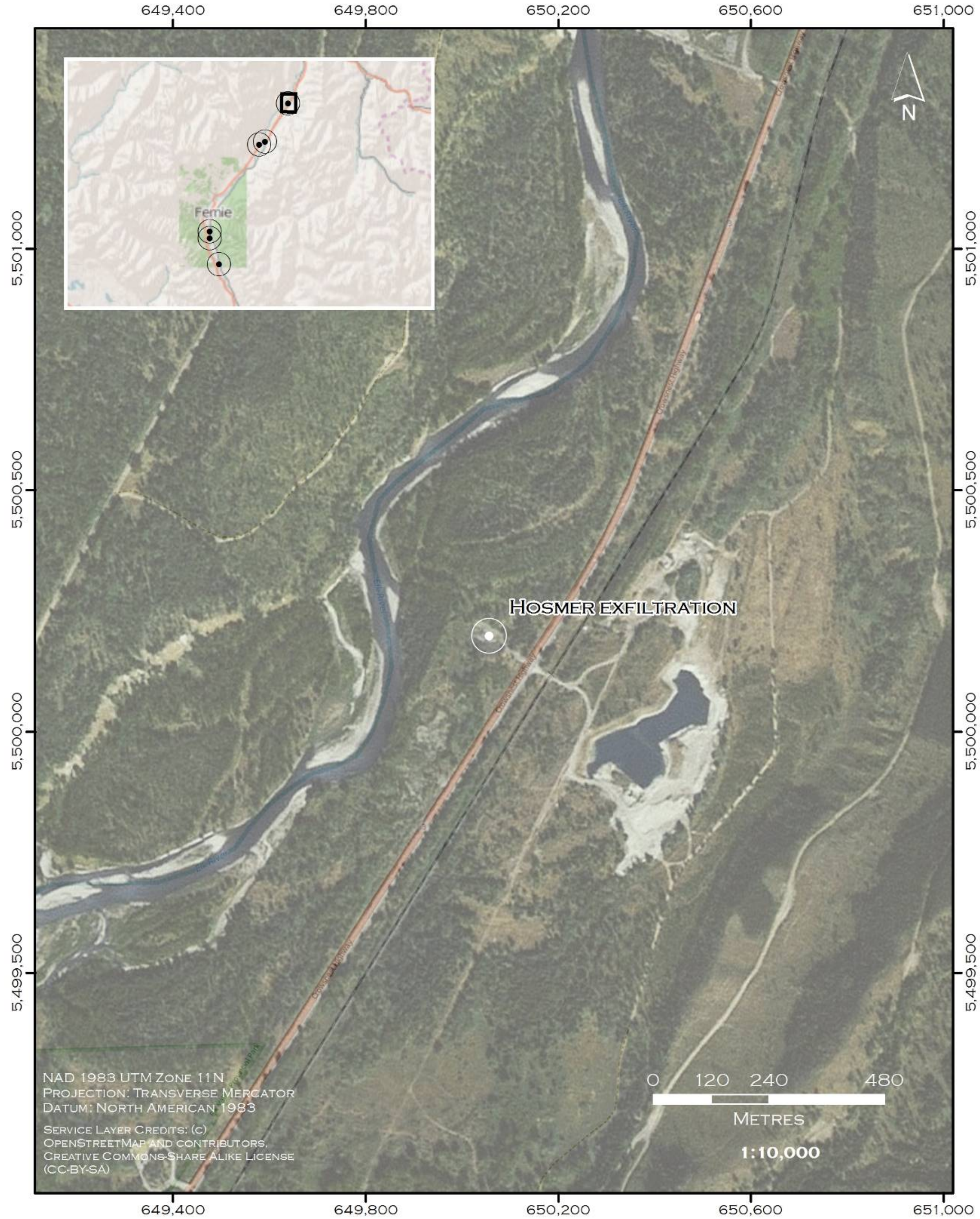

Figure 4. Hosmer Exfiltration Ponds site location map.

4.2 Concept

The general concept of Option A would be to move the Ponds to put this infrastructure outside of the erodible corridor and therefore out of the potential path of the Elk River. The Ponds could be relocated to the other side of Highway 3. The existing location would be reclaimed so that it provides functional floodplain habitat. This will involve filling in the lagoons, removing infrastructure and re-vegetating the disturbed area. Existing site contamination will need to be considered.

Option B is to protect the current structure by constructing a dike to protect again flooding from the Elk River. A dike averaging 1.5 m above current ground plus 1 m keyed into the ground would be constructed to tie into Highway 3 at both the upstream and downstream ends, and surround the existing ponds. The total length of the dike would be 222 m and is estimated to be 1.5 m thick in cross-section. Vegetated riprap would be placed on the west face (exposed to the Elk River). Final dike alignment, crest elevation, and riprap sizing/thickness would be determined by the Project Engineer.

Both options for this project are considered proactive relative to others listed in this report. Option A is preferred by the Consultant as it has the benefit of completing this project as a proactive step in reducing the potential consequence of flooding. Infrastructure avoidance within the floodplain of the Elk River is the ultimate flood mitigation strategy. Option B is not preferred as it effectively increases development within the erodible corridor and will impede river movement in the future, should the Elk River migrate to this location.

4.3 Cost estimate

The cost estimate includes the following pre-construction tasks (Table 1):

- Engineering assessment – an assessment of the new pond location in terms of construction feasibility and geotechnical suitability.
- Environmental assessment – determination of the risk of contamination at the existing site to inform the decision on whether material excavation would be required. As well, an assessment of the proposed site would be required.
- Land acquisition (Option A) – purchase of the land at the new exfiltration pond location.

Construction costs include:

- Mobilization and demobilization of equipment and crews to the existing and new sites
- Option A pond relocation – Construction of the new ponds and access road. Reclamation of the old site – assuming contouring (no hauling out material), soil cover, and revegetation
- Option B dike construction – assumes new construction of a 400 m long by 1.5 m high dike plus toe. Costs include land clearing and rip-rap on the upstream face.

Table 1. Hosmer exfiltration ponds cost-estimate.

Option A: Relocation	
Cost	**Item**
$ 16,250	mob/demob
$ 97,500	New pond construction
$ 65,000	Reclamation
$ 26,813	Engineering assessment
$ 7,600	Environmental assessment
$ 10,658	Project Management
$ 150,000	Land acquisition
$ 74,764	20% contingency
$ 449,000	**Project total (rounded to nearest $1,000)**

Option B: Dike	
Cost	**Item**
$ 7,500	Topographic survey
$ 90,700	mob/demob
$ 7,500	Clearing
$ 907,000	Dike construction
$ 151,905	Engineering assessment
$ 4,500	Environmental assessment
$ 58,455	Project Management
$ 245,512	20% contingency
$ 1,473,000	**Project total (rounded to nearest $1,000)**

4.4 Information requirements

The following Information requirements would be required to further assess this option:

1. Environmental site assessment of both existing and proposed sites (Option A)
2. Land acquisition options analysis for new site (Option A)
3. Engineering/geotechnical assessment of new site (Option A)
4. Topographic survey (Option B)
5. Hydraulic assessment of existing site (Option B)

5 Site 2 Hosmer town site

5.1 Existing condition

Hosmer is a small town of approximately 100 residences situated half way between Fernie and Sparwood along Highway 3. The portion of the town that is at risk of flooding is the area located within the Elk River floodplain called lower Hosmer. This area also encompasses the lower reaches of Hosmer and Mine Creeks, which are tributaries to the Elk River (Figure 5). This site was identified as a priority by the RDEK as it is known to have flooded in the past. The objective for this site is to reduce the risk and occurrence of flooding in lower Hosmer.

Flooding has historically been an issue for lower Hosmer residents, situated on the west side of Highway 3 in the Elk River floodplain (Figure 6). The cause of flooding is not yet well understood. For this assessment we reviewed air photos taken during the June 2013 flood, results from the flood simulations produced for the Elk River Flood Solutions report, and visited the area during a site survey. It was initially suspected that flooding in lower Hosmer was primarily caused by the Elk River overtopping its banks and occupying the floodplain. However, each line of evidence suggests that Mine Creek is more likely the prime reason for the flooding that occurs. It is also still poorly understood as to what role effect Hosmer Creek and the Elk River aquifer have on localized flooding. It is possible that Hosmer Creek contributes to flooding within lower Hosmer near its confluence with Mine Creek. It is also possible that flooding is the result of a higher alluvial (Elk River) water table elevation. This area of Hosmer shows a very shallow water table (close to the surface) at all times of year.

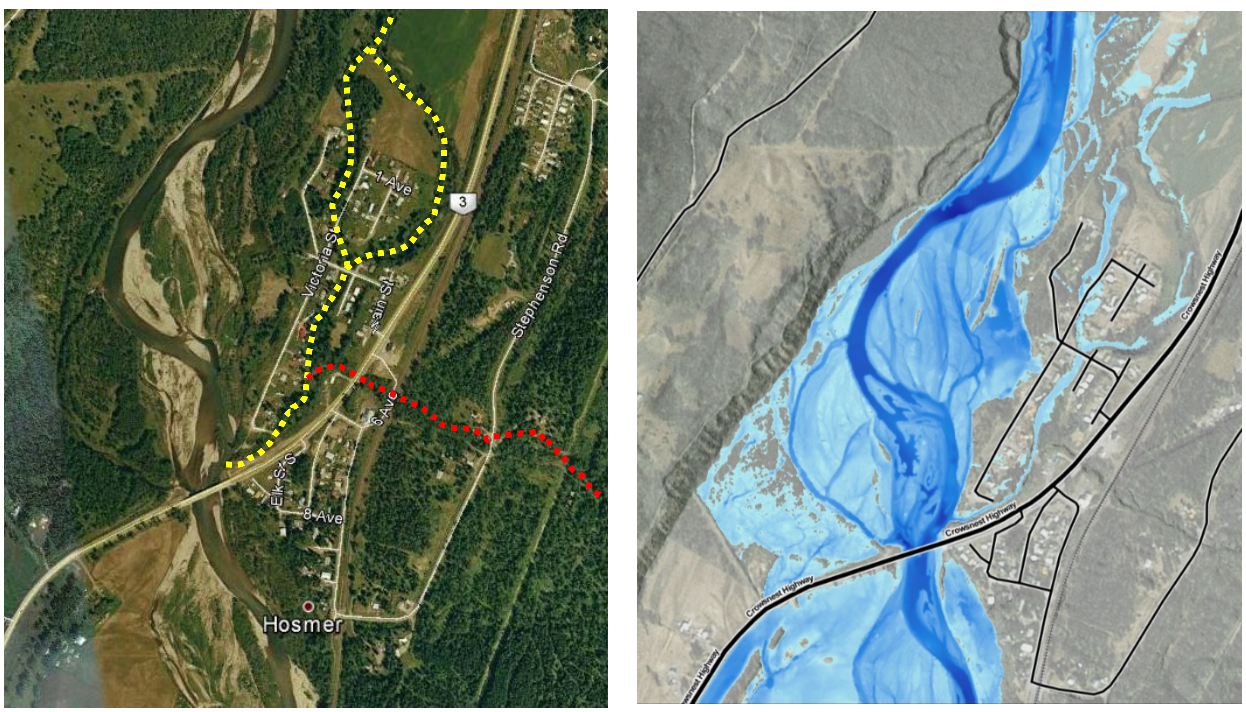

Figure 5. Hosmer town site at low flow (left) and under simulated inundation during a 1:200 year return period flood event. Yellow dashed line = Mine Creek. Red dashed line = Hosmer Creek. NOTE: This simulation is for visual purposes only; it was developed from a preliminary hydraulic model of the Elk River with results plotted against a Lidar-based Digital Elevation Modelling.

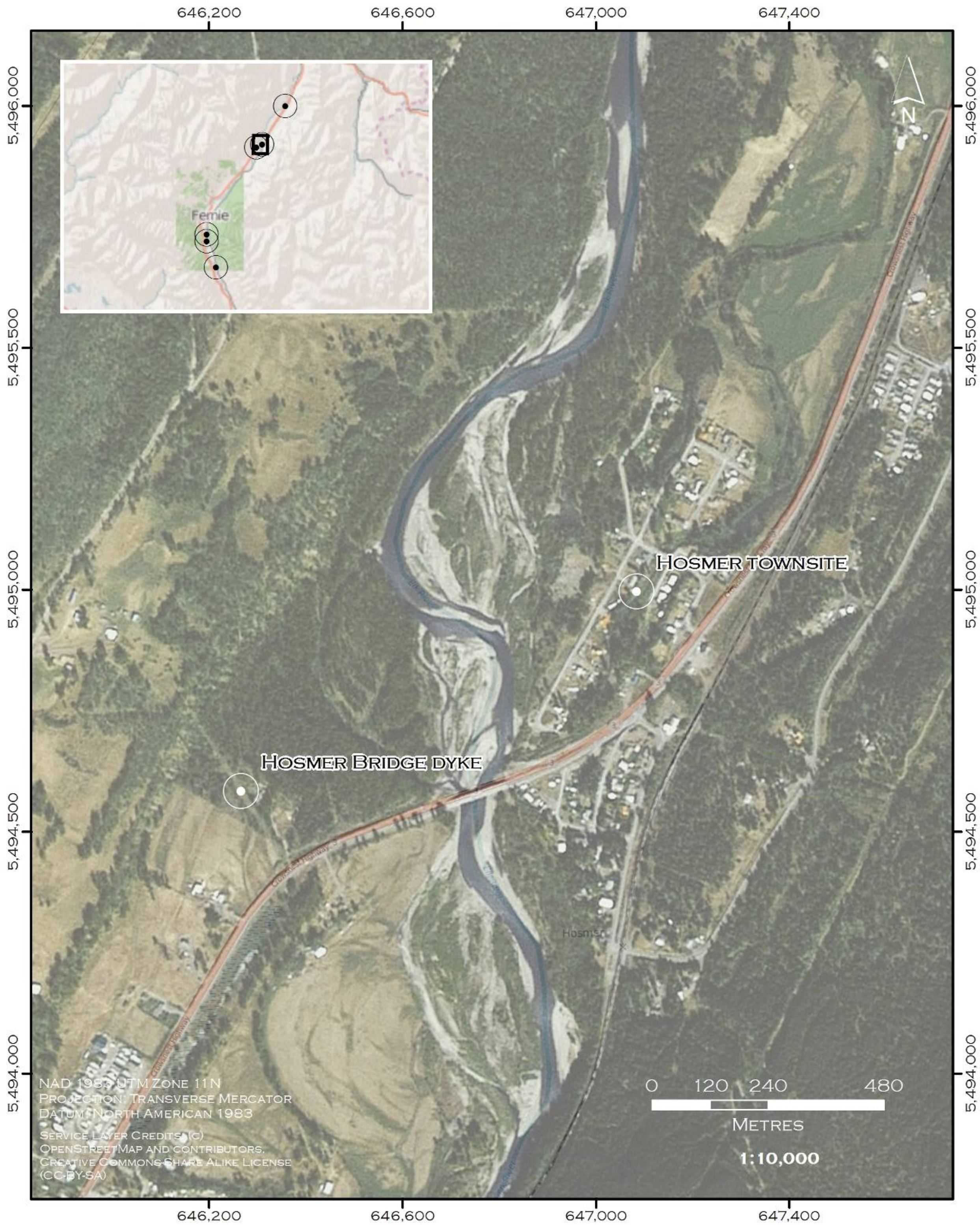

Figure 6. Hosmer town site location map.

Air photo interpretation best explains the current understanding of flooding in lower Hosmer. Figure 7 shows a downstream (south) view of lower Hosmer during the June 2013 flood. The two red arrows show the left and right braids of Mine Creek as it flows into lower Hosmer. The yellow circle shows the culvert crossing location of Mine Creek and Main Street. This structure appears to have been incapable of conveying the flood flows. It caused water to back up behind the road prism, flooding the houses upstream of the road. Flow on the right side of the photo (yellow arrow) shows where Mine Creek water is suspected to be flowing back to the Elk River, and not the Elk River flowing into lower Hosmer. Further downstream (red circle) there is substantial flooding near the confluence of Mine Creek and Hosmer Creek.

Figure 7. Flooding in Hosmer on June 21, 2013 (looking south). Mine Creek is indicated by the red arrow (Source: RDEK).

Given the number of properties potentially impacted, this site is considered to be one of the highest priorities for the RDEK. However, given the number of sources potentially contributing to the flooding (three streams, plus shallow groundwater), it is also one of the more complex flood mitigation sites. This complexity requires further hydrological investigation before a concept design can be put forth. We recommend that a detail hydrologic study be completed to accurately map flooding in lower Hosmer, so that the most effective solutions can be identified. We recommend completing this assessment as part of the hydrologic assessment of the Highway 3 Dike Project (described in Section 6).

An additional factor that should be investigated is the role that the Highway 3 bridge crossing may play in flooding of Hosmer. Observations of channel morphology at the bridge crossing suggest that this structure may be backing up water during high flow events, resulting in higher water elevations near Hosmer than might occur naturally.

Floodplain culverts were investigated at a preliminary stage using the Flood Strategy hydraulic model. The model simulated 1-in-200 year flood flows with and without the addition of a 2 m high by 30 m wide culvert installed at the current ground elevation on the right downstream bridge approach. The results show the additional capacity of the floodplain culverts does not drastically change the water levels seen in Hosmer under this flood scenario. This option would need to be investigated further with improved modelling. Work could be done to see if floodplain culvert size or inlet elevation could provide more flood relief. Modelling could also be used to investigate the benefit of these structures under larger floods, such as that experienced in 2013.

Figure 8. Downstream view of wide flooded area backwatered by Highway 3 (Source: RDEK).

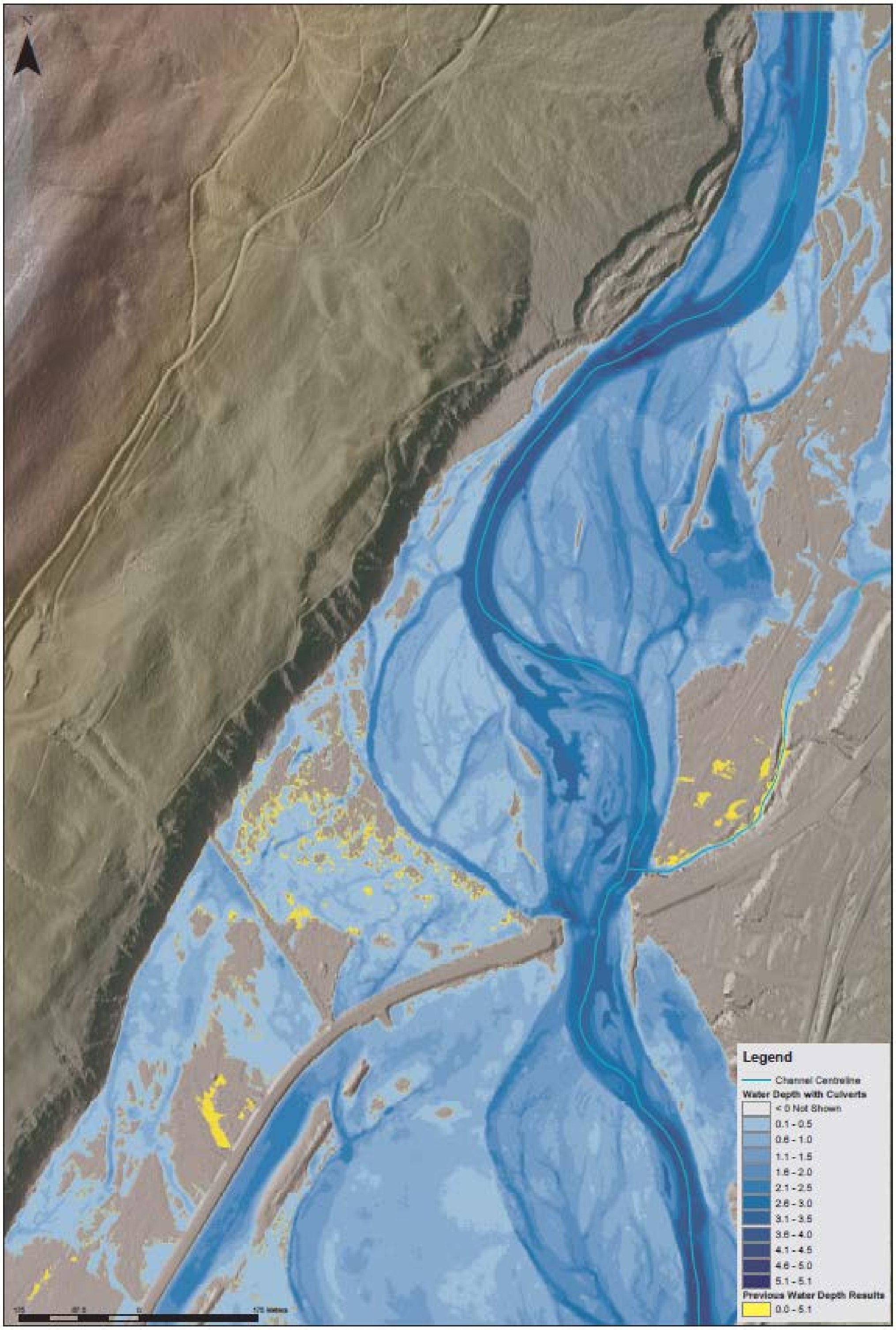

Figure 9. Hosmer townsite area under simulated inundation during a 1:200 year return period flood event. NOTE: This simulation is for visual purposes only. It was based developed from on a preliminary hydraulic model of the Elk River with results plotted against a LiDarLidar-based Digital Elevation Modelling.

5.2 Cost estimate

A detailed hydrologic study cost is estimated to cost $110,000. This study would describe flooding in lower Hosmer in regards to the possible sources of flood water. It would include collecting topographic survey data of the Elk River for approximately 5 to 6 km upstream from lower Hosmer. This does not include floodplain mapping.

5.3 Information requirements

Much work remains to properly describe flooding in lower Hosmer and then to assess and compare suitable mitigation options. A key information gap is to accurately identify the cause of flooding so that options can be designed to address specific hazards presented by tributaries, alluvial groundwater, and the Elk River. Potential mitigation options include: diverting flood flows from Mine Creek into the Elk River upstream of lower Hosmer; improving flow through Mine Creek by replacing culverts in lower Hosmer with bridges; and/or, diverting flood flows in Hosmer Creek to the Elk River downstream of the Highway 3 bridge.

Other information requirements include:

1. Topographic survey data
2. Detailed hydraulic modelling
3. Engineering/geotechnical assessment (preliminary and final)
4. Environmental site assessment

6 Hosmer/Highway 3 set-back dike

6.1 Existing condition

A dike was constructed in 1948 to the west of the Highway 3 Bridge near Hosmer to prevent flooding of private properties to the west of the highway (Figure 10). The area is well-vegetated. Two privately owned lots exist to the north of the dike, between the Elk River and the dike. The dike is currently situated on one of the properties.

This dike partially failed in 2013 (Figure 11) and resulted in some flooding of downstream properties, including a trailer park with multiple residents (Figure 12). Some emergency works were done in 2013 to stop water from flowing over the dike. Reconstructing this dike (set back as far from the river as possible) would help minimize flooding of nearby properties. Relocating the dike to the upstream side of the two properties currently unprotected, would extend protection to additional land. The objective of the RDEK for this site is to reduce the flood hazard for the private lands to the south and possibly north of the dike structure.

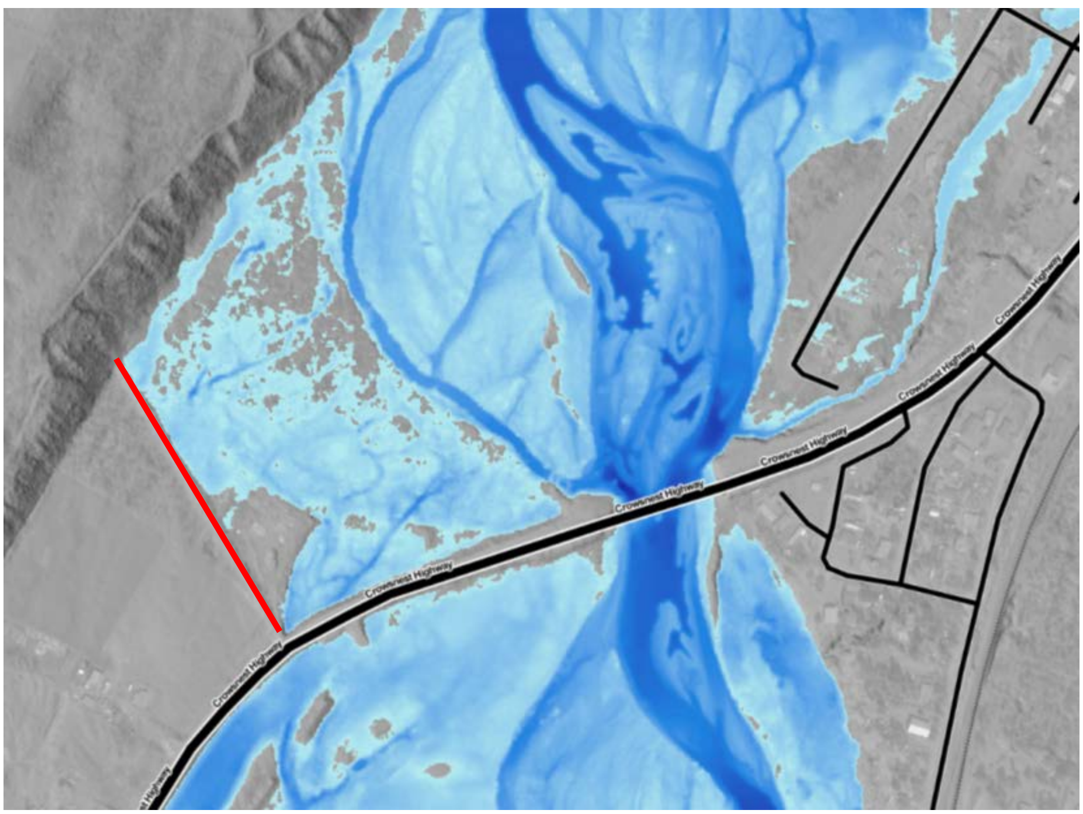

Figure 10. Simulated extent of inundation during a 1:200 year flood event. Red line = existing dike. NOTE: This simulation is for visual purposes only; it was developed from a preliminary hydraulic model of the Elk River with results plotted against Lidar-based Digital Elevation Modelling.

Figure 11. Water overtopping dike in June 2013 (source: RDEK).

Figure 12. Downstream trailer park and multiple properties affected by the June 2013 flood event.

Figure 13. Hosmer/Highway 3 set-back dike site location map.

6.2 Concept

Option A of this project would bring the existing dike to an elevation such that flows would not breach it in a 1:200 event. The existing structure is approximately 310 m long and ties into the hillslope on the west end and the highway road fill on the east. Vegetation will be used to stabilize the upstream face of the dike to the extent possible, as directed by the engineering team. It is likely that this structure will need to be routinely inspected, which will require clear observation of the upstream face.

Option B is to relocate the dike to the north to protect the additional two properties currently outside of the dike protection area. This would require full dike reconstruction and clearing of a new right-of-way. Design criteria would be similar to the existing dike in terms of level of protection (assumed 1:200 event in this report). It would however require riprap on the upstream face given the increased impingement high velocity of flows it is expected to experience during flooding. The rip rap could be vegetated, however, this was not included in the cost estimate given that it is a setback dike and not immediately on the river bank. The Option B dike would be approximately 420 m long and is estimated to need to be constructed to an elevation that is 2 m above the existing ground. It would also tie into the hillslope on the west end and the highway road fill on the east.

6.3 Cost estimate

The following cost estimate includes pre-construction tasks of (Table 2):

- Engineering assessment – an assessment to determine the final dike elevation.
- Environmental assessment – determination of the existing habitat values in the area and consequences of the proposed works.

Construction costs include:

- Mobilization and demobilization of equipment and crews to the work site
- Engineering assessments – Option B would have an added hydraulic assessment in response to potential effects of the dike to flooding in lower Hosmer and the Highway 3 bridge. Approximately 6.5 ha of floodplain will be lost with the realigned dike location option.
- Environmental assessments
- Option A dike construction – assumes increasing the elevation of the existing approximately 310 m long dike by 1 m on average. Does not assume rip-rap on the upstream face.
- Option B dike construction – assumes new construction of a 420 m long by 2 m high dike. Costs include land clearing and rip-rap on the upstream face.

Table 2. Hosmer/Highway 3 set-back dike cost-estimate for Option A and Option B.

		Option A: Dike
$	2,500	Clearing
$	164,000	Dike construction
$	28,185	Engineering assessment
$	2,700	Environmental assessment
$	10,939	Project Management
$	45,945	20% contingency
$	**276,000**	**Option A Project total (rounded to nearest $1,000)**

		Option B: Dike
$	7,500	Topographic survey
$	64,600	mob/demob
$	7,500	Clearing
$	646,000	Dike construction
$	157,132	Engineering assessment
$	4,500	Environmental assessment
$	60,459	Project Management
$	253,927	20% contingency
$	**1,202,000**	**Project total (rounded to nearest $1,000)**

6.4 Information requirements

The following information will be required to further investigate options at this site:

1. Topographic survey data
2. Engineering/geotechnical assessment
3. Final dike elevation and configuration
4. Environmental site assessment
5. Land use – both options involve construction on private land. Land owner consent and statutory rights-of-ways will be required.
6. Option B should include a hydraulic assessment to assess the potential affect that the dike relocation may have on lower Hosmer and the Highway 3 bridge. The Option B dike location will effectively remove approximately 6.5 ha of floodplain capacity.

7 Elk River near Mt. McLean Street

7.1 Existing condition

The subject property is located on the outside bend (left-downstream bank) of the Elk River on the boundary between RDEK land and the City of Fernie. The property is accessed from Mt. McLean Street. This site is the furthest upstream of three consecutive meanders that are listed as priority sites in this report (see Sections 8 and 9). Furthermore, it is preceded by two armoured meanders (one near the Stanford Inn, one near West Fernie) and the West Fernie dike complex.

This property is mapped as having approximately 400 m of water front. Bank erosion is occurring along the entire property and is particularly noticeable at the primary residence where an eroding bank approximately 4 m high was observed. Much of the riparian area has fallen into the river as the bank eroded.

This site is an “area that was brought to the RDEK attention as having flood and/or erosion risk”. The objective is to limit further erosion at this location.

Figure 14. Downstream view of eroding bank (left downstream bank) and primary dwelling on property.

Figure 15. Elk River near Mt. McLean Street site location map.

7.2 Concept

The concept will be to use a tiered design to offset some of the impact that meeting this objective will have on channel morphology (Figure 16). The tiered design would begin at the streambed with a keyed in toe similar to a traditional rip rap design (Appendix 1). The rock would extend upslope to an elevation near or slightly above bankfull levels, where a floodplain bench would be constructed. We recommend that a 2 m wide floodplain bench is constructed over the entire 150 m site (i.e., the bank nearest the log home on the property), for a floodplain bench of 300 m^2. The core of the bench would be constructed of coarse material that will not avulse when overtopped by flood flows (approximately 1-in-2 year to 1-in-5 year return). It would be capped with a growing medium capable of supporting vegetation. Planting can be completed as a combination of grass seeding and live staking (e.g., willow and dogwood species). The slope up from the floodplain bench to a design elevation determined by the project engineer would be treated by constructing a vegetated geogrid (Appendix 2). The bank will first be resloped. The slope of this would be determined in subsequent design phases, but typically a final slope of 2:1 is desired. Successive horizontal benches parallel to the stream are excavated where cuttings will be set in. Benches are to be spaced 1 m apart, with the first located at or near the floodplain bench. The number of benches is determined by the bank height. Benches will be spaced at 1 m slope distance. Cuttings are placed on the benches and covered with a thin layer of growing medium. Coconut coir matting is placed in the trench, backfilled and ran upslope to key into the next bench in sequence or a top trench if it is the upper most layer. Live stakes can be used to hold down the jute and to provide vegetation cover. The area is lastly seeded with an applicable grass seed mix. The top of this slope would tie into existing ground, effectively advancing the toe into the stream from its currently location. This concept assumes two brush layers in the geogrid on average.

The intent of this design is to provide a vegetated buffer along the channel, while meeting the objective of limiting further bank erosion. The tiered approach provides immediate protection while allowing the upslope area to become revegetated. One limitation to this approach is that the upslope area will be somewhat vulnerable to erosion immediately following construction, but will improve as vegetation establishes over time.

Figure 16. Example of tiered bank protection design with revegetated floodplain incorporated (Ymir, BC).

7.3 Cost estimate

The following cost estimate includes pre-construction tasks of (Table 3):

- Engineering assessment – an assessment to determine the final rip rap sizing and elevation.
- Environmental assessment – determination of the existing habitat values in the area and consequences of the proposed works.

Construction costs include:

- Mobilization and demobilization of equipment and crews to the work site
- Bank protection – assumes 150 m of bank protection, uses a tiered design to achieve a vegetated floodplain within two section of rip rap armouring. Design does not include a toe apron. Assumes two brush layers in the vegetated geogrid.

Table 3. Elk River near Mt. McLean Street cost-estimate.

Cost		Item
$	25,457	mob/demob
$	238,668	Rock armouring
$	15,900	Floodplain bench and planting
$	28,910	Vegetated geogrid
$	39,619	Engineering assessment
$	3,600	Environmental assessment
$	17,608	Project Management
$	70,431	20% contingency
$	**440,000**	**Project total (rounded to nearest $1,000)**

7.4 Information requirements

The following information will be required to further investigate options at this site:

1. Engineering/geotechnical assessment
2. Environmental site assessment
3. Maintenance cost estimate

8 Elk River at Vanlerberg Road

8.1 Existing condition

The Elk River is causing bank erosion along two properties located at the end of Vanlerberg Road. The site is at a point on the outside of a slight meander bend. The lateral erosion to the west is creating an issue with the private land upslope. It is understood that flooding is not a concern at this site. This site was listed as a priority as it was an area known to have issues in the recent flood events. The objective for this site is to reduce the rate of bank erosion on the west bank (i.e., right downstream).

The Elk River flows across the channel from the left bank to this site on the right bank. It flows into the bank at Vanlerberg Road at a moderate angle at the upstream end of the site. It then flows parellel along the bank and the subject property at risk to continued erosion. The area has existing habitat value in the form of riparian vegetation. Any proposed project should work to maintain and enhance this aspect of the site. No houses were considered to be in immediate danger of being lost due to bank failure from continued erosion.

Figure 17. Upstream view of Elk River migrating towards private land on the right downstream bank (left of photo).

Figure 18. Elk River at Vanlerberg Road site location map.

8.2 Concept

The concept at this site is to reduce the risk of property loss created by the current bank erosion by limiting further lateral movement of the Elk River to the west. The channel is narrow at this location; therefore, a tiered design similar to that recommended for the Elk River near Mt. McLean Street was not considered to be optimal. Employing a similar design at this location would require shifting the toe into the channel to an extent that it may likely create erosion issues on the opposite bank (left-downstream bank) downstream of the site. As such, a more traditional bank amour design would be recommended at the upstream end of this site, and a bioengineered bank where flows run parallel the bank at the lower end of the site. Note, bank protection is considerd to be a short to- medium-term solution that requires maintenance.

Rip rap bank armouring will be installed to protect the toe of slope and bank and for the upper 50 m of the site. We recommend vegetated riprap to reduce the impact of the treatment by providing some habitat value and to improve riprap stability as the shubs establish overtime (Figure 19). We estimate that the vegetated 50 m along the bank and run 2 m upslope above the bankfull elevation at a slope of 2:1 for a slope distance of 4.5 m. It would be approximately 1.5 m thick. Riprap limits, sizing, and thickness would be confirmed during a hydraulic assessment in subsequent stages. Vegetated riprap is constructed with live cuttings installed as brush layers among the riprap slope. Cuttings are placed in sona tubes filled with a gowth medium and protected by a layer of strand board on the upslope side. The proposed design will have two brush layers over the slope of the riprap.

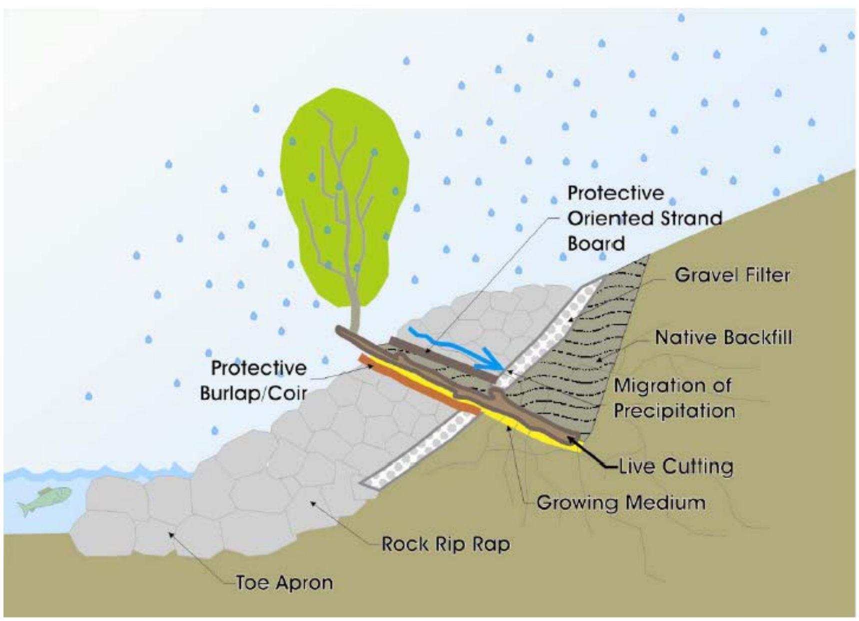

Figure 19. Vegetated riprap concept drawing (AMEC 2012).

The following 150 m of bank downstream from the vegetated riprap will be treated with a combination of a riprap toe (Appendix 2) and a brush mattress (Figure 20) to protect the slope. The riprap toe will be a keyed in toe similar to a traditional rip rap design (Appendix 1). The rock extends upslope to an elevation determined by the Project Engineer. This is typically higher than bankfull flood stage, but not as high as traditional protection (e.g., 1 in 200 year flood return). A brush mattress will be installed upslope from the riprap by placing a layer of interlaced live stems on the exposed bank. The live stems are long enough so that the bottoms are keyed in behind the riprap and extend to the water table. They are also long enough to cover the exposed face of the bank. Cuttings are then covered with a layer of soil, coconut coir, and secured to the bank by a combination of pins driven into the bank and horizontal lengths of rope between pins.

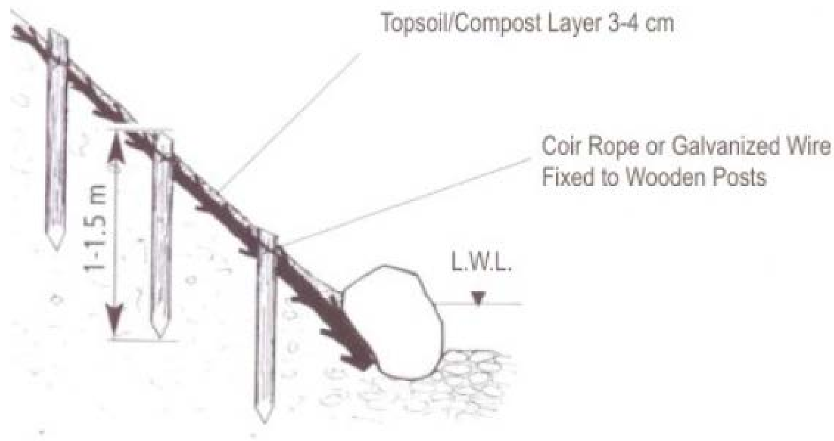

Figure 20. Vegetated riprap concept drawing (AMEC 2012).

8.3 Cost estimate

The cost estimate includes pre-construction tasks of an engineering assessment (to design bank protection) and an Environmental assessment to determine the existing habitat values in the area and consequences of the proposed works (Table 4). Construction costs include: mobilization and demobilization of equipment and crews, and bank armouring construction. Maintenance costs are not included.

Table 4. Elk River near Vanlerberg Road cost-estimate.

Cost		Item
$	19,609	mob/demob
$	196,090	Rock armouring (vegetated)
$	187,705	Rock toe
$	30,000	Brush mattress
$	65,011	Engineering assessment
$	3,600	Environmental assessment
$	25,101	Project Management
$	105,423	20% contingency
$	**633,000**	**Project total (rounded to nearest $1,000)**

8.4 Information requirements

1. Engineering/geotechnical assessment
2. Environmental site assessment
3. Maintenance cost estimate
4. Land use – the project is on private land. The RDEK require special permission to work here.
5. Land acquisition requirements (i.e., which lots specifically) and acquisition process

9 Elk River at Hill Road

9.1 Existing condition

Landowners along Hill Road have experienced flooding and erosion along the outside meander bend of the Elk River. The subject properties are located on the east bank (left downstream) of the Elk River. Two properties are currently experiencing the erosion issues. The extent of flooding appears to be limited to field/pasture areas, and not as much structures. As such, we have assumed erosion is the primary concern.

In 2013, an existing dike was eroded and lost along with a large portion of the bank and mature cottonwoods. Until the dike was lost it did provide some protection from flooding to the properties on Hill Road. In early 2014, a low, non-engineered berm was constructed on the southern-most of the two properties. In 2015, Disaster Financial Assistance funds were used to reconstruct the dike that was lost in the flood. This dike was not armoured, nor was the bank below it. The 2015 dike was constructed set back from the top of bank to spare the remaining riparian vegetation and to allow space for riprap to be placed in the future. A section of bank armouring was also completed at the upstream limit of this site. This work was completed by Canadian Pacific Railway (CPR) to protect a section of railway track that is approximately 120 m long.

Figure 21. Upstream view of eroding bank and existing riparian area at Hill Road.

Figure 22. Elk River at Hill Road site location map.

9.2 Concept

The objective for this site is limiting bank erosion. To do so, the current lateral migration of the Elk River must be restricted. We recommend using a tiered design to offset some of the impact that meeting this objective will have on stream morphology. This concept is similar to that proposed for the Elk River near Mt. McLean St (see Section 7).

The overall site length is 475 m from the existing rip rap bank constructed by CPR to a point downstream of the second subject property. The tiered bank protection would be constructed over this entire length. A rock toe would be constructed to extend from the stream bed to an elevation near or slightly above the bankfull level where a floodplain bench is constructed. We recommend that a 2 m wide floodplain bench is constructed over the entire 475 m long site, for a floodplain bench of 950 m^2. The core of the bench would be constructed of coarse material that will resist erosion when overtopped by flood flows. It would be capped with a growing medium capable of supporting vegetation. Planting can be completed as a combination of grass seeding and live staking (e.g., willow and dogwood species). The slope up from the floodplain bench to a design elevation determined by the project engineer would be treated by constructing a vegetated geogrid (Appendix 2).The intent of this design is to provide a vegetated buffer along the channel, while meeting the objective of limiting further bank erosion.

9.3 Cost estimate

A cost-estimate has been provided in Table 5. Maintenance costs are not included in this value. It includes pre-construction tasks of:

- Engineering assessment – an assessment to determine the final rip rap sizing and elevation
- Environmental assessment – determination of the existing habitat values in the area and consequences of the proposed works

Construction costs include:

- Mobilization and demobilization of equipment and crews to the work site
- Bank protection – assumes 475 m of bank protection, uses a tiered design to achieve a vegetated floodplain within a rip rap toe and a vegetated geogrid.

Table 5. Elk River near Hill Road cost-estimate.

Cost	Item
$ 98,625	mob/demob
$ 796,599	Rock armouring
$ 48,600	Floodplain bench and planting
$ 141,048	Vegetated geogrid
$ 141,574	Engineering assessment
$ 4,500	Environmental assessment
$ 61,547	Project Management
$ 258,499	20% contingency
$ 1,551,000	**Project total (rounded to nearest $1,000)**

9.4 Information requirements

The following information will be required to further investigate opportunities at this site:

1. Determine the risk of flooding versus erosion
2. Confirmation that emergency dike is adequate
3. Engineering/geotechnical assessment
4. Environmental site assessment
5. Maintenance cost estimate
6. Land acquisition requirements (i.e., which lots specifically) and acquisition process

10 Elk River at Thompson Road

10.1 Existing condition

This site is located on Thompson Road (off of Cokato Road), approximately 1.4 km upstream from the City of Fernie water treatment lagoons (Figure 23). The property is one of approximately eight properties located on a narrow portion of land between the left downstream bank (east bank) of the Elk River and Thompson Road. The area of land ranges from approximately 120 m wide to 220 m wide, depending on the property.

This site is an "area that was brought to the RDEK attention as having flood and/or erosion risk". The area is within a portion of the Elk River floodplain that was almost entirely inundated by flooding in June 2013 (Figure 24). Although with prior flooding, there were bank erosion concerns.

The Thompson Road area was visited in November 2015 where the RDEK identified one property in particular where the landowners had expressed concern of bank erosion. Observations found the area to have already been addressed through rip rap armouring being placed over the slope (Figure 25). Bank armouring had been completed over a section of the left bank that extended for approximately 120 m, ending at a residence within 30 m from the bank. The section of bank was bisected by a relict flood channel flowing in from the east. Given that instream work has already been done to armour the bank in this area, it may be that this site is at low risk (assuming it was done adequately). However, if the RDEK wishes to investigate this site further, then the initial design and as-built specifications must be reviewed by an engineer to determine if the structure has been constructed properly. For example, a review would look at the rip rap sizing, thickness, filter-fabric or filter rock layer, and keying in of the riprap toe.

The RDEK also mentioned the apparent concern the landowner had with a log jam located at the apex of a mid-channel bar located near the right downstream bank, across from the subject properties. The concern was that the jam was forcing flows towards the property and exacerbating bank erosion on the left downstream bank. Our assessment of the site found that the left downstream bank was primarily eroding because it was on the outside meander bend of the Elk River. The outside of a meander bend is typically where erosion occurs as this is where water velocity is the highest. The high velocities occur as water accelerates around the corner. The opposite is true for the inside of a meander bend, where water velocities are lower and promote sediment deposition. This is why the log jam has remained in its current location, even after June 2013 flooding. The ability for a stream to function properly and maintain effective geomorphic processes, such as sediment transport, depend largely on it maintaining proper channel morphology. The log jam on the right downstream bank is an important feature that will act to stabilize the mid-channel gravel bar and allow it to become vegetated. Removing the log jam has the potential to create an over-widened stream section. Over-widened sections have the potential to aggrade, causing the stream bed elevation to rise. As aggradation progresses, the ability for the channel to overtop its banks becomes easier. Furthermore, removal of large woody debris may be considered under the federal *Fisheries Act* to be detrimental to the "commercial, recreational, and aboriginal" fishery that exists in the Elk River. Therefore, it is suggested that the log jam on the right downstream bank not be removed.

Figure 23. Elk River near Thompson Road site location map.

Figure 24. Properties adjacent the Elk River along Thompson Road during the June 2013 flood.

Figure 25. Rip-rapping along properties at the adjacent the Elk River along Thompson Road site.

11 Literature cited

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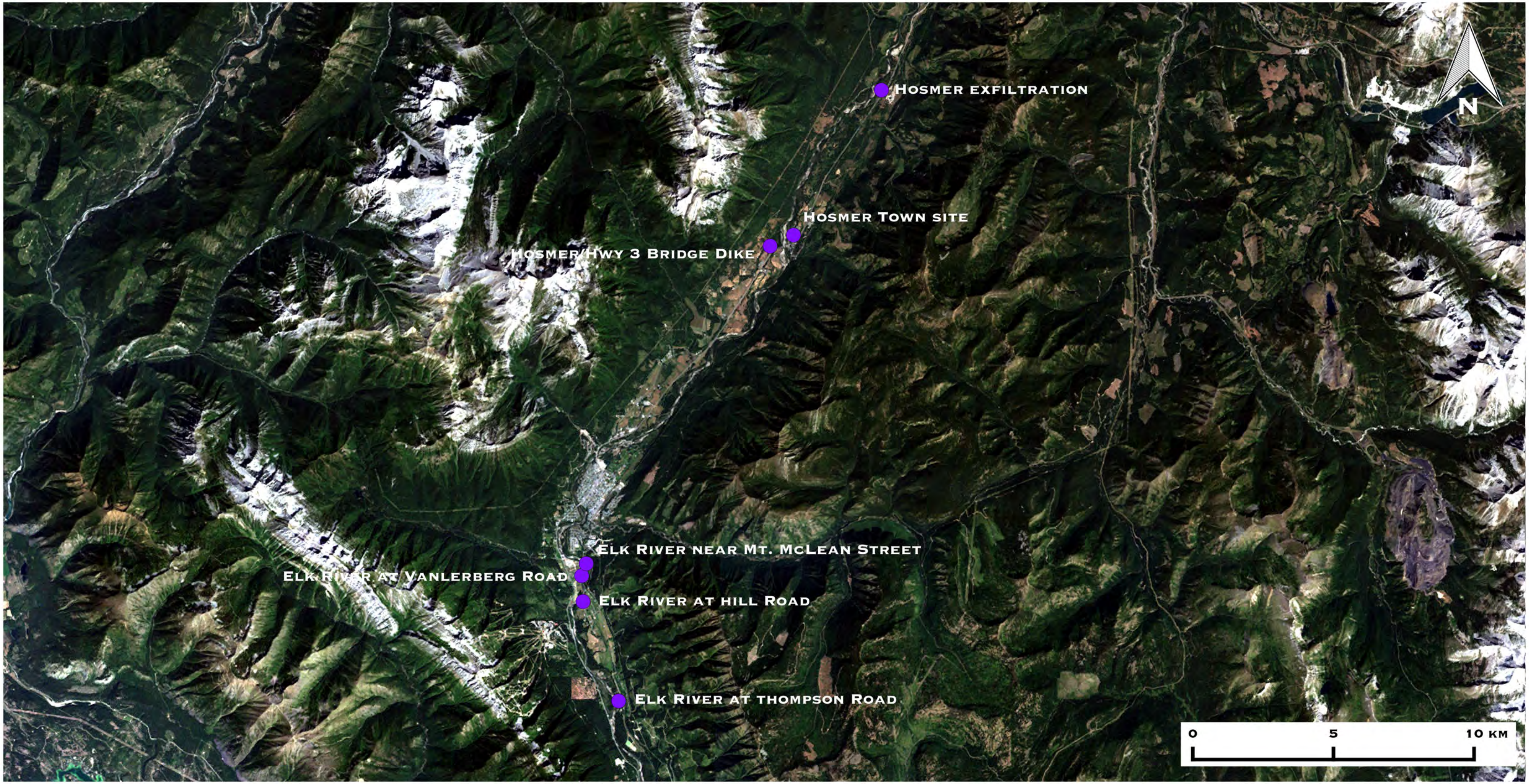
Walker L.[1], R. MacDonald[2], S. McPherson[3], M. Robinson[3], C Barnes[4], C. Cipriano[1], G. Preston[1], M. Clarke[1], M. Chernos[2], and D. Marcotte[2]. 2016. Elk River Flood Solutions Strategy. Prepared by Elk River Watershed Alliance[1], MacDonald Hydrology Consultants Ltd[2], Lotic Environmental Ltd.[3], and University of Lethbridge[4].

12 Appendices

Appendix 1. Concept designs



Clients:

Regional District of East Kootenay

Elk River Alliance

Design Consultants:

Lotic Environmental

Specialists in Freshwater Ecosystems

GCS: North American 1983

Source: CanImage

Date: 2016-03-16

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Flood mitigation and erosion protection concept designs

RDEK Priority Sites - Overview

Photo 1: View of access road and ponds from Highway 3.

Photo 2: View of ponds from access gate.

Concept Notes:

1) Option A - Pond relocation
  a) Remove fencing and excavate material as directed by environmental assessment.
  b) Contour pond berms and access road material.
  c) Apply cover as directed to promote revegetation.
  d) Revegetate footprint.
2) Option B - Dike
  a) Construct dike to desired flood elevation.
  b) Surface outboard face with vegetated riprap.

Clients:

Regional District of East Kootenay

Elk River Alliance

Design Consultants:

Lotic Environmental

Specialists in Freshwater Ecosystems

GCS: North American 1983

Source: 2011 Orthos Geobase

Date: 2016-06-01

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Hosmer Exfiltration Flood Mitigation and Erosion Protection Concept Designs

Option A - Pond relocation

Option B - Dike

Private Lands

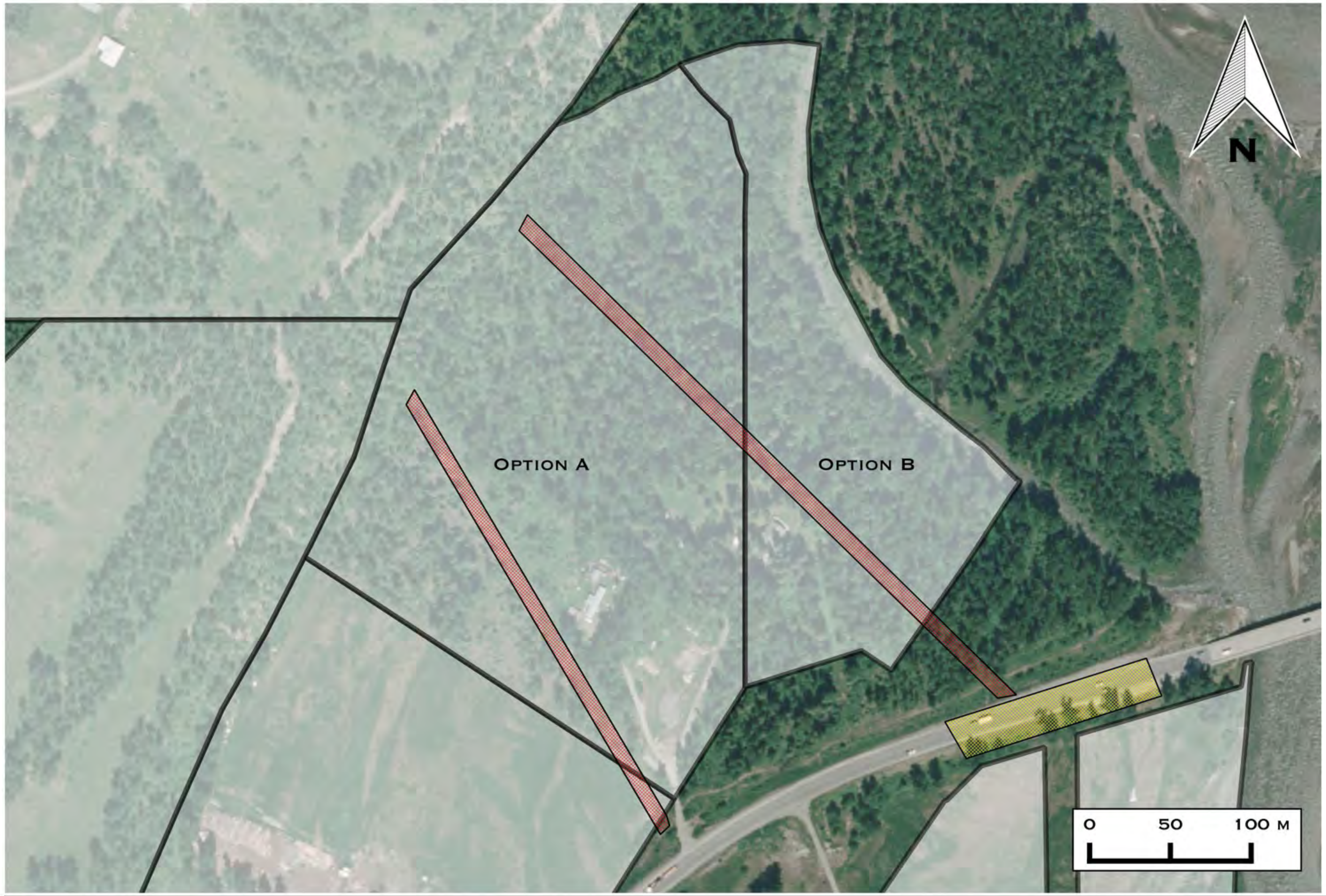

Photo 1: View of existing dike from Highway 3.

Photo 2: View of property at flood risk to west of Highway 3 and downstream of the existing dike.

Concept Notes:
1) Bring existing dike to elevation as directed by engineering assessment.
2) Armour upstream face with rip rap as directed in engineering design.
3) Ensure dike is complete and no breach points exist.

Clients:

Regional District of East Kootenay

Elk River Alliance

Design Consultants:

Lotic Environmental
Specialists in Freshwater Ecosystems

GCS: North American 1983

Source:
2011 Orthos
Geobase

Date: 2016-05-24

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Hosmer/Hwy 3 Bridge Dike Flood mitigation and erosion protection concept designs

- Culvert
- Dike
- Private lands

Concept Notes:

1) Install riprap toe at new alignment into the channel to create final desired slope tie-in to existing bank.
2) Bring rock toe up to floodplain elevation.
3) Construct two meter floodplain bench, cap with soil, seed and plant.
4) Continue rip rap up slope at 2:1 to final elevation.

Photo 1: Downstream view of eroding bank and house on subject property.

Photo 2: Downstream view of barn and second dwelling further downstream on subject property.

Clients:

Regional District of East Kootenay

Elk River Alliance

Design Consultants:

Lotic Environmental

Specialists in Freshwater Ecosystems

GCS: North American 1983

Source: 2011 Orthos Geobase

Date: 2016-05-24

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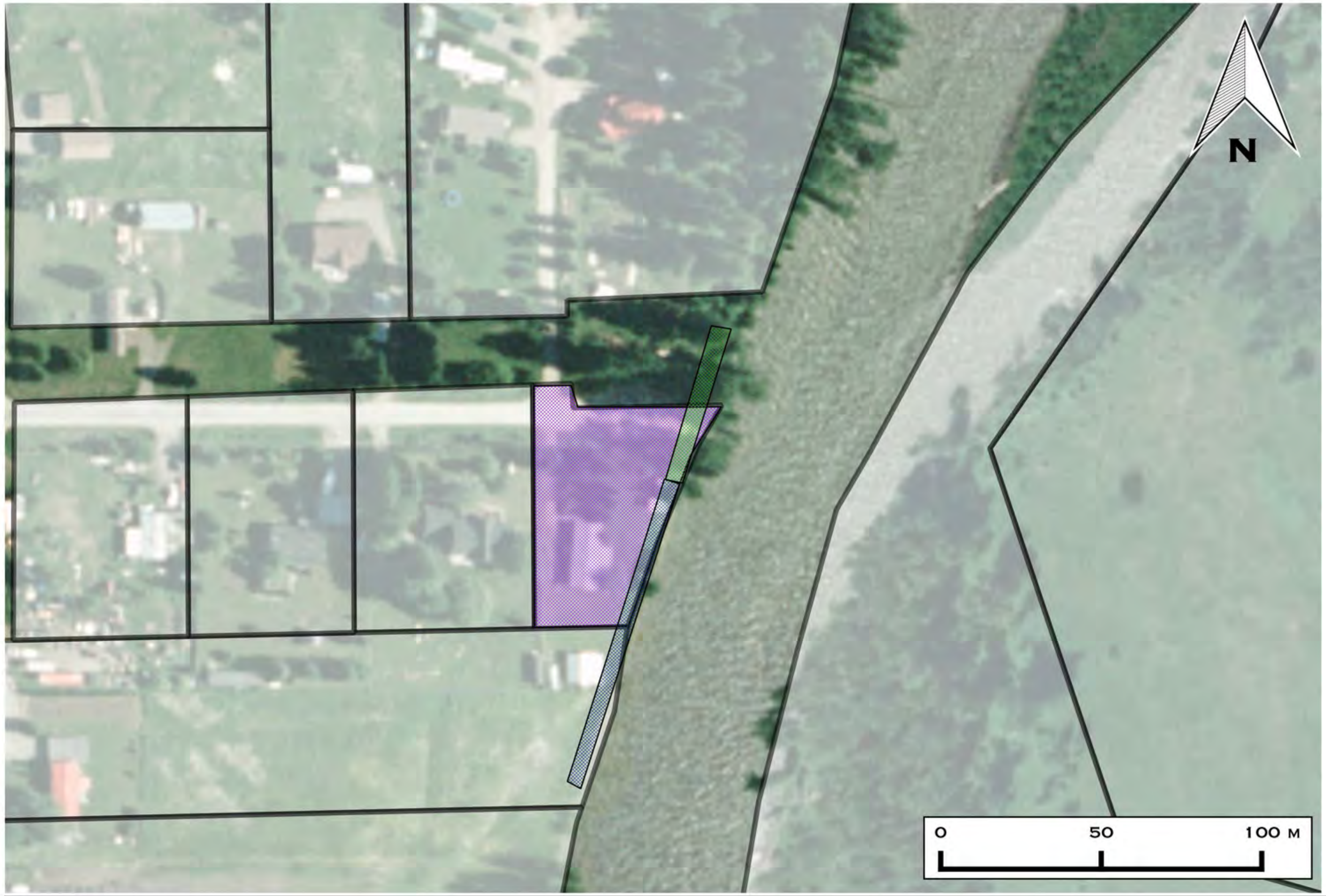
Elk River near Mt. McLean Street Flood mitigation and erosion protection concept designs

- Bank treatment location
- Subject property
- Private lands



Concept Notes:
1) Install riprap toe to protect the right downstream bank from erosion.
2) Consider tiered bank to increase flood capacity and provide vegetated floodplain bench.
3) Install rock spurs off the toe of the riprap bank move the thalweg towards the center of the channel away from the right downstream bank.
4) Vegetate the top of the rock platform with willow to provide fish and wildlife benefits.
5) Attempt to maintain as much of the existing vegetation as is possible.

Photo 1: Upstream view of bank erosion on right downstream bank (left side of photo).

Photo 2: Downstream of existing riparian vegetation within the site.

Clients:
Regional District of East Kootenay
Elk River Alliance

Design Consultants:
Lotic Environmental
Specialists in Freshwater Ecosystems

GCS: North American 1983

Source: 2011 Orthos Geobase

Date: 2016-05-24

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Elk River at Vanlerberg Road Flood mitigation and erosion protection concept designs

- Bank treatment location - Rip rap toe and brush mattress
- Bank treatment location - Vegetated rip rap
- Subject property
- Private Lands

Photo 1: Upstream view of eroding bank and remaining riparian vegetation.

Photo 2: Downstream view of existing berm constructed post-2013.

Concept Notes:

1) Construct tiered bank on left downstream bank. Install rip rap armouring along the lower section of the bank. Construct a flood bench above this and vegetate. Follow up with a sloped bank that may be rock armouring with a soil/vegetation cover.
2) Project footprint should extend upstream and tie into CPR rip rap work.
3) The vegetation will provide riparian benefits to fish and wildlife, and provide bank stability.
4) Consider adding spurs to direct flow towards the center channel, away from the toe of the rip rap and vegetated area.
5) Ensure the design minimizes downstream impacts on the highway.
6) Ensure that the works maintain the existing cottonwood stand along river corridor.

Clients:

Regional District of East Kootenay

Elk River Alliance

Design Consultants:

Lotic Environmental

Specialists in Freshwater Ecosystems

GCS: North American 1983

Source: 2011 Orthos Geobase

Date: 2016-03-16

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Elk River at Hill Road Flood mitigation and erosion protection concept designs

Bank treatment location

Subject property

Private lands

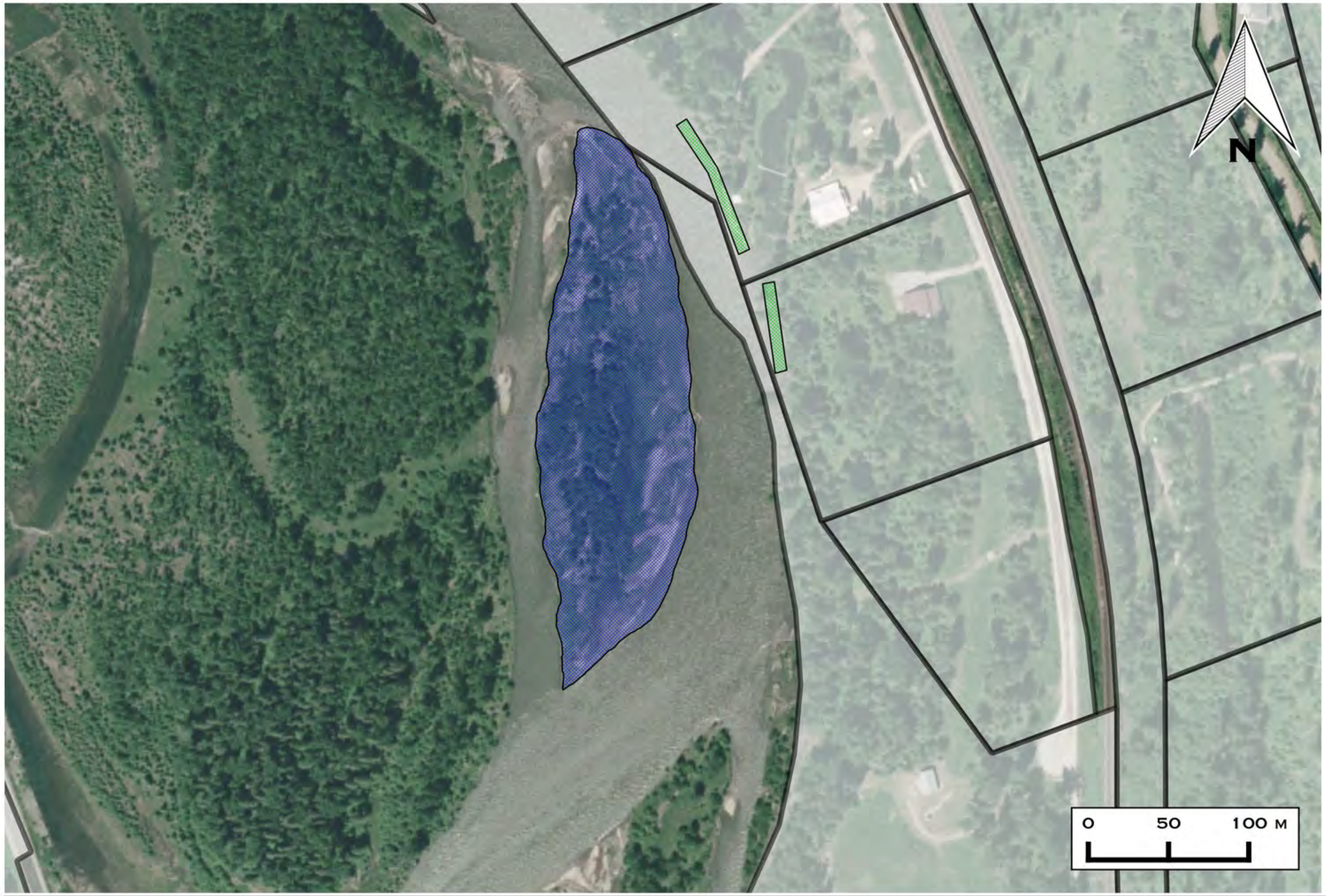


Photo 1: Downstream view of existing rip rap work.

Photo 2: Cross-channel view of subject gravel bar on left bank.

Concept Notes:

1) Install additional LWD jams to enhance existing work already done at the site.
2) Consider rock spurs.
3) Avoid LWD and/or vegetation removal on opposite side of the Elk River (i.e., west side).

Clients:

Regional District of East Kootenay

Elk River Alliance

Design Consultants:

Lotic Environmental

Specialists in Freshwater Ecosystems

GCS: North American 1983

Source: 2011 Orthos Geobase

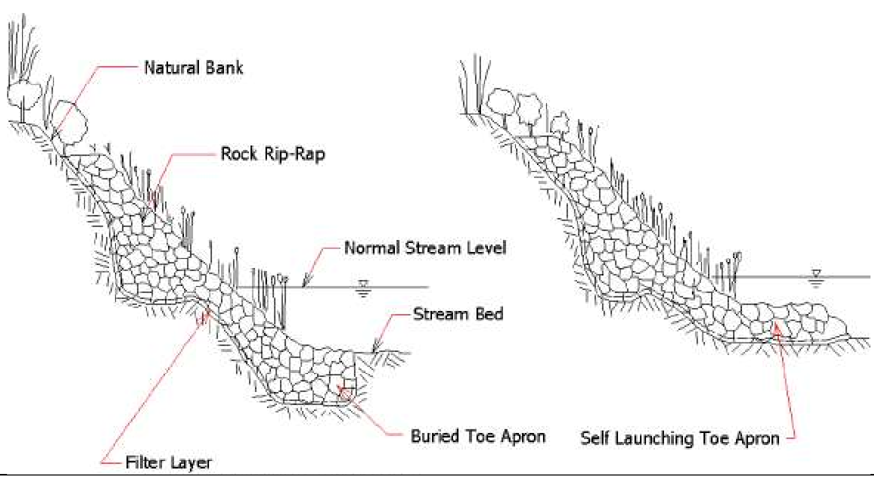
Date: 2016-03-16

1:5,000

Elk River at Thompson Road Flood Mitigation and Erosion Protection Concept Designs

- Bank treatment locations
- Subject gravel bar
- Private lands

Appendix 2. Typical drawings and details of treatment options (McPherson and Robinson 2013)

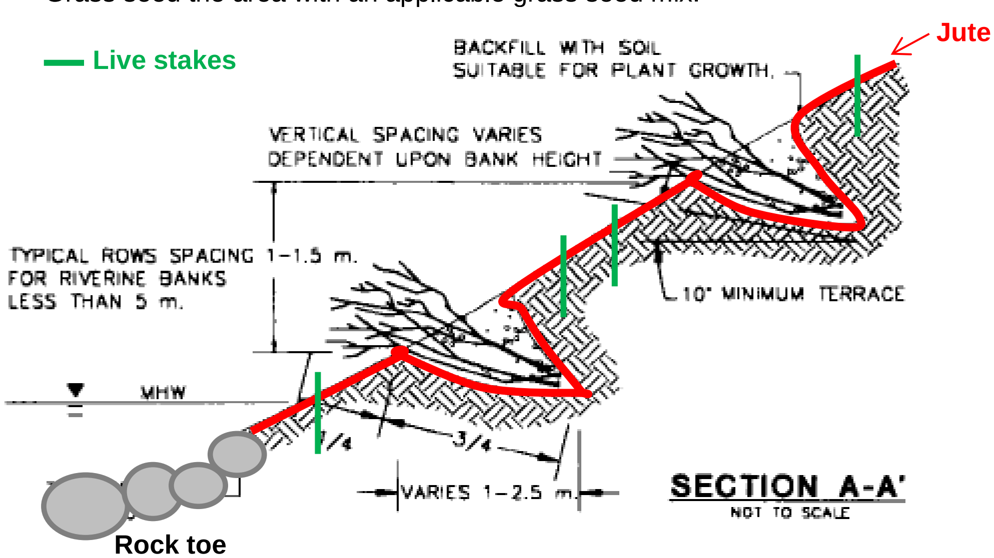
Rock toe	
Benefits	Rock toe (or rip rap) is a layer of large angular rock placed at the toe of the bank to limit erosion. When installed correctly, it is an effective technique for addressing erosion concerns, but has been criticized for impacts to fish habitat and riparian vegetation, and negative aesthetic values. Where feasible, a hybrid approach of rock, combined with natural vegetation and wood along the bank will be planned for. This will increase the stability of the slope and provide habitat for fish and wildlife species.
Design	• The Toe Zone is the portion of the bank normally inundated, located between the bankfull high water (bfh) and low water levels. Typically, only the toe zone requires rock armouring and the remainder of the slope can either be fully armoured with ripraip or may be treated with a bioengineering technique such as a vegetated geogrid of planting. • Rock armouring is constructed so that the final slope is at least 2:1 ratio. Where possible, a 3:1 ratio is preferred as it is more stable. • Areas with low eroding banks this may simply require lining the bank with a minimal amount of large rock (e.g., within 1 metre of the existing toe). • In areas with higher over-steepened eroding banks it may be necessary to advance the rock toe into the channel to restore a more stable slope. This technique typically requires keying in the toe to the channel or installing a self-launching tow apron. Other stabilization efforts such as revegetation may then occur upslope. This more intensive approach would require a greater level of site specific planning to be completed prior to implementation. • The following are some preliminary details that are to be considered: ▪ Applicability of installing a layer of granular material on the exposed slope. ▪ Suitable size of rock that will not be moved by design flood flows. ▪ Source of rock so as to ensure it is clean and free of silt and that it is not sourced from other parts of the lake where it is serving as habitat. ▪ Placement of smaller rock to fill the voids and help lock the rocks together. ▪ Placement of wood structure and/or topsoil and vegetation to provide added stability, habitat, and improve aesthetics. ▪ Consider a vegetated riprap design where possible to enhance habitat value. 
References	Fisheries and Oceans Canada 2013, Fisheries and Oceans Canada 2011, Slaney and Zaldokas 1997, Quek 2013.

<table>
<tr><th colspan="2">Vegetated Geogrid</th></tr>
<tr><td>Benefits</td><td>

Addresses steep slope erosion issues.
Uses plants with natural materials (logs, live stakes, live brush bundles etc.) to provide a natural appearance and fish and wildlife habitat.
Vegetated geogrids provide immediate erosion protection and are useful where steep banks cannot be sloped back.

</td></tr>
<tr><td>Design</td><td>
Construct a vegetated geogrid, which is repeated layering of live cuttings, soil and jute matting as follows:

First armour the toe of the slope with large rock (see Rock Armouring Design). This is to provide immediate protection to portion of the slope that will be affected by wave action over much of the year.
Collect cuttings that are at least 1 m in length and approximately 1-2 cm in diameter (See Revegetation Design for plant species and timing details).
Shape the bank, by pulling the slope back to a more stable angle (1:1.5), or by allowing this to occur naturally over time, and create successive horizontal benches parallel to the lake where cuttings will be set in. Benches are to be spaced 1 m apart, with the first located at 0.25 m above the mean annual wetted shoreline.
Once the benches are created, place a layer of geotextile or jute material down. Then place down cuttings in a criss-cross fashion. No more than 0.2 m of the cuttings are to be exposed.
Cover the cuttings in soil and extend the topsoil between the layers. The topsoil should greater than 0.1 m thick to support grass establishment.
Extend the jute over the slope up to the next brush layer bench. The jute is intended to prevent minor surface erosion until grasses establish.
Use live stakes to hold down the jute and to provide vegetation cover.
Grass seed the area with an applicable grass seed mix.



Cross-sectional view of vegetated geogrid with rock toe (modified from Slaney and Zaldokas 1997).
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<tr><td>References</td><td>Slaney and Zaldokas 1997</td></tr>
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<tr><th colspan="2">Revegetation</th></tr>
<tr><td>Benefits</td><td>

Promotes natural vegetation to become re-established. A naturally vegetated bank prevents contaminants or excess nutrients from entering the water; prevents erosion caused by rain, wind, wave and ice action; and supplies food, shade and cover for fish in the shallow water. When damage occurs, revegeted banks have the potential to re-establish themselves often without assistance.
Live cuttings are an inexpensive method of improving bank stability and vegetative cover to a stream.
The roots of these plants will extend into the soil and provide support to the bank.
Trees and shrubs immediately adjacent to a stream are also beneficial as they provide shade and cover for fish, and allochthonous organic matter that can be utilized by aquatic invertebrates and habitat for terrestrial invertebrates that may enter the stream as a food source for fish.

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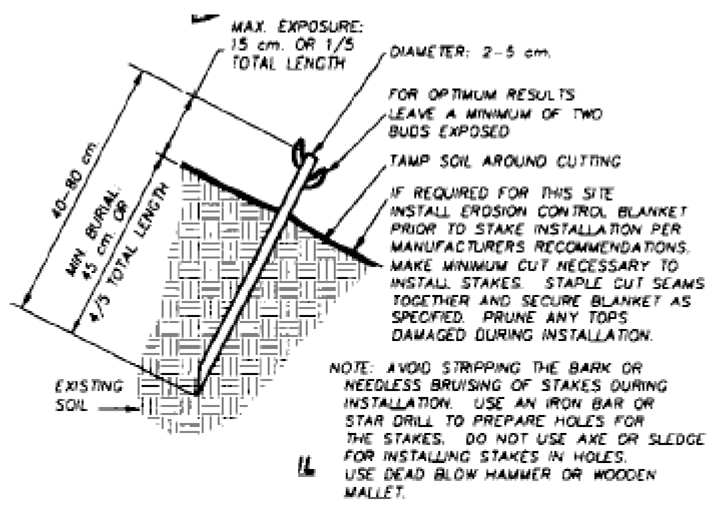
<tr><td>Design</td><td>

Prepare the site by shaping the bank where necessary, by pulling the slope back to a more stable angle (1.5:1), or by allowing this to occur naturally over time, and covering the area to be vegetated with top soil.
Select plant species according to the micro-site that they will be planted into. Neighbouring naturally vegetated slopes should be used as a guide. Use rooted stock or live cuttings or a combination of both.
Rooted stock involves planting native species that are common to the area.
Plant in the spring or fall when plants are dormant and weather is cool and moist. Densities are to be 1.6 shrub stems/m^2 (0.8 m spacing), and 0.1 tree stems/m^2 (3 m spacing).
Live cuttings consist of woody plant material often taken from first or second year growth of species that will root from cuttings. Typical native species used for live cuttings are willow and red-osier dogwood, however, these plants require moist, well-drained banks. Dogwood is also to be treated with a rooting hormone. Cuttings may be installed as live stakes or whips. Cuttings are typically planted in late autumn after buds have set or in spring after snowmelt when moisture stress is low. A standard planting density is 1 m by 1 m spacing in a grid pattern.



Live cutting installation (Slaney and Zaldokas 1997)
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<tr><td>References</td><td>Slaney and Zaldokas 1997</td></tr>
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