ANALYSIS OF SKEENA RIVER TRIBUTARIES DOWNSTREAM FROM THE PROPOSED ENBRIDGE PIPELINE

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By Jack A. Stanford[1], and Diane C. Whited[1]

[1]Flathead Lake Biological Station, The University of Montana, Polson, Montana 59860 USA (Jack.Stanford@umontana.edu)

INTRODUCTION

We were contracted by the Northwest Institute for Bioregional Research (Smithers, BC) to use our existing databases to produce a series of maps describing the geomorphology of tributaries of the Skeena River, British Columbia that will be crossed by the proposed Enbridge pipeline. The objective was to develop and map metrics that delineate the areas of the Skeena River and its tributaries most vulnerable to potential pipeline spills associated with the proposed Enbridge corridor to Kitimat, BC.

The issue of concern is that bitumen, condensate or other petrochemicals could enter the tributaries at or near pipeline crossings should there be a pipeline breach (Swift et al. 2011). In the case of a spill that enters a river channel, petrochemicals will be transported downstream and contaminate river water and aquatic habitat in relation to: a) the slope of the channel (which determines water velocity), b) the volume of water in the channel, c) the geomorphology of the river and its alluvial aquifers and d) the amount and characteristics of the petrochemicals. In this analysis, we examined the geomorphic character of the river channels downstream of crossings. Our analysis was based on the likely scenario that a spill would result in petrochemicals being carried downstream and distributed in the channels in relation to the geomorphology.

Unless completely constrained by bedrock, most rivers are alluvial, meaning that porous bed-sediments underlie the flowing water and compose the river flood plains. High gradient headwater streams or river segments in bedrock constrained canyons may be expected to transport petrochemicals very quickly downstream, whereas aggraded flood plains retard water velocity and increase contact with the bed-sediments as well as the alluvial aquifers contained within the bed-sediments of the channel and its flood plains (see Figure 1). If the river is flooding during a spill, petrochemicals may spread expansively across flood plains and directly contaminate riparian vegetation. In any spill scenario, some portion of the river channel and the alluvial aquifers influenced by influx of surface water will be contaminated.

The key point here is that contamination from petrochemical spills in alluvial rivers like the Skeena will occur in 3 spatial dimensions: upstream to downstream, laterally across the channel and its flood plains, and vertically into the alluvial aquifer (Figure 1). The fourth dimension is time; if the spill is of short duration and small volume, the contamination attenuates more rapidly than if the spill is catastrophic and of long duration. Exchange of water and materials in the water in these 4 dimensions is precisely what makes floodplain rivers like the Skeena great salmon producers. Habitat and productivity maximizes in the expansive floodplain reaches, which is not to say that constrained reaches and small tributary streams are not important in overall productivity of the river. Although a spill of any magnitude will be toxic regardless of channel morphology for some distance downstream from the spill, the aggraded floodplain reaches are the most vulnerable because these are the areas where the contaminants will attenuate by entraining in the floodplain riparian vegetation, the bed sediments and the alluvial aquifers. The extent of longitudinal, lateral and vertical contamination depends on volume and duration of the spill and the characteristics, such as specific gravity, water solubility, and volatility, of the petrochemicals. But it is a safe bet that a spill of any magnitude will contaminate some portion of the river in all three dimensions over some time period. Hence, we equated vulnerability with floodplain area in this analysis, recognizing, of course, that the most vulnerable reaches are those closest to the spill, regardless of geomorphology.

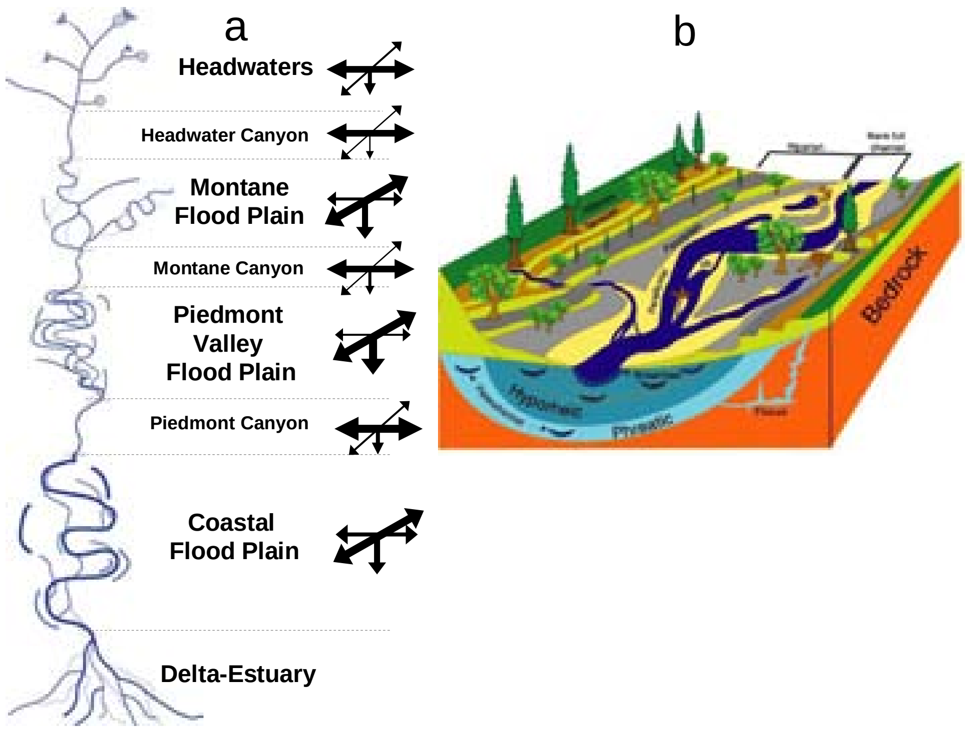

Figure 1. Idealized view of (a) the longitudinal distribution of flood plains and canyons ("beads on a string") within a river ecosystem from headwaters to the ocean and (b) the 3-D structure of alluvial the flood plains (beads), emphasizing dynamic longitudinal, lateral and vertical dimensions and recruitment of wood debris. The groups of arrows in (a) indicate the expected strength of ground- and surfacewater exchange (vertical), channel and flood plain (lateral) interactions and upstream to downstream or longitudinal (horizontal) connectivity in the context of (b). The floodplain landscape contains a suite of structures produced by the legacy of cut and fill alluviation as influenced by position within the natural-cultural setting of the catchment. The hyporheic zone is defined by penetration of river water into the alluvium and may mix with phreatic ground water from hillslope or other aquifers not directly recharged by the river. Alluvial aquifers usually have complex bed sediments with interstitial zones of preferential groundwater flow (paleochannels). From Stanford et al. (2005).

We produced physical metrics that were summarized in 4 maps: a map of the Skeena River catchment showing the proposed pipeline corridor; maps of the Babine, Morice-Bulkley and Clore- Zymoetz corridors. These are the river corridors most likely to be directly affected by a pipeline breach. However, a catastrophic spill at or near any of the crossing points could extend through the entire Skeena River system and its estuary. The maps highlight the locations and areas of flood plains where contamination from spills will likely be most pervasive because flood plains and their alluvial aquifers are where river water and materials entrained in the river water is circulated most expansively. Furthermore, these aquatic and riparian habitats determine river biodiversity and productivity and are crucial to successful salmon spawning and rearing.

METHODS

Data sources

The majority of the data used in the analysis were compiled by the Flathead Lake Biological Station within the Riverscape Analysis Project (RAP). RAP data and analysis can be viewed at http://rap.ntsg.umt.edu. See Luck et al. (2010) for a detailed description of the database.

We used supplemental data from GeoBase Canada (http://www.geobase.ca/geobase/en/index.html) and Johanna Pfalz at Eclipse GIS to provide detailed base layers for map generation. In addition we downloaded and compiled a 25-m resolution Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM from the National Aeronautics and Space Administration *(*NASA*)* Jet Propulsion Laboratory (http://asterweb.jpl.nasa.gov/content/03_data/01_Data_Products/release_DEM_relative.htm) to improve our floodplain delineation within the Skeena catchment.

Floodplain delineation

Flood plains were identified from the Aster 25 m digital elevation model (DEM) using a modified Arc/INFO and Arc Macro Language (AML)/C code program developed by Scott Basset at the University of Nevada, Reno. DEM-derived stream order and elevation information was used to identify flood plains and estimate floodplain areal extent based on lateral distances and maximum elevation thresholds perpendicular to and along the DEM-derived river flow path. For each stream order, buffer distances and maximum elevation thresholds were established to define the corresponding floodplain spatial extent. Buffer distances and maximum elevation thresholds (Table 1) were increased for larger stream order categories to account for larger floodplain areas consistent with larger rivers.

Stream elevation profiles

We resampled the ASTER 25 m DEM to a coarser 100 m DEM to minimize the elevation variability inherent in the ASTER DEM. We generated stream elevation profiles from this resampled DEM to represent the potential flow paths of petrochemicals and highlighted stream reaches with flood plains and lakes as zones of retention as described above. Although the resampling smoothed out some of the variability within the DEM, some elevation variability remained within the profiles; this variability is expressed as “roughness” of the profiles. However, the steep versus aggraded (i.e., flat) reaches of the stream profiles were clearly evident.

Table 1. Buffers around stream channels were used to set the maximum extent of floodplains during extraction from DEMs.

Stream Order	Elevation (m)	Buffer Distance (m)
1	1	300
2	1	600
3	1.5	1200
4	2	1500
5	2	1750
6	3	2000
>6	4	2500

RESULTS AND DISCUSSION

The four maps that we produced are appended to this report, along with a summary table comparing the areas of flood plains in the primary tributaries. Maps should be printed in large format and in color to be most useful.

The map of the entire Skeena catchment provides perspective on the distribution of floodplain reaches throughout the system. In general, the headwaters of the system have substantial areas that are low gradient wetlands and small flood plains. The river is very constrained in canyons above and below the Babine confluence, except for lower reaches of the Sustut. The mainstem is mainly confined in canyon reaches until below the Zymoetz confluence near Terrace, BC. From there to the expansive estuary, the mainstem river has broad flood plains with complex channel networks.

The Sutherland-Babine, Morice-Bulkley and Clore-Zymoetz corridors were mapped in detail because the pipeline crosses them in the mountainous headwater areas and therefore the points of direct spills into the system would be distributed from these rivers and through their associated flood plains (Table 2). Note that the pipeline is proposed very close to the Gosnell Creek/Morice River for over 60 km. Note also that the Gosnell Creek/Morice River is an expansive floodplain river throughout most of its course and therefore is very vulnerable to spills that could flow into the river anywhere along this 60 km reach. A spill on the Sutherland River could contaminate its floodplain reaches and deliver petrochemicals into Babine Lake. A spill along the tributaries to Helene and Taltapin Lake would greatly impact these lakes, as well as Pinkut Creek (a large sockeye spawning tributary) that drains directly into Babine Lake. A spill on the high gradient Clore system could rapidly move into the flood plains of the Zymoetz and on into the expansive flood plains of the mainstem Skeena.

Table 2. Comparison of floodplain area and normalized floodplain area per river km for the three potentially affected river reaches.

Potentially affected River Reaches	Floodplain Area (Ha)	Normalized Floodplain area (Ha) per river km
Babine Corridor		
Sutherland River to Babine Lake	1589.08	34.73
Above Helene Lake to Babine Lake	263.32	13.19
Above Taltapin Lake to Babine Lake	514.29	12.48
Below Babine Lake to Confluence with Skeena	1561.25	16.10
Bulkley Corridor		
Buck Creek Above Confluence	483.56	20.49
Bulkley River Below Morice River Confluence	8244.98	50.35
Maxan Creek/Bulkley River Above Morice River Confluence	4101.30	46.06
Gosnell Creek/Morice River Above Bulkley River Confluence	6783.94	65.66
Clore/Zymoetz Corridor		
Clore River Above Zymoetz River Confluence	416.14	9.52
Zymoetz River Below Clore River Confluence	343.73	9.46

Compared with adjacent river systems, the Skeena has a fairly large ratio of flood plains to total catchment area (Figure 2). The Nass and Fraser rivers are very constrained by narrow canyons throughout the catchments. The Stikine has very expansive flood plains in its lower reach; and, even though it also has dramatic canyons, the ratio is quite high (Figure 2). Nonetheless, all four river systems have very high physical complexity values (Table 3). The intent of this comparison is simply to underscore the point that the Skeena's abundant and expansive flood plains operate with the on-channel lakes, notably Babine Lake, to provide a complex array of habitats that drive system biodiversity and productivity, especially for salmon, steelhead, and resident fishes and their food webs.

Table 3. Summary of RAP metrics that describe physical complexity of the Skeena River in comparison to adjacent river systems. The term, nodes, refers to channel junctions or places where channels separate or converge.

	Number of Main Channel Nodes	Nodes per FP river km	Nodes per river km	Number of Tributary Nodes	Tributary Nodes per river km
Skeena	855	1.283	0.096	640	0.072
Fraser	1283	1.275	0.031	2791	0.067
Nass	502	1.251	0.146	262	0.076
Stikine	2224	1.791	0.258	663	0.077

Petrochemical spills are problematic for any river system but the impact may be expected to intensify if the rivers are broadly three-dimensional, as is the Skeena. The tributaries crossed by the proposed pipeline are especially vulnerable in this regard. All are well known to function as primary spawning and rearing areas for Skeena fisheries.

Indeed, within the Babine catchment, five stream reaches and lake bodies are vulnerable and would be affected by a pipeline spill or rupture. The Babine drainage is the largest tributary to Skeena River and supports diverse stocks of chinook, pink, sockeye, coho, and steelhead salmon. The freshwater fish community is composed of rainbow and cutthroat trout, Dolly Varden, bull trout, and lake char, kokanee, lake and mountain whitefish, lamprey, burbot, sculpins, suckers, and shiners (Gottesfeld and Rabnett 2008). A potential spill from Kilometer Post (KP) 851 to 869 would flow into the Sutherland River and from KP 881 to 912.5 into the Pinkut Creek system.

The Sutherland River supports sockeye salmon and kokanee spawning, as well as spawning, rearing, and holding habitat for coho, steelhead, and rainbow trout. Sutherland River rainbow trout are a singular race of large late-maturing trout, contributing 66% of the rainbow trout found in Babine Lake (Bustard 1990). Pinkut Creek system supports sockeye, coho, and pink salmon spawning, as well as burbot, kokanee, lake trout, lake whitefish, and rainbow trout spawning and rearing. Pinkut Creek is the second most productive salmon tributary to the Babine basin, and over the last 20 years, along with the adjacent spawning channel, has seen an annual average return of 211,165 sockeye spawners (Gottesfeld and Rabnett 2008).

Fish values in the Bulkley basin are rated very high due to anadromous coho, sockeye, pink, and chinook salmon, as well as steelhead and Pacific lamprey. Dolly Varden, rainbow trout, and mountain whitefish are present in most fish bearing waters, and bull trout, lake trout, burbot, and a coarse fish community utilize various habitat types in the Bulkley upstream of Morice as well as the Morice system (Gottesfeld and Rabnett 2008). The proposed pipeline crosses through 119 km of the Bulkley drainage, which includes 34 km paralleling the gravel bed Reach 2 of Morice River, which is of high fisheries value (Bustard and Schell 2002).

The pipeline is proposed to cross 12 km within the Zymoetz (Copper) River upstream of the Clore Canyon. This generally high elevation area supports bull trout, Dolly Varden, and rainbow trout (Bustard 1996). Downstream of Clore Canyon, the Copper supports coho, chinook, sockeye, pink, chum, steelhead, and a suite of freshwater residents (Gottesfeld and Rabnett 2008).

CONCLUSIONS

The portion of the Skeena catchment along the proposed pipeline route that was examined in this analysis has an abundance of complex, productive floodplain habitat that is very important for the persistence and production of resident and anadromous fishes. Unfortunately, the characteristics of floodplain habitat that make it productive for fisheries also makes it highly susceptible to impacts from a pipeline breach. Therefore, our conclusions are that a pipeline breach could have severely negative impacts on resident and anadromous fishes.

Additionally, all the anadromous fish in the Babine, Bulkley, and Zymoetz systems have already been impacted by 130 years of relatively high exploitation rates due to coastal mixedstock fisheries. As well, all anadromous and freshwater resident fish have had varying degrees of habitat modification due to development activities, including linear perturbations such as railroad, highways, transmission and pipeline corridors, agriculture, urbanization, forestry, and mining, with particular impacts to the productive floodplain habitats. An oil spill or rupture from the proposed pipeline would have significant environmental effects within and beyond the Skeena River system.

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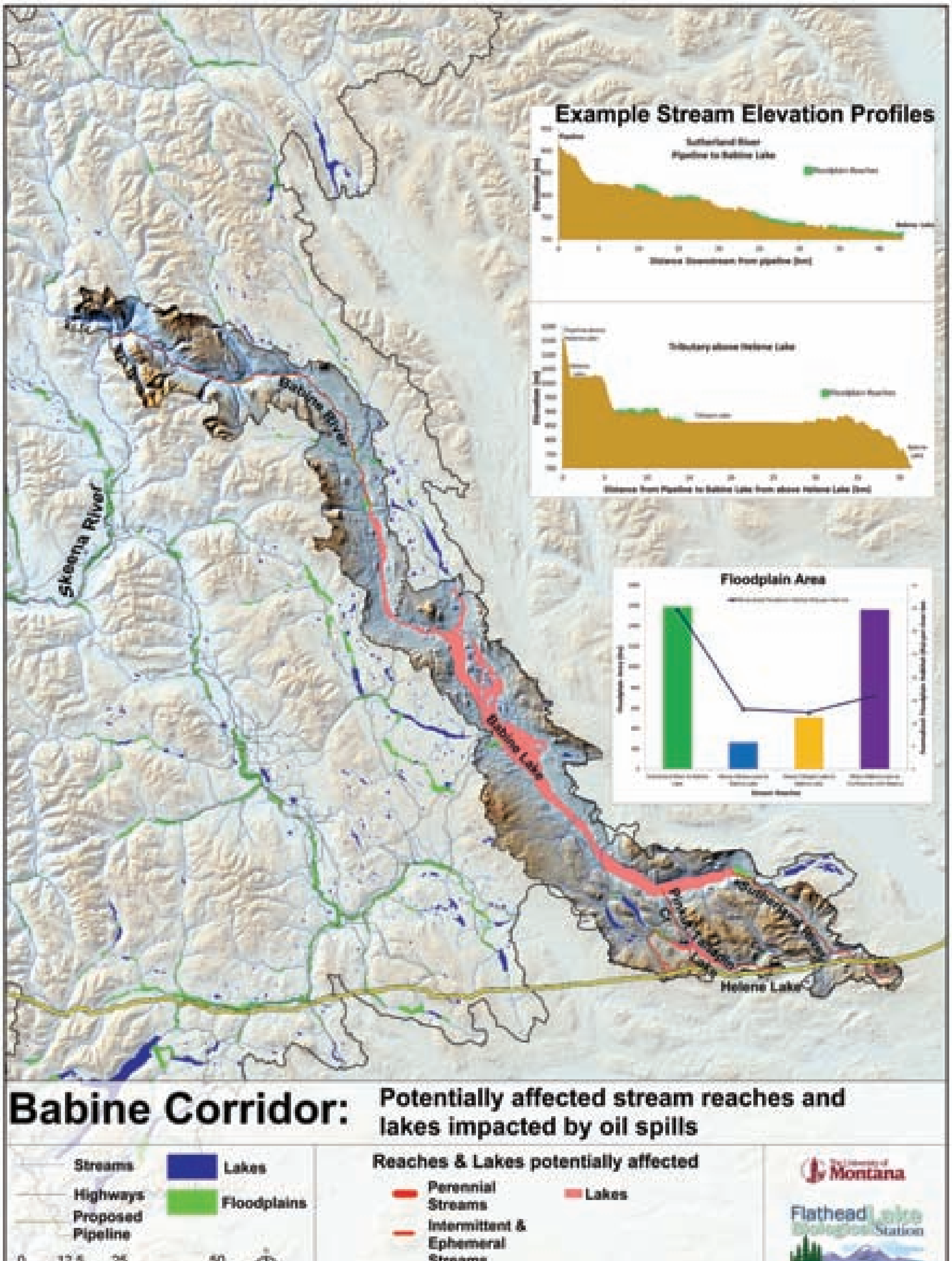
Example Stream Elevation Profiles
Floodplain Area
Skeena River
Babine River
Babine Lake
Helene Lake
Babine Corridor:
Potentially affected stream reaches and lakes impacted by oil spills
Streams
Highways
Proposed Pipeline
Lakes
Floodplains
Reaches & Lakes potentially affected
Perennial Streams
Intermittent & Ephemeral Streams
Lakes
0 12.5 25 50 Km
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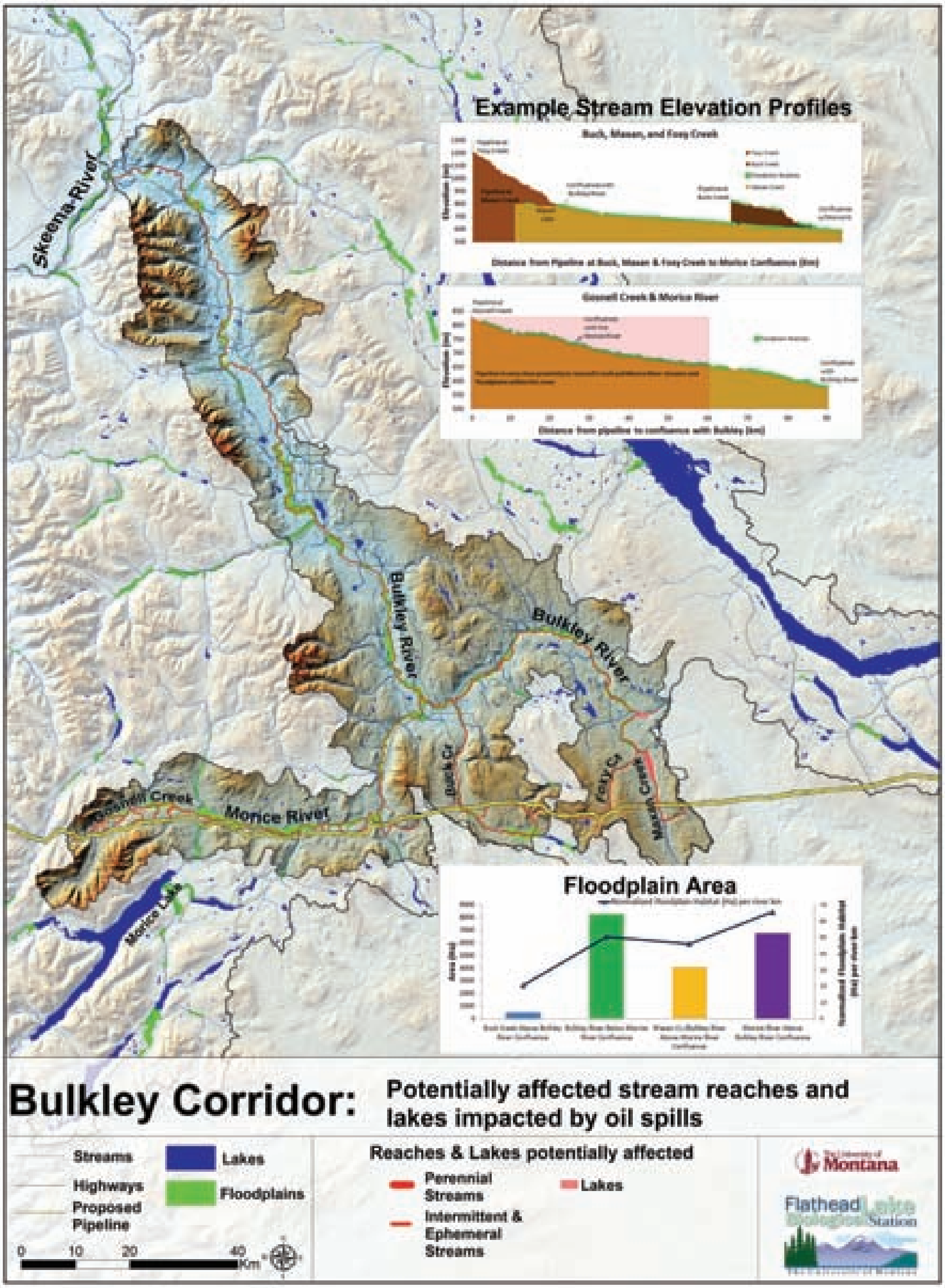
Example Stream Elevation Profiles
Gosnell Creek & Morice River
Distance from pipeline to confluence with Bulkley (km)
Floodplain Area
Skeena River
Bulkley River
Bulkley River
Gosnell Creek
Morice River
Buck Cr
Foxy Cr
Maxan Creek
Morice Lake
Bulkley Corridor:
Potentially affected stream reaches and lakes impacted by oil spills
Streams
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Lakes
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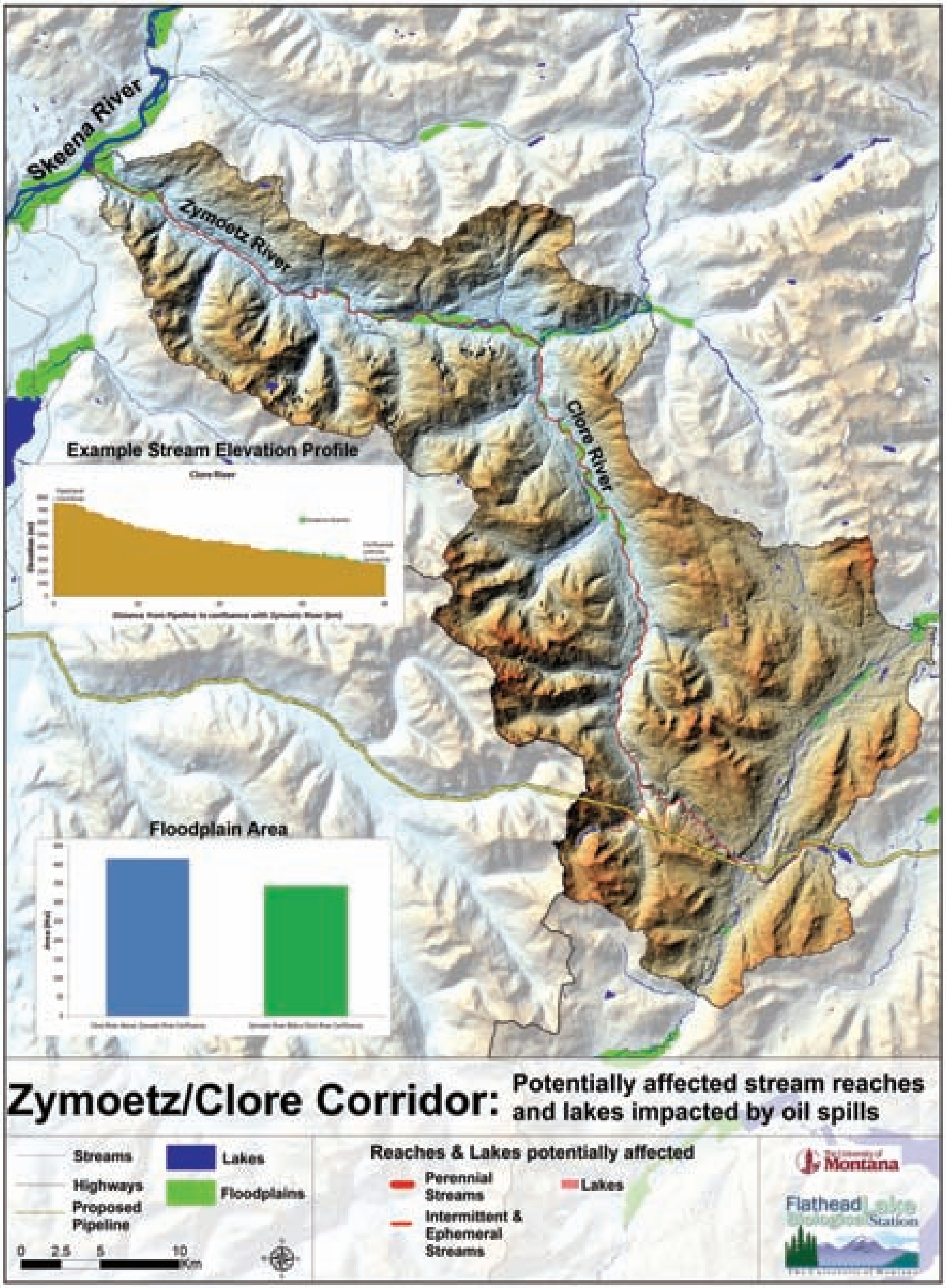
Skeena River
Zymoetz River
Clore River
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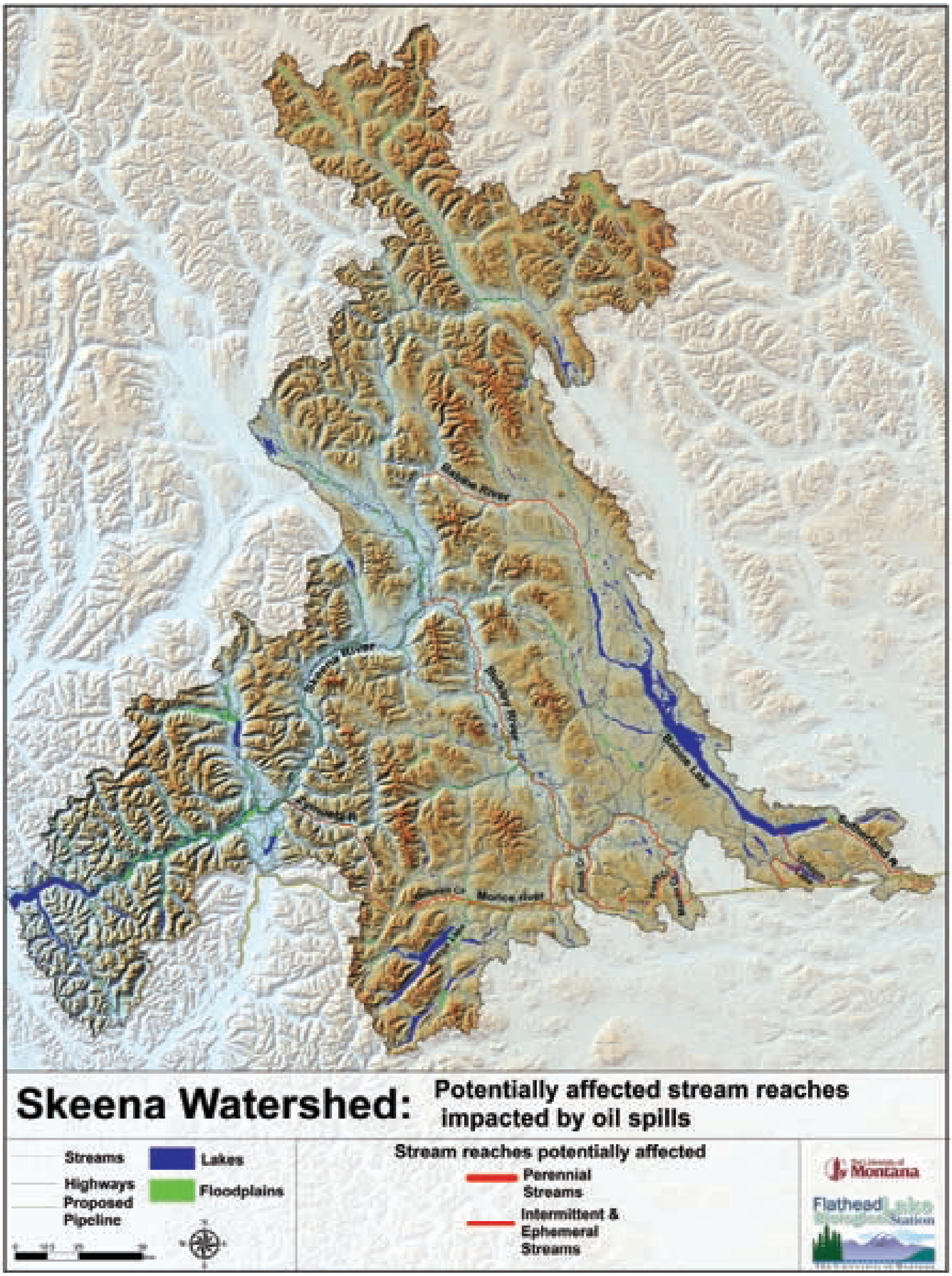
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