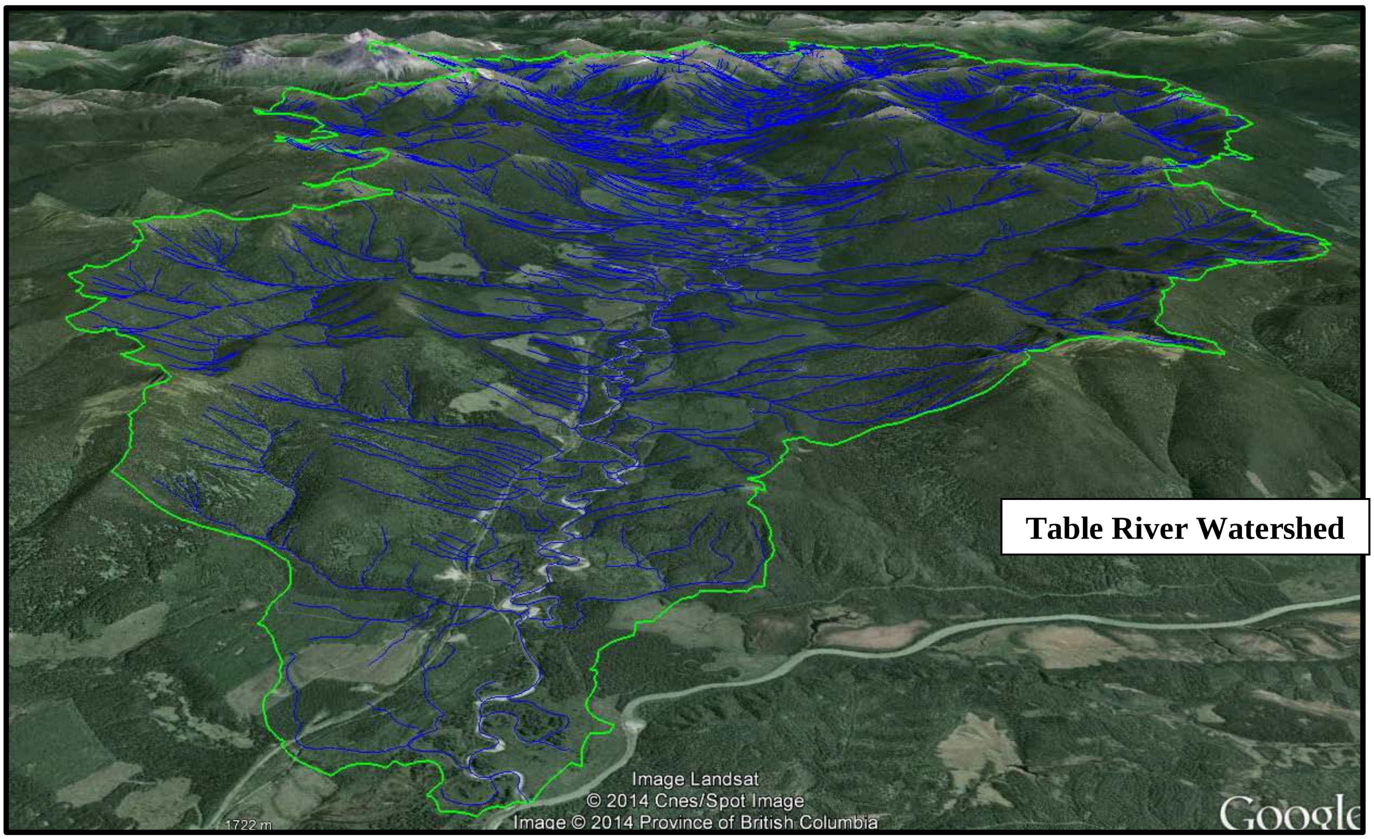
Assessment and Assignment of Sensitivity Ratings to Sub-Basins of the Table Watershed in the Parsnip Drainage – Omineca Region

Contract Number: GS15823011



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June, 2014

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1.0 INTRODUCTION

The evaluation and designation of Fisheries Sensitive Watersheds (FSWs) is a high government priority. The Table watershed is a priority watershed in the East Parsnip area of the Williston watershed. It is also identified in the provincial GAR Implementation Plan and is the next area of focus identified in the Region 7 2014/15 GAR Implementation Plan. Confirmation of watershed sensitivity is necessary to meet specific FRPA Government Actions Regulation and OGAA Environmental Protection and Management Regulation tests to realize government's conservation business priorities. The need for this information recognizes the proposed Enbridge pipeline route and other related activity through this watershed.

The objectives of this project include the following:

1) For the Table watershed, and using the 1:20,000 Freshwater Atlas, identify and delineate sub-basins of appropriate size for the application of FSW objectives

2) For each of the sub-basins identified, describe the physical conditions and inherent sensitivities using the methodology as developed for and described in the document 'Methodology: Stuart Takla Watershed Fisheries Sensitive Watershed Selection Process (prepared by P. Beaudry & Associates Ltd., November 30, 2011)

3) For each of the sub-basins assess and calculate the resultant Sensitivity Rating

4) Summarize the results of this work in a Sensitivity Indicator Table.

2.0 GENERAL DESCRIPTION OF THE TABLE RIVER WATERSHED

The Table River watershed is located in the Missinchinka Range of the Rocky Mountains, approximately 93 km north-northeast of Prince George and 70 km southeast of Mackenzie (Figure 1). The watershed is 504 km^2 in size and is dominated by the ESSFwk2 and SBSvk biogeoclimatic subzones. The elevation of the watershed ranges between 728 m and 2471m and has a stream density of 2.62 km/km^2. The watershed is mountainous with some steep slopes. The floodplain is a wide alluvial, glacial outwash type with a meandering and sometimes braided river system. The width of the floodplain, in the lower watershed, varies between 0.5 and 1.5 km. About 15% of the watershed has slopes less than 10% and 9% of the watershed has slopes greater than 60%.

The Table River watershed has been impacted by both timber harvest and linear development in the form of the BCR railway and road construction (Blackman 1998). Up to 30% of the stream length has been logged up to or in the riparian zone (Mathias et al. 1998). Blackman (1995) has noted that floodplain and streambank logging in the Table River watershed may have increased channel widening, water temperature and reduced inputs of large woody debris (LWD). Heavy silt loads and slide activities, caused by railway construction during the early 1980's, severely impacted fish production in the system. The Peace-Williston Fish and Wildlife Compensation Program (PWFWCP) has conducted fish habitat assessments and stream surveys throughout the Table River mainstem and tributaries, and have consequently identified numerous areas of concern, including recommendations for future assessments or restoration work in these areas.

Several features have been identified throughout the Table River watershed which impact fish species distribution. Based on existing literature there are three specific areas of difficult passage on the Table River mainstem. At 37.6 km upstream from the mouth, a 2.0 m high vertical water fall exists. BB, GR, MW and RB have been documented from the mouth upstream to this falls, however they have not been documented upstream of this area. The second obstruction to fish passage exists at km 42.7 (cascades, 1.5m high falls, and chute) and the third area for difficult passage exists at km 54 (10% gradient change). BT have been documented upstream of all three obstructions with their upper limit of distribution being close to the headwaters of the system (PBA 2000).

Seven sub-basins of the Table River watershed were identified and assessed for their sensitivities to increased peak flows. The entire Table River watershed was also assessed for its sensitivity to increased peak flows. The names of the watersheds reviewed are as follows and are mapped in Figure 2.

1) Table Sub-basin #1
2) Table Sub-basin #2
3) Table Sub-basin #3
4) Table Sub-basin #4
5) Table Sub-basin #5
6) Table Sub-basin #6
7) Table Sub-basin #7
8) Entire Table River Watershed

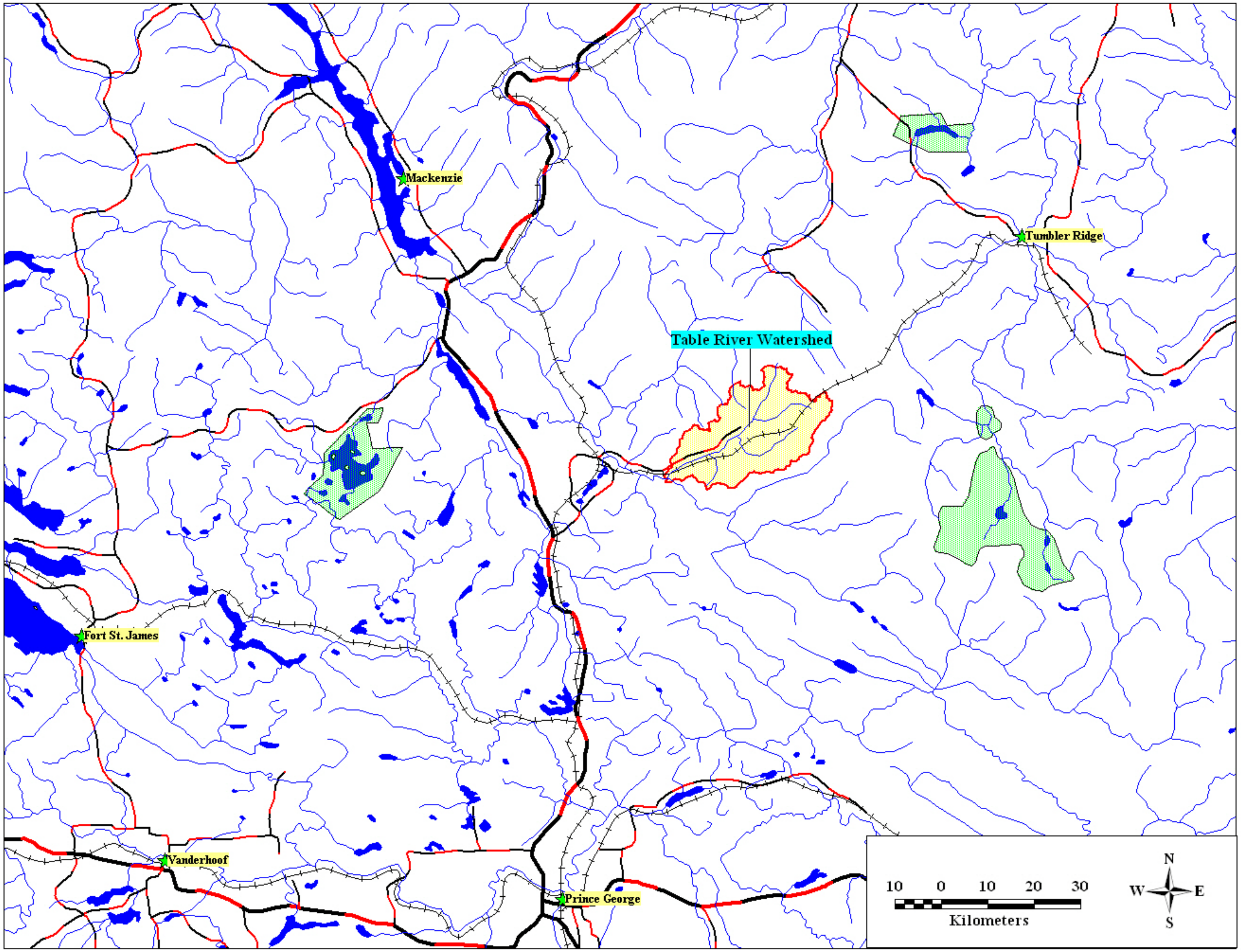

Figure 1. General location of the Table River Watershed

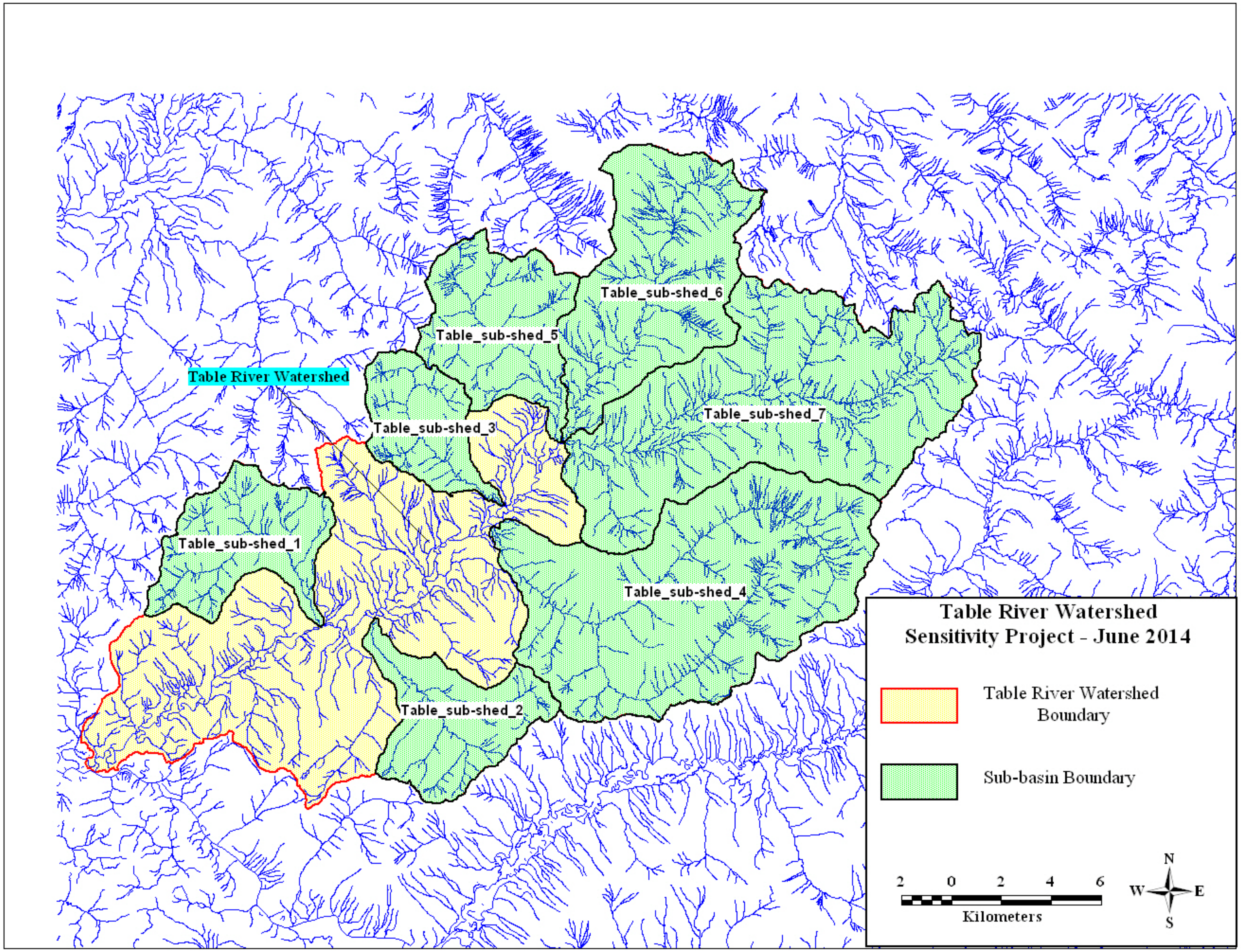

Figure 2. Map of the Table River Watershed and the sub-basins identified for this project.

3.0 RESULTS

3.1 Physical Characteristics of the sub-basins of the Table River Watershed

A summary of the physical characteristics of each of the sub-basins reviewed are provided in Table 1. The assessed sensitivity for each sub-basin to increased peakflows is provided in Table 2. Sections 3.3 to 3.15 provide a short description of the information provided in these tables.

Table 1. Summary Information – Watershed Characteristics

Water-shed Name	Size (km^2)	Domin-ant BEC Zones	Dominant NDT	Elevation Range (m)	Dominant Surficial Geology	Stream Density (km/km^2)	Biggest % of watershed in same elevation band[1]	Distribution of slope gradients within the watershed (% of watershed)			
								<10% slope	10 to 30% slope	30 to 60% slope	>60% slope
Table sub-basin_1	28.5	ESSF	NDT1	790-1676	Medium textured till	2.48	53	6.7	32.6	56.9	3.8
Table sub-basin_2	27.7	ESSF	NDT1	790-1711	Medium textured till	1.96	47	8.3	46.7	42	3
Table sub-basin_3	19.3	ESSF	NDT1	822-1749	Medium textured till	2.46	45	4.5	36.5	52.3	6.7
Table sub-basin_4	99.2	ESSF	NDT1	820-1863	Medium textured till	2.39	46	6	31	53	10
Table sub-basin_5	32.8	ESSF	NDT1	822-1972	Medium textured till	2.42	41	8.3	34.7	46	11
Table sub-basin_6	55.1	ESSF	NDT1	822-2471	Medium textured till	2.80	31	13	28	38	21
Table sub-basin_7	99.8	SBS	NDT2	817-1984	Medium textured till	2.69	33	10	36	38	16
Table Entire basin	504.1	ESSF	NDT1	728-2471	Medium textured till	2.62	33	15	34	42	9

[1] The entire watershed is divided into 300 m elevation bands. The less elevation bands there are and the more area is represented by any given single elevation band, then the greater will likely be the effect of forest harvesting on increased peak flows due to the theoretical concept of "synchronization" (i.e. the melt from the cutblocks is synchronized as much of it comes from the same elevation), and the greater sensitivity it will have.

3.2 Assessed sensitivities of the sub-basins of the Table River Watershed

Table **2**. Rating of "Sensitivity" of Watershed to Increased Peak Flows at the lower reaches

Watershed Name	Rosgen Stream Channel Type	Rosgen Stream Channel Sensitivity Score	Sensitivity score relative to topography	Sensitivity score relative to lateral connectivity	Sensitivity score relative to vertical conductivity	Sensitivity score relative to climate	Sensitivity score relative to flow synchroniza-tion potential	Sensitivity score relative to NDT type	Sensitivity Score	Sensitivity Rating
Table sub-basin_1	C4- Mod unstable/ disturbed	4.5	1	1.1	1	1.1	1.09	1.07	6.33	Very High
Table sub-basin_2	C4- Mod unstable/ disturbed	4.5	1	1.1	1	1.1	1.06	1.07	6.19	Very High
Table sub-basin_3	C4- Stable onto fan	3.8	1.25	1.1	1.05	1.1	1.05	1.07	6.81	Very High
Table sub-basin_4	B4- stable - out onto active fan	3.25	1.25	1.1	1.05	1.1	1.06	1.07	5.85	Very High
Table sub-basin_5	B4- stable - out onto active fan	3.25	1.25	1.1	1.05	1.1	1.04	1.07	5.73	Very High
Table sub-basin_6	C4- Lightly unstable/ disturbed	4	1.25	1.1	1.05	1.1	1.00	1.07	6.78	Very High
Table sub-basin_7	C4- Lightly unstable w disturbed fan	4.2	1	1.1	1	1.1	1.01	1.03	5.26	Very High
Table Entire basin	C4- Lightly unstable w disturbed fan	4.2	1	1.1	1	1.1	1.01	1.07	5.47	Very High

3.3 Description of the physical characteristics of Table sub-basin #1

Table sub-basin #1 has an area of 28.5 km^2 and is dominated by the ESSFwk2 biogeoclimatic sub-zone. Figure 3 provides an overview image of this sub-basin obtained from Google Earth, while Figure 4 provides a view of the lower reaches of this sub-basin. This basin has an elevation range between 790 and 1676 m with a stream density of 2.48 km/km^2. Only 22% of this watershed is located within the lowest elevations band of between 790 and 1090 m. This basin has a fairly steep topography with only 6.7% of the watershed having slopes less than 10% and 61% with slopes greater than 30%.

The lower reaches of this sub-basin are dominated by a Rosgen C4 channel type, which is moderately disturbed and shows clear signs of instability (Figure 4). The combination of a sensitive stream channel type (C4-disturbed), the evidence of instability and the physical characteristics of the watershed (Table 1) has generated a “Very High” peak flow sensitivity rating for this sub-basin (Table2).

3.4 Description of the physical characteristics of Table sub-basin #2

Table sub-basin#2 has an area of 27.7 km^2 and is dominated by the ESSFvk biogeoclimatic sub-zone. Figure 5 provides an overview image of this sub-basin obtained from Google Earth, while Figure 6 provides a view of the lower reaches of this sub-basin (note the extensive riparian disturbance and channel erosion). This basin has an elevation range between 790 and 1711 m with a stream density of 1.96 km/km^2. Only 16% of this watershed is located within the lowest elevations band of between 790 and 1090 m. This basin has a fairly steep topography with only 8.3% of the watershed having slopes less than 10% and 45% with slopes greater than 30%.

The lower reaches of this sub-basin are dominated by an unstable and heavily disturbed Rosgen C4 channel type (Figure 6). The combination of a sensitive stream channel type (C4), and the physical characteristics of the watershed (Table 1) has generated a “Very High” peak flow sensitivity rating for this sub-basin (Table2).

3.5 Description of the physical characteristics of Table sub-basin #3.

Table sub-basin #3 has an area of 19.3 km^2 and is dominated by the ESSFwk2 biogeoclimatic sub-zone. Figure 7 provides an overview image of this sub-basin obtained from Google Earth, while Figure 8 provides a view of the lower reaches of this sub-basin. This watershed has an elevation range between 822 and 1749 m with a stream density of 2.46 km/km^2. Forty-five percent of this watershed is located within the lowest 300 m elevations band of between 822 and 1122 m. This basin has a generally steep and well coupled topography with only 4.5% of the watershed having slopes less than 10% and 59% with slopes greater than 30%.

The lower reaches of this sub-basin are dominated by a Rosgen C4 channel type which flows out onto a small stable fan. The combination of a sensitive stream channel type (C4), and the physical characteristics of the watershed (Table 1) has generated a “Very High” peak flow sensitivity rating for this sub-basin (Table2).

3.6 Description of the physical characteristics of Table sub-basin #4

Table sub-basin #4 has an area of 99.2 km^2 and is dominated by the ESSFwk2 biogeoclimatic sub-zone. Figure 9 provides an overview image of this sub-basin obtained from Google Earth, while Figure 10 provides a view of the lower reaches of this sub-basin. This watershed has an elevation range between 820 and 1863 m with a stream density of 2.39 km/km^2. Forty-six percent of this watershed is located within the lowest 300 m elevations band of between 820 and 1120 m. This basin has a generally steep and well coupled topography with only 6% of the watershed having slopes less than 10% and 63% with slopes greater than 30%.

The lower reaches of this sub-basin are dominated by a Rosgen B4 channel type which flows out onto a small active fan (Figure 10). The combination of a moderately sensitivity stream channel type (B4 onto fan), and the physical characteristics of the watershed (Table 1) has generated a "Very High" peak flow sensitivity rating for this sub-basin (Table2).

3.7 Description of the physical characteristics of Table sub-basin #5

Table sub-basin #5 has an area of 32.8 km^2 and is dominated by the ESSFwk2 biogeoclimatic sub-zone. Figure 11 provides an overview image of this sub-basin obtained from Google Earth, while Figure 12 provides a view of the lower reaches of this sub-basin. This watershed has an elevation range between 822 and 1972 m with a stream density of 2.42 km/km^2. Forty-one percent of this watershed is located within the lowest 300 m elevations band of between 822 and 1122 m. This basin has a generally steep and well coupled topography with only 8% of the watershed having slopes less than 10% and 57% with slopes greater than 30%.

The lower reaches of this sub-basin are dominated by a Rosgen B4 channel type which flows out onto a small active fan (Figure 12). The combination of a moderately sensitivity stream channel type (B4 onto fan), and the physical characteristics of the watershed (Table 1) has generated a "Very High" peak flow sensitivity rating for this sub-basin (Table2).

3.8 Description of the physical characteristics of Table sub-basin #6

Table sub-basin #6 has an area of 55.1 km^2 and is dominated by the ESSFwk2 biogeoclimatic sub-zone. Figure 13 provides an overview image of this sub-basin obtained from Google Earth, while Figure 14 provides a view of the lower reaches of this sub-basin. This watershed has an elevation range between 822 and 2471 m with a stream density of 2.80 km/km^2. Thirty-one percent of this watershed is located within the lowest 300 m elevations band of between 822 and 1122 m. This basin has a generally steep and well coupled topography with 13% of the watershed having slopes less than 10% and 59% with slopes greater than 30%.

The lower reaches of this sub-basin are dominated by a lightly unstable Rosgen C4 channel type which flows out onto a small active fan (Figure 14). The combination of a high sensitivity stream channel type (C4 onto fan), and the physical characteristics of the watershed (Table 1) has generated a "Very High" peak flow sensitivity rating for this sub-basin (Table2).

3.9 Description of the physical characteristics of Table sub-basin #7

Table sub-basin #7 has an area of 100 km^2 and is dominated by the SBSvk biogeoclimatic sub-zone. Figure 15 provides an overview image of this sub-basin obtained from Google Earth, while Figure 16 provides a view of the lower reaches of this sub-basin. This watershed has an elevation range between 817 and 1984 m with a stream density of 2.69 km/km^2. Thirty-three percent of this watershed is located within the lowest 300 m elevations band of between 817 and 1117 m. This basin has a generally steep and well coupled topography with 10% of the watershed having slopes less than 10% and 54% with slopes greater than 30%.

The lower reaches of this sub-basin are dominated by an unstable Rosgen C4 channel type which flows out onto a lightly disturbed active fan (Figure 16). The combination of a high sensitivity stream channel type (C4 onto fan), and the physical characteristics of the watershed (Table 1) has generated a “Very High” peak flow sensitivity rating for this sub-basin (Table2).

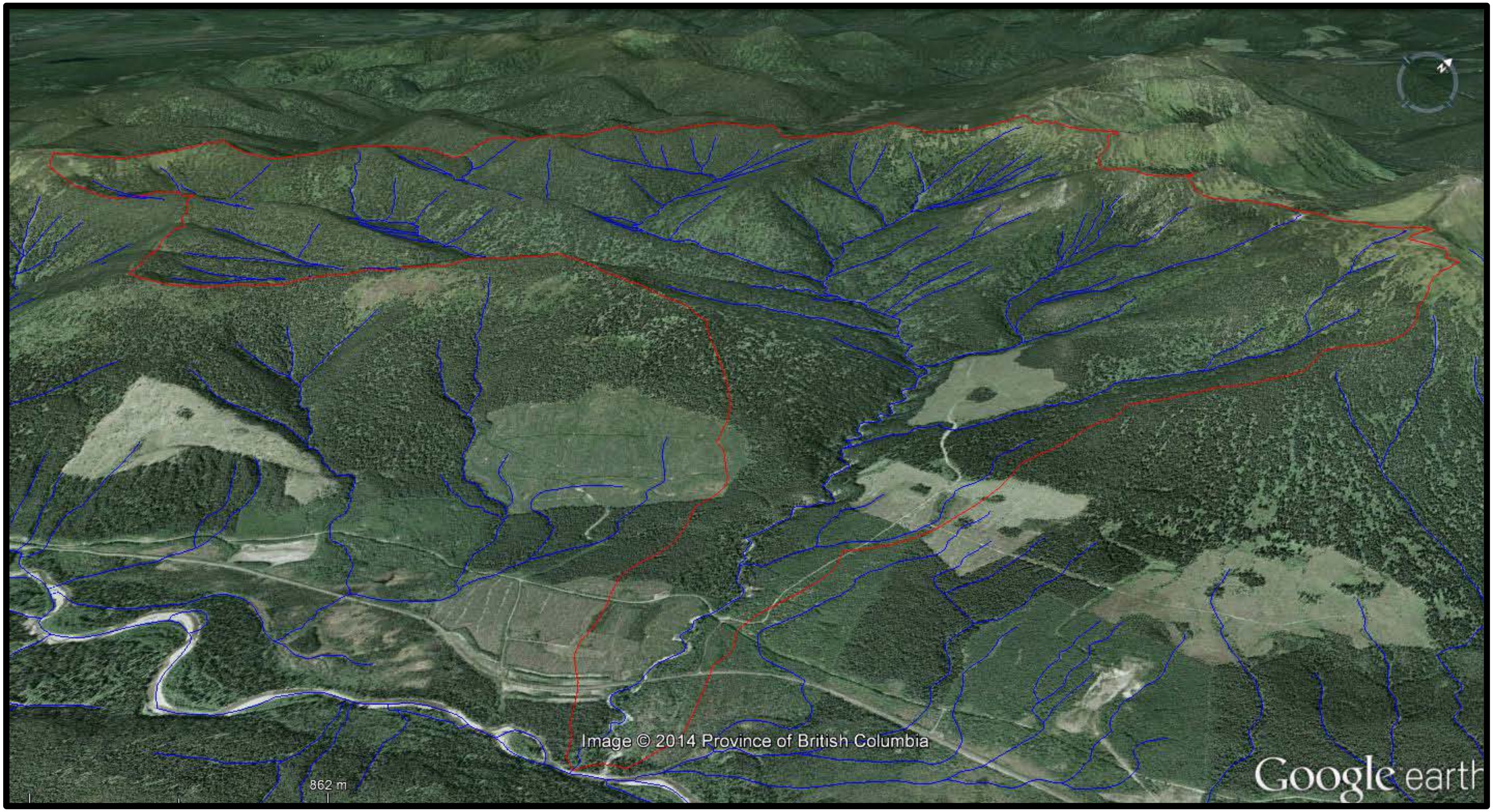

Figure3. Google Earth image of Table sub-basin #1, looking upstream into the watershed.

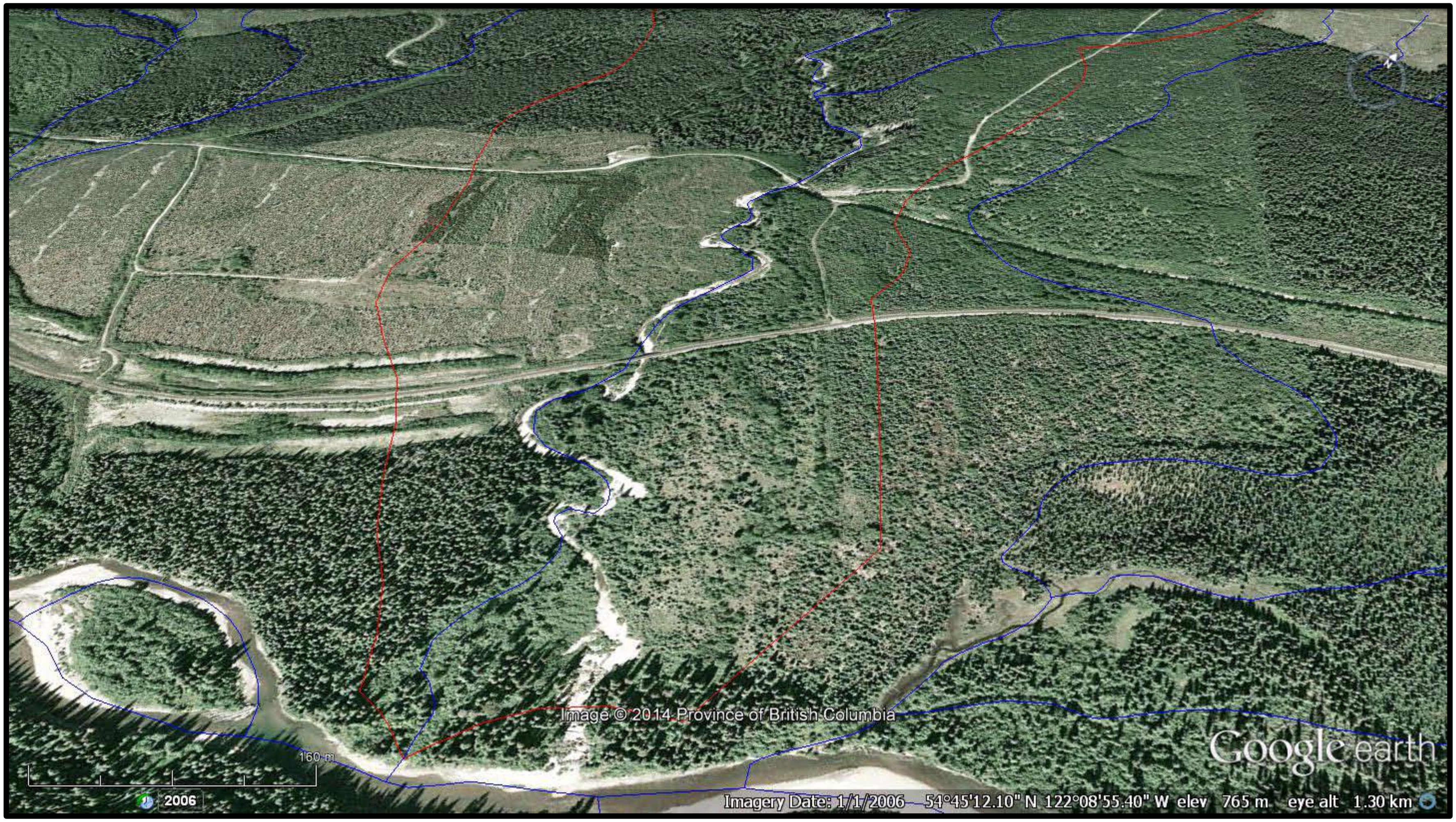

Figure 4 Google Earth image of the lower reaches of sub-basin #1 looking upstream into the watershed.

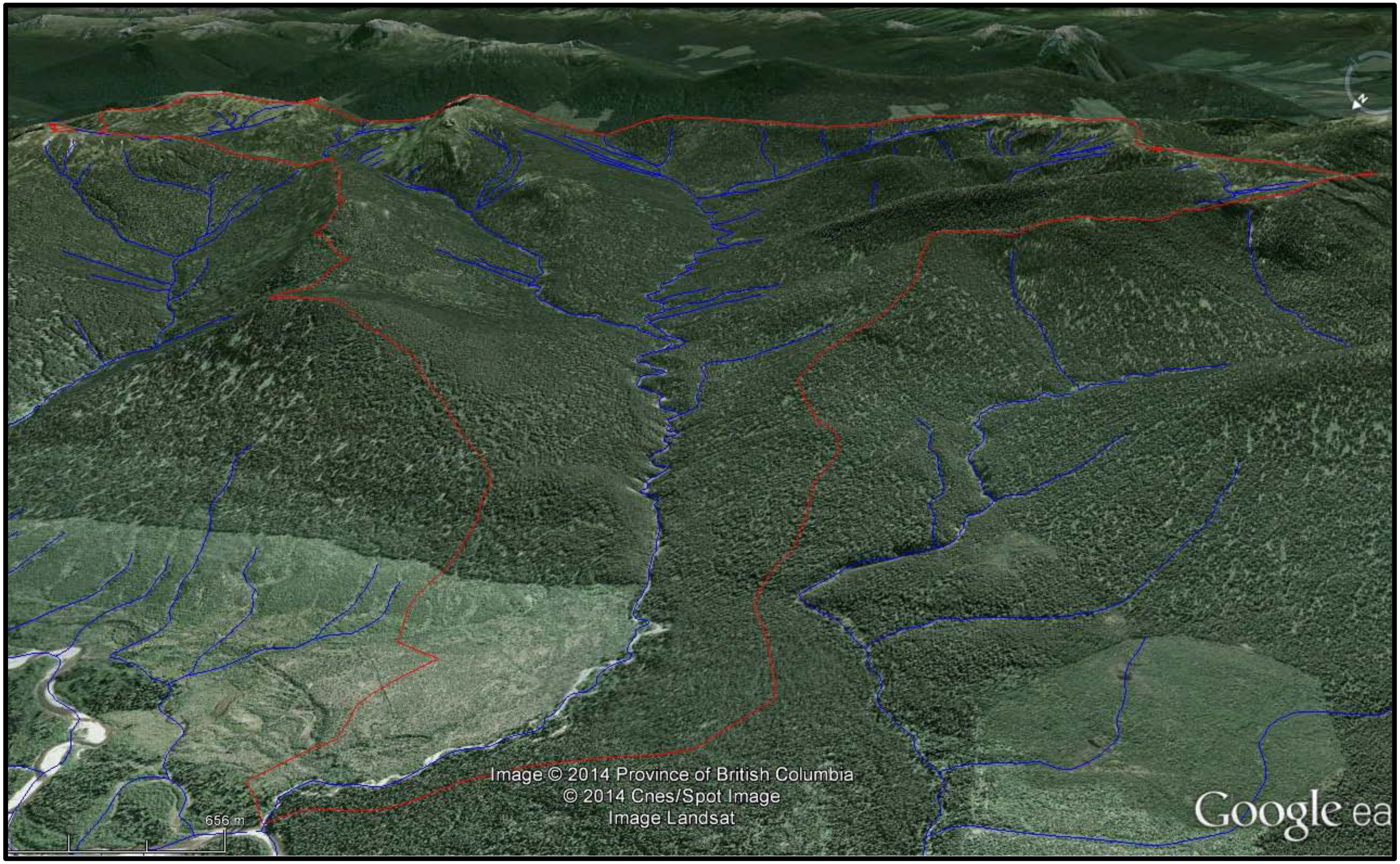

Figure 5. Google Earth image of the Table sub-basin #2, looking upstream into the watershed.

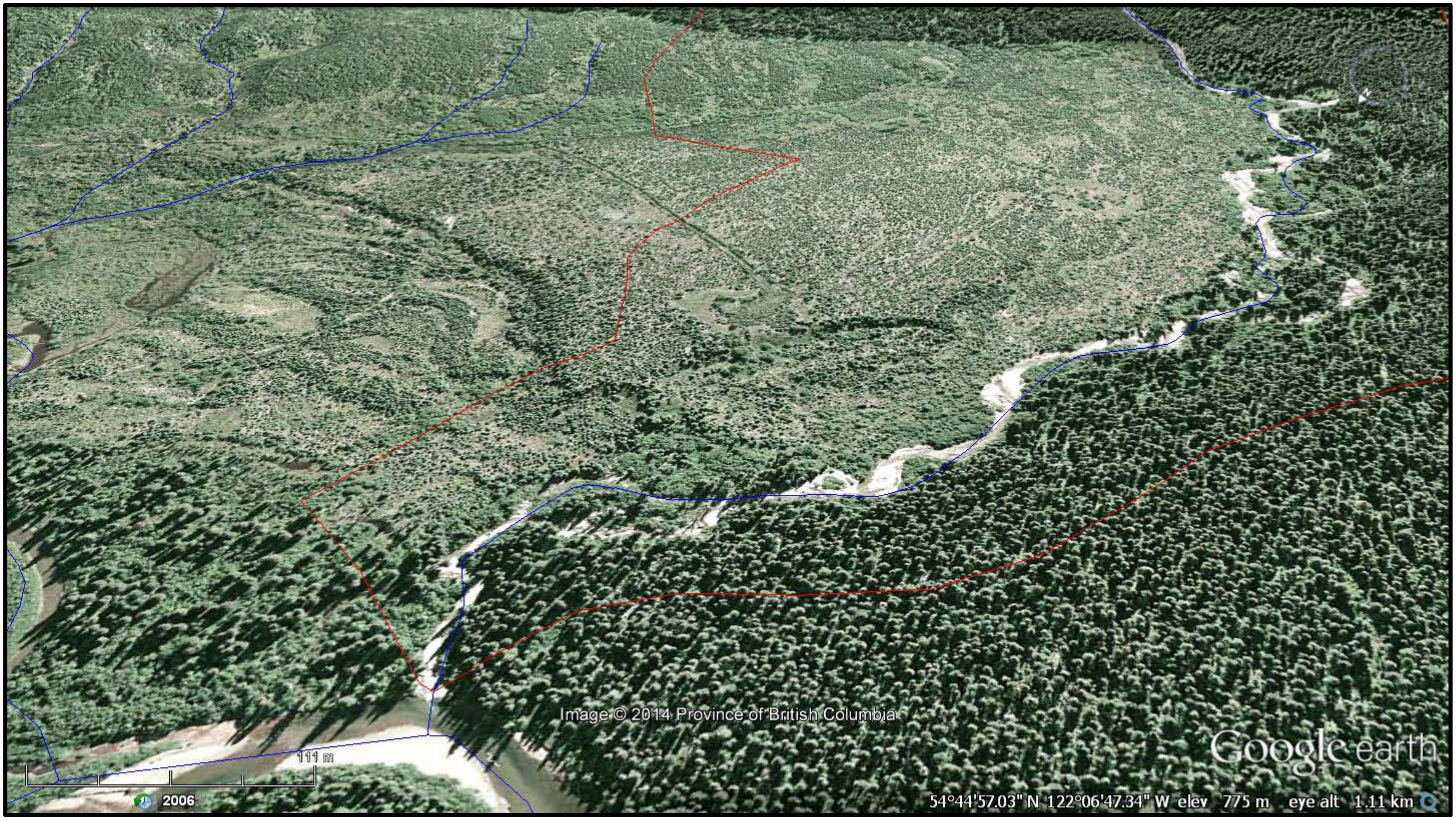

Figure 6. Google Earth image of the lower reaches of Sub-basin #2.

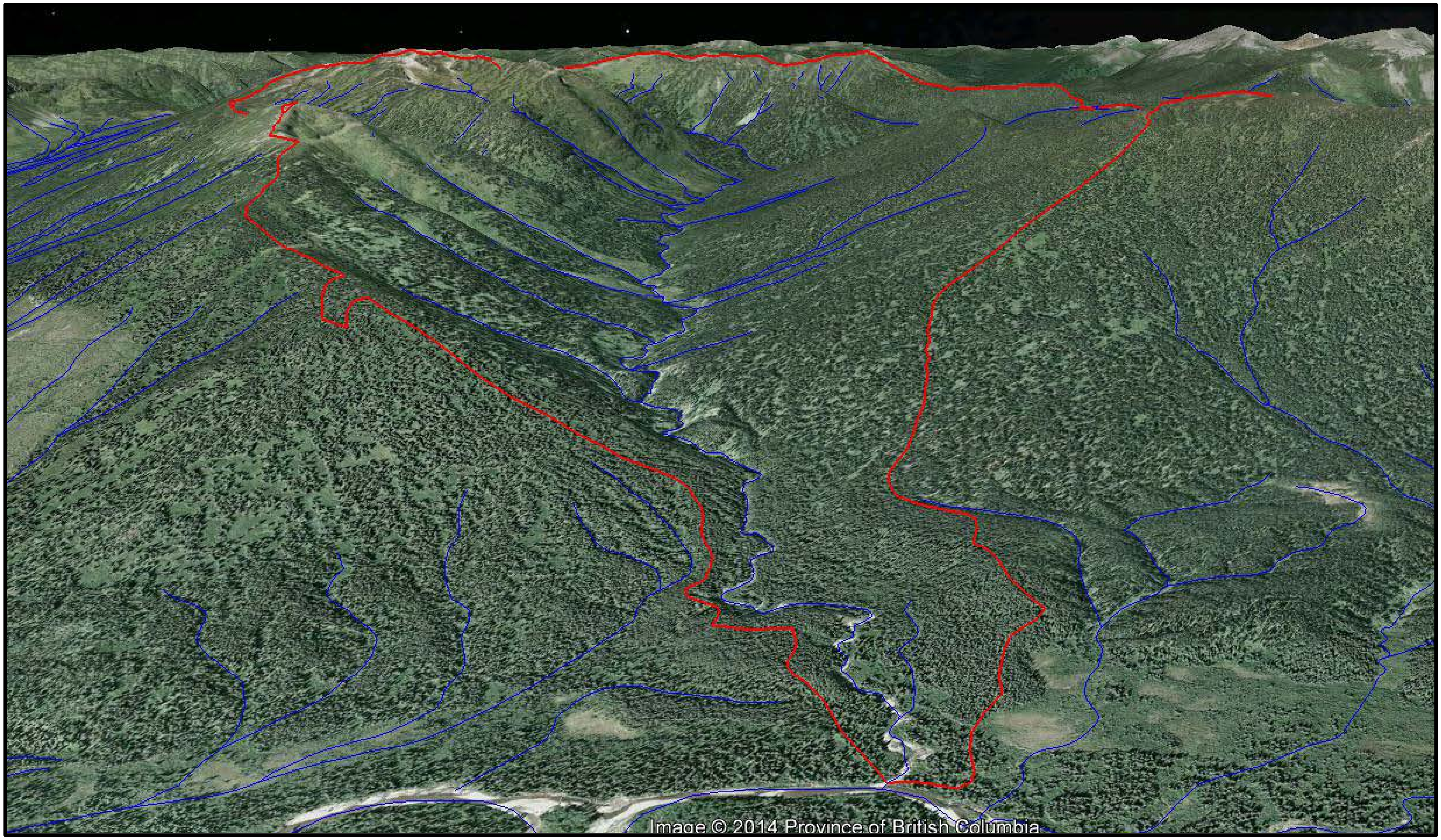

Figure 7. Google Earth image of Table sub-basin #3, looking upstream into the watershed.

Figure 8. Google Earth image of the lower reaches of Sub-basin #3.

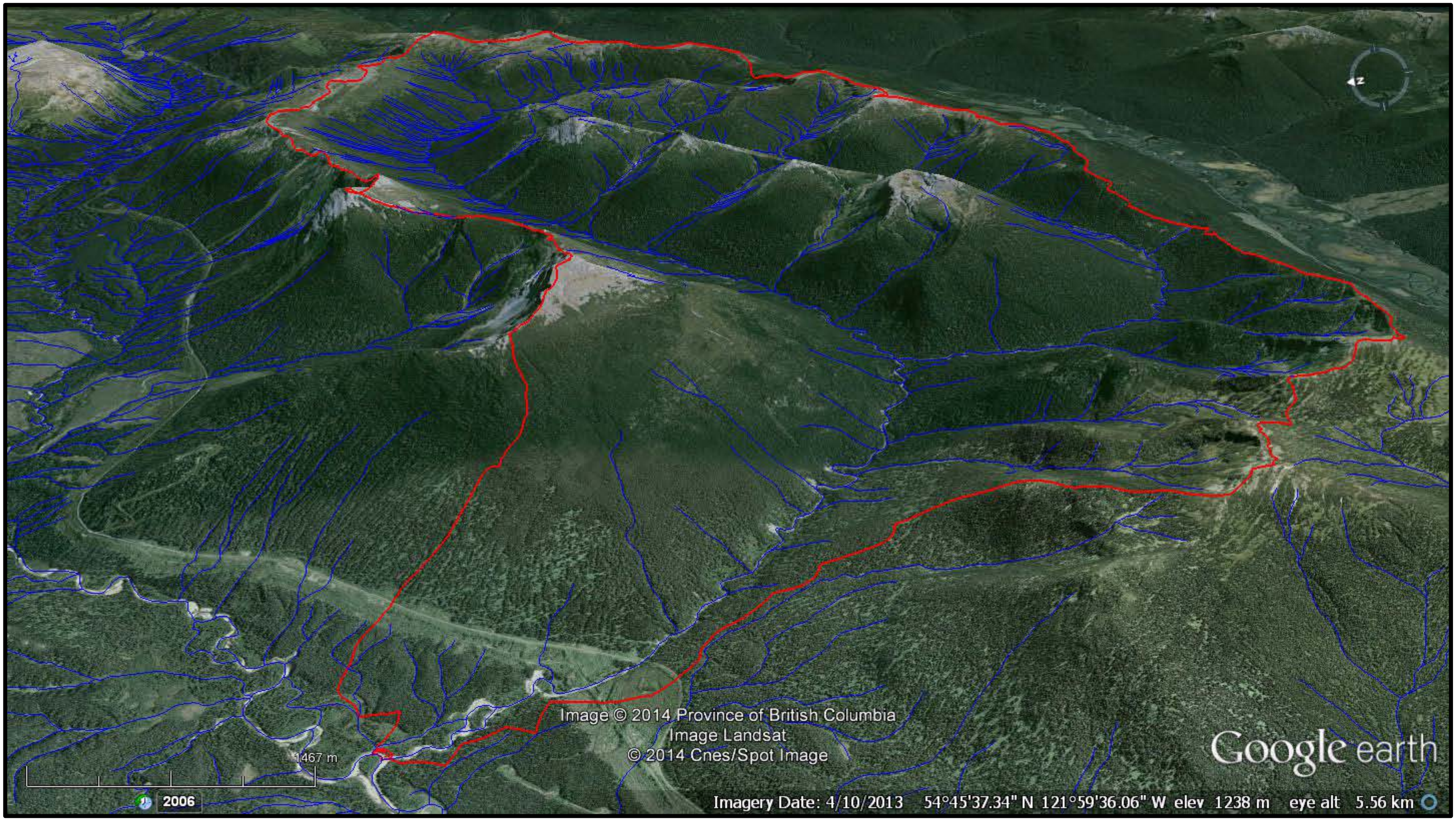

Figure 9. Google Earth image of Table sub-basin #4, looking upstream into the watershed.

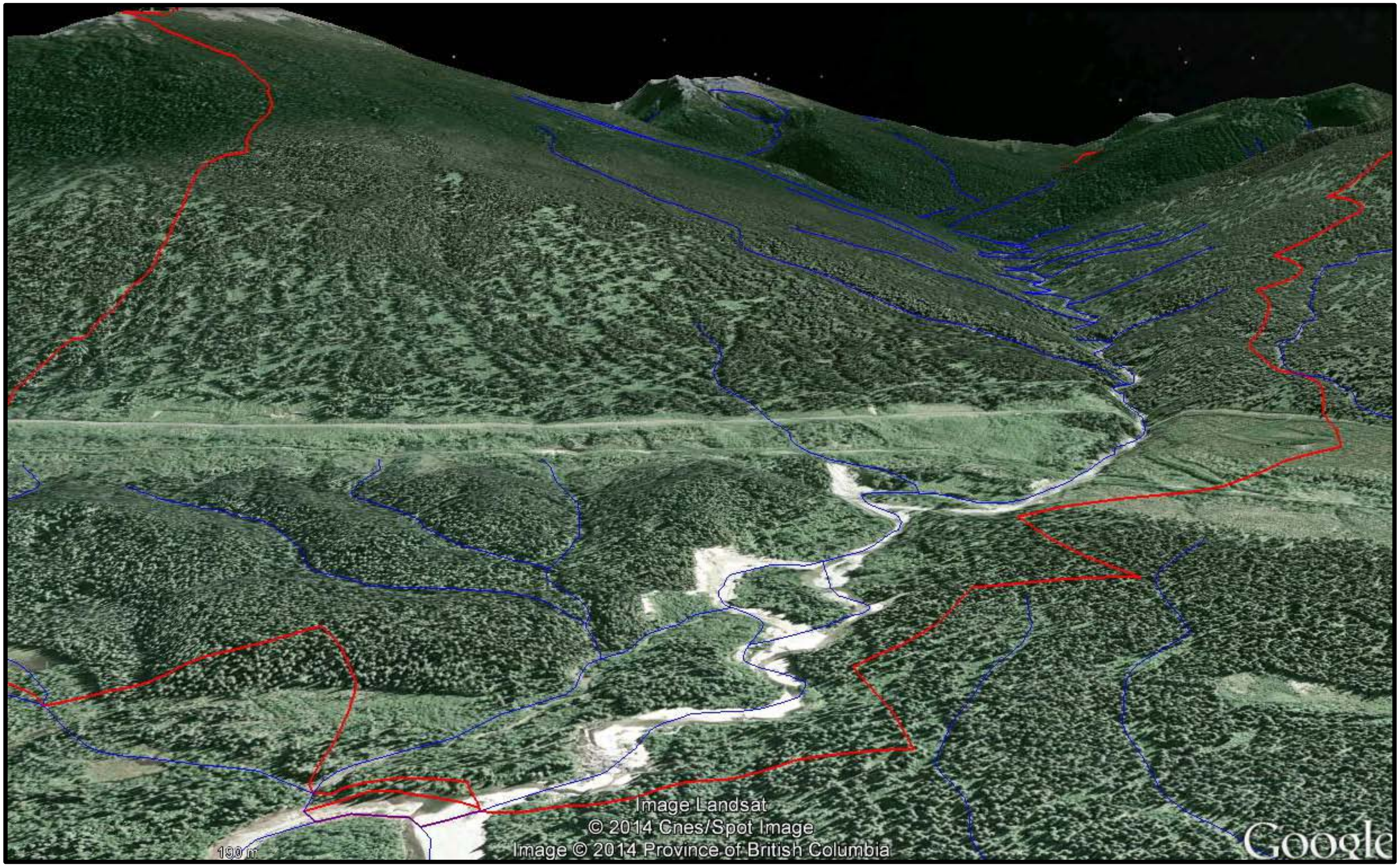

Figure 10. Google Earth image of the lower reaches of Sub-Basin #4. .

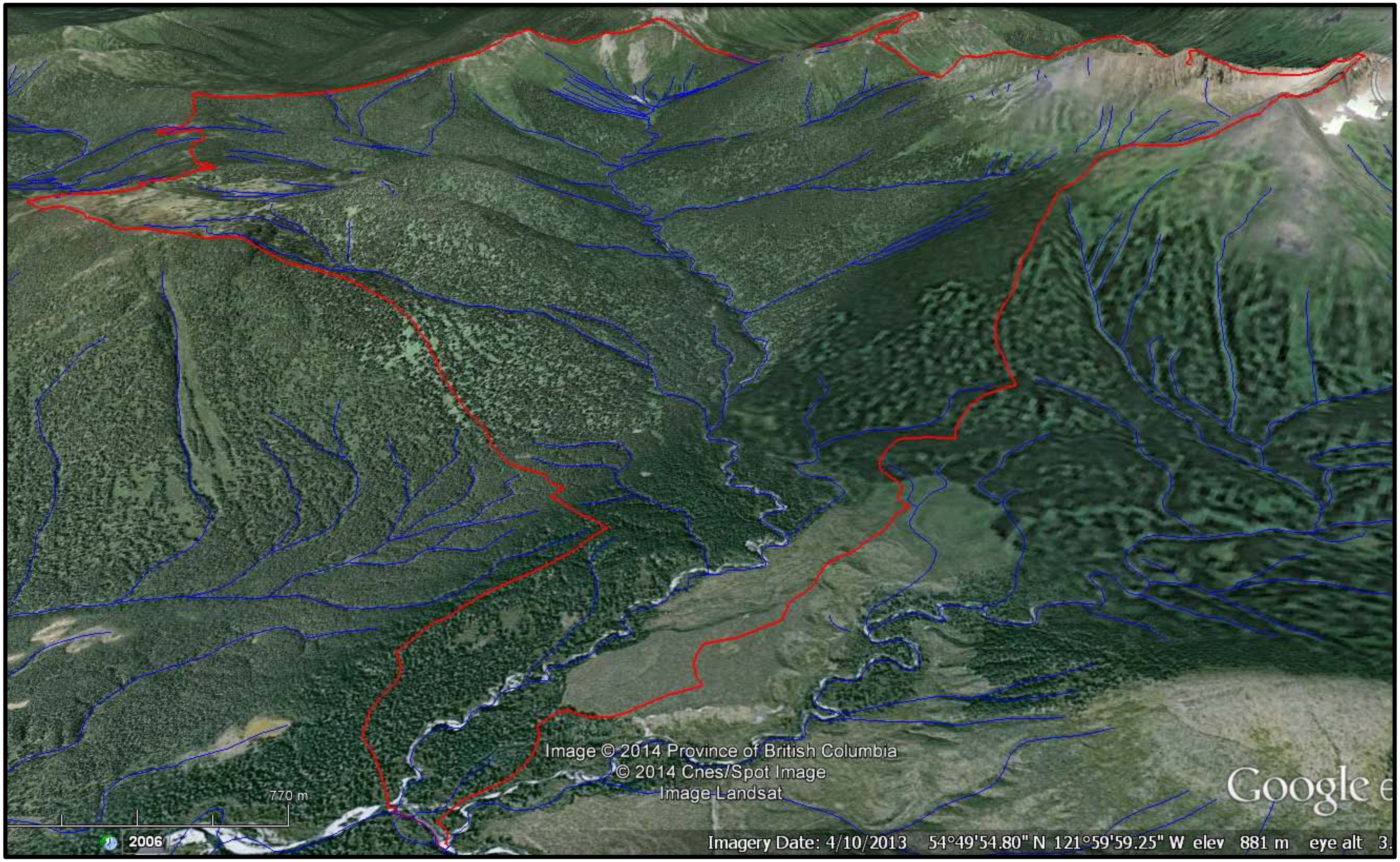

Figure 11. Google Earth image of Table sub-basin #5, looking upstream into the watershed.

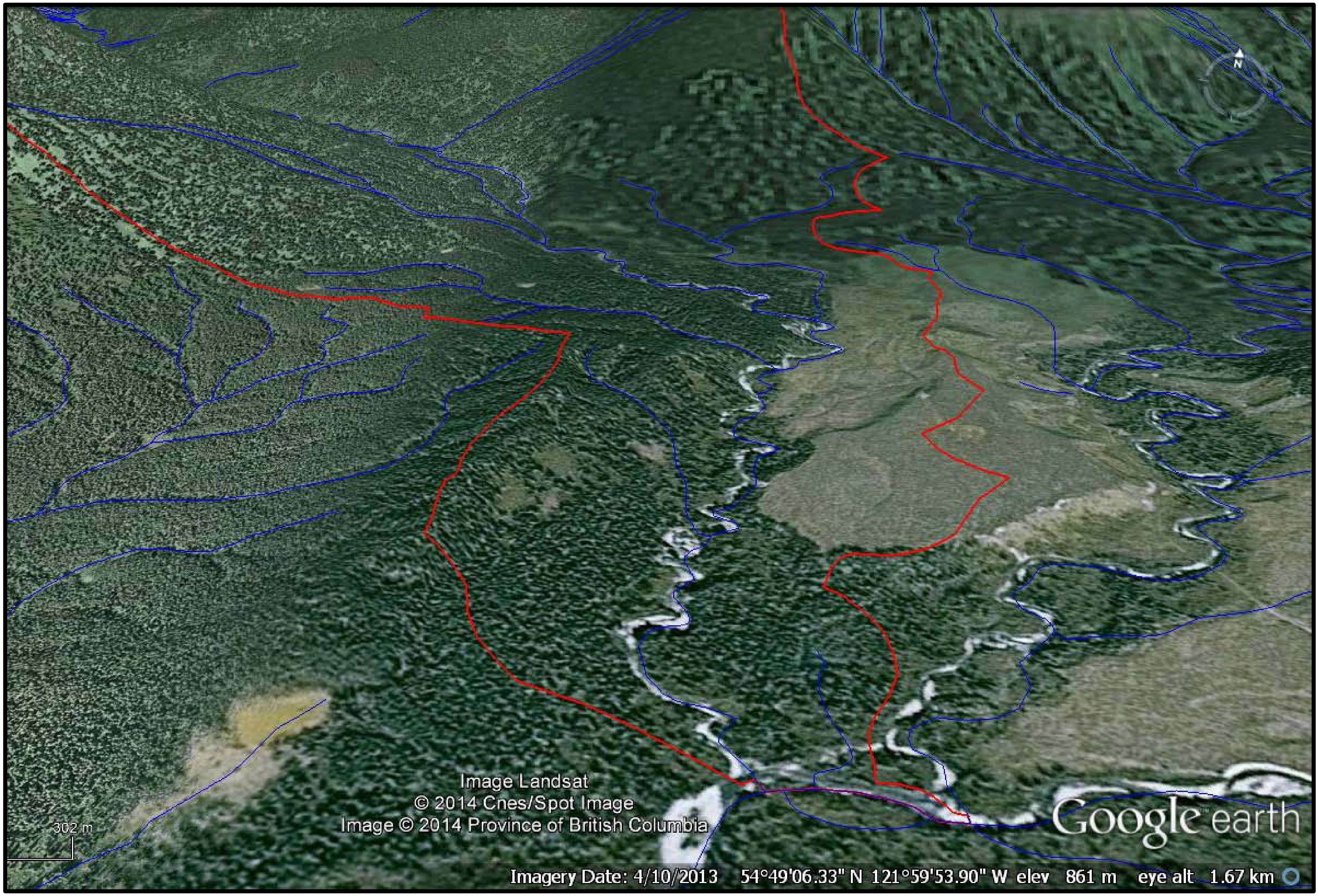

Figure 12. Google Earth image of the lower reaches of Sub-Basin #5.

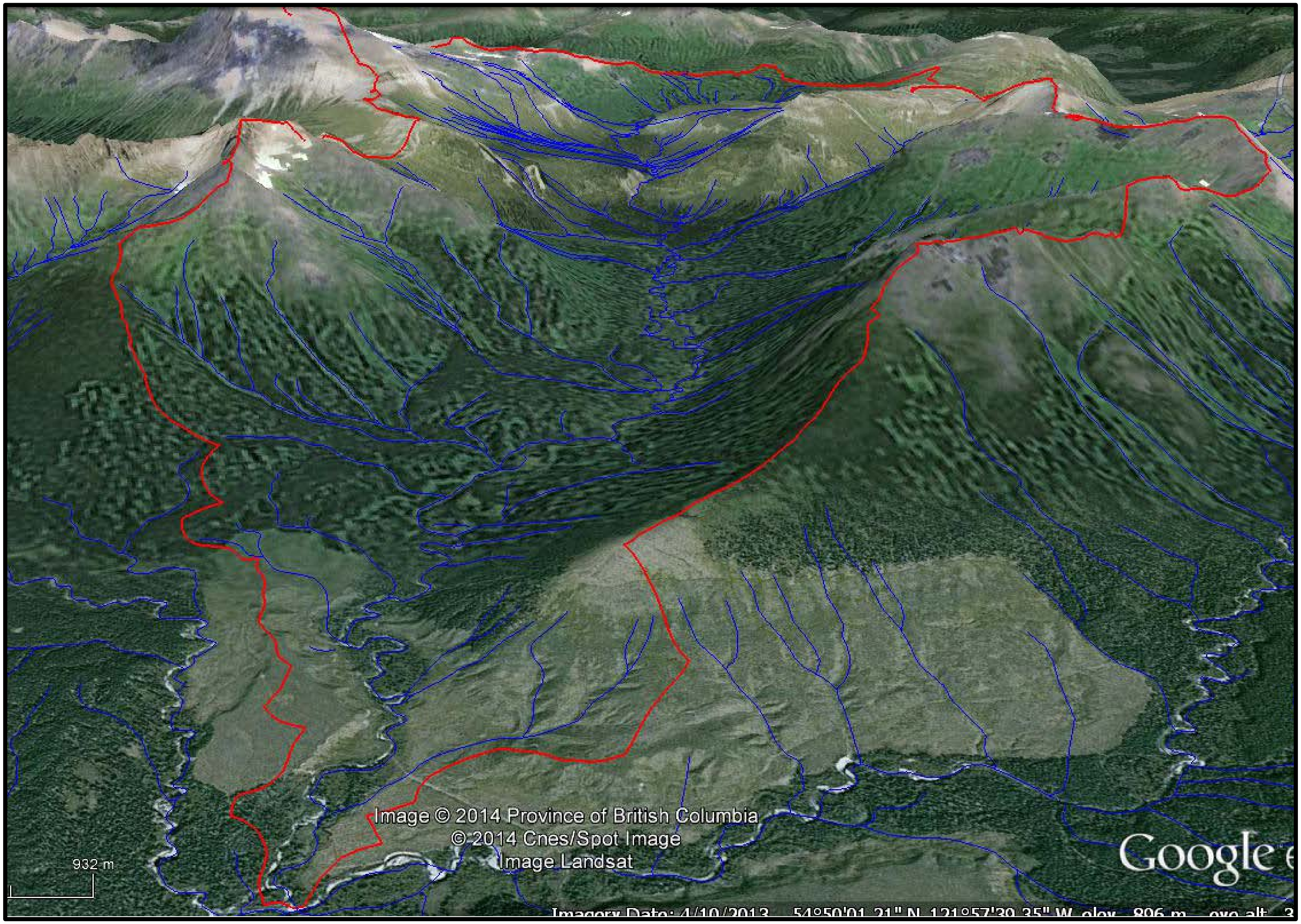

Figure 13. Google Earth image of Table sub-basin #6, looking upstream into the watershed.

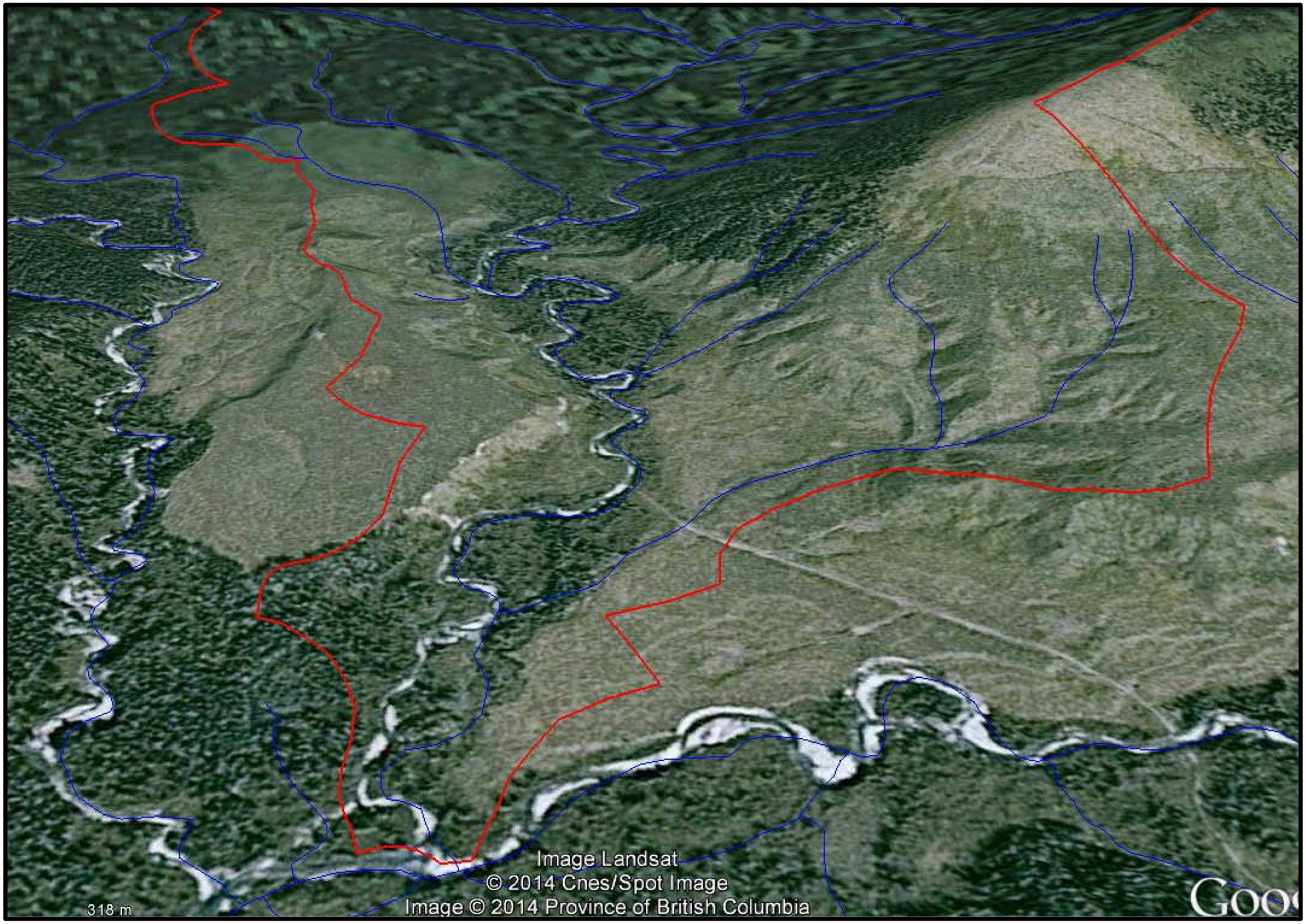

Figure 14. Google Earth image of the lower reaches of Sub-Basin #6.

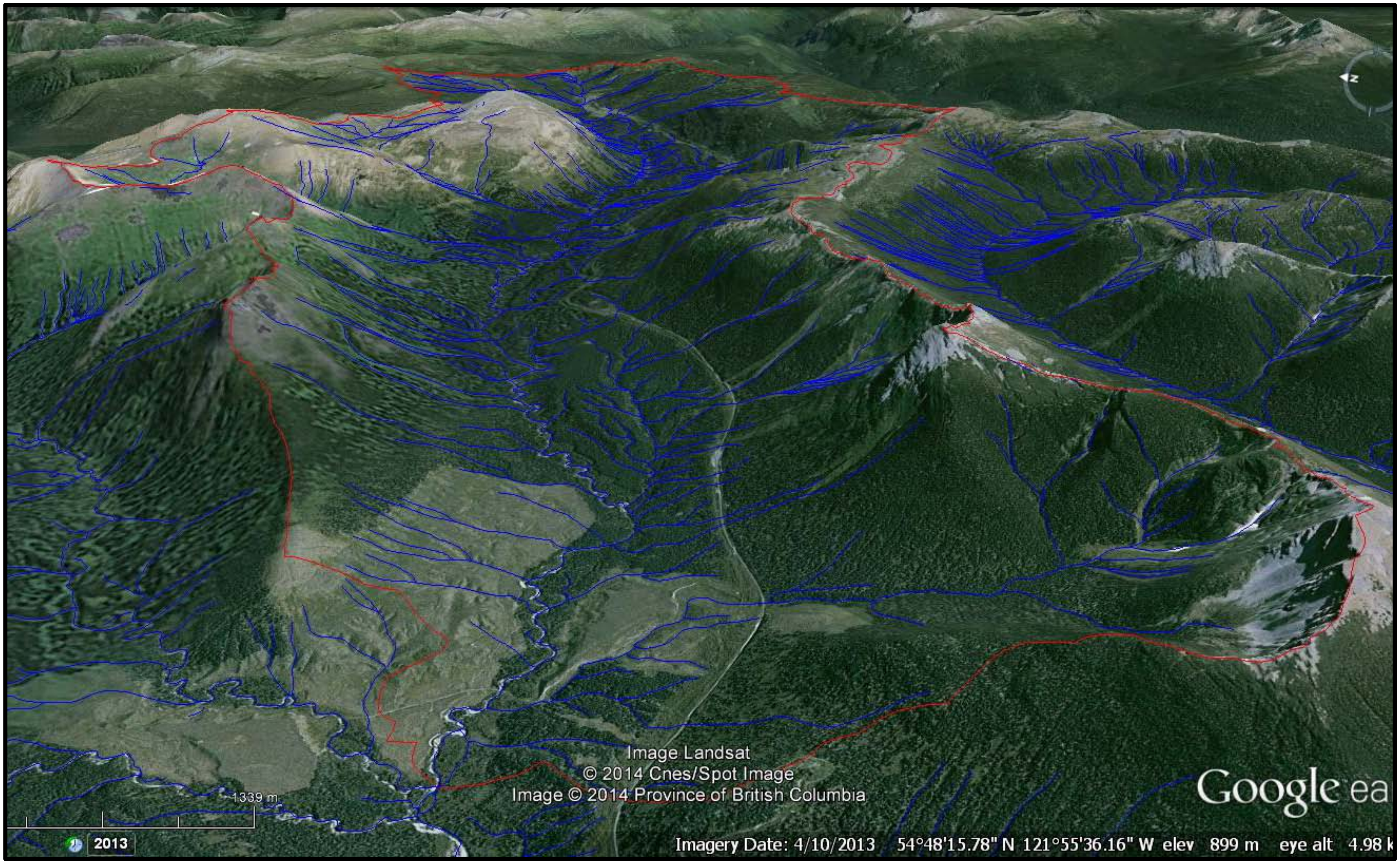

Figure 15. Google Earth image of Table sub-basin #7, looking upstream into the watershed.

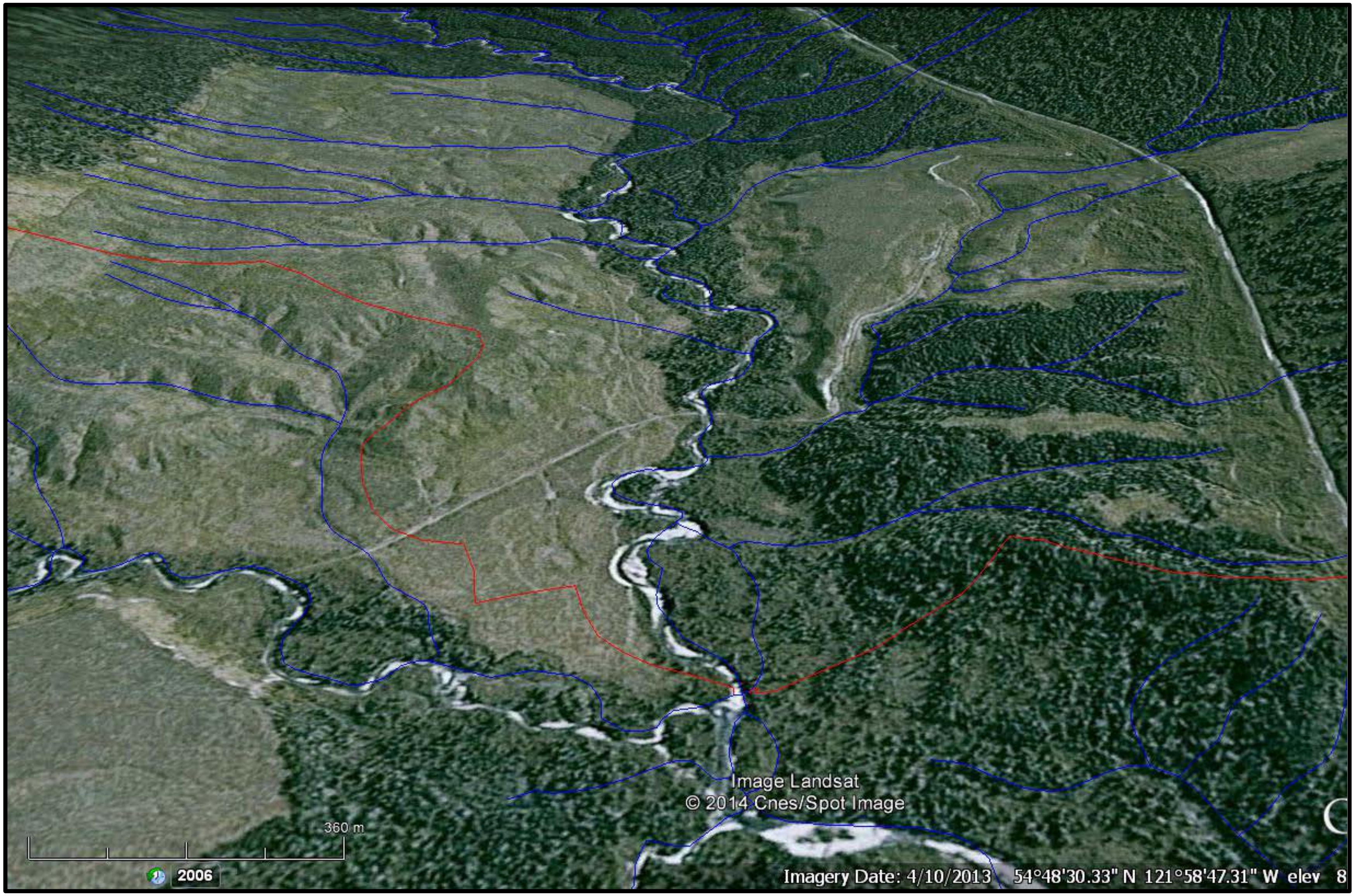

Figure 16. Google Earth image of the lower reaches of Sub-Basin #7.

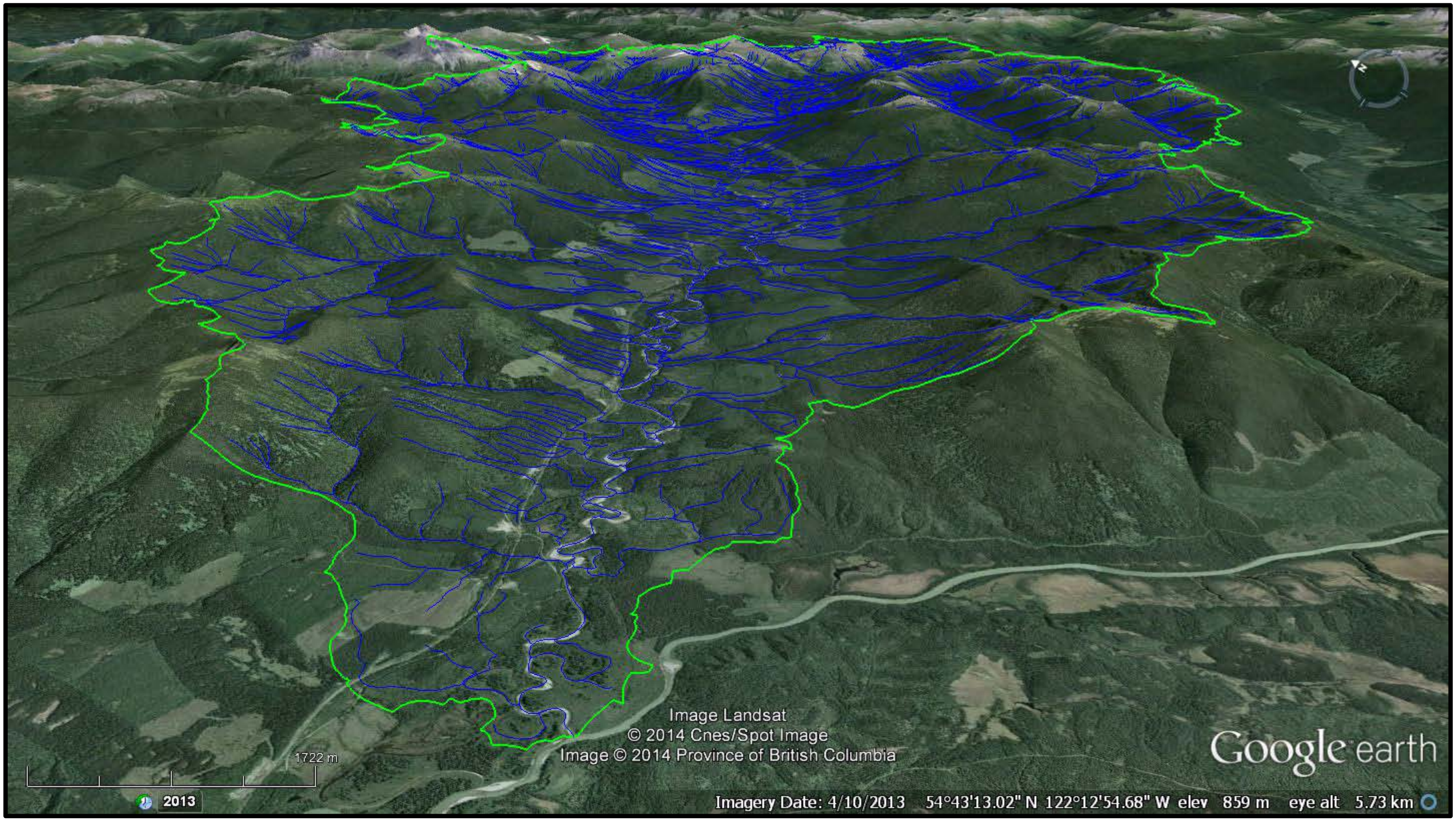

Figure 17. Google Earth image of entire Table River watershed, looking upstream into the watershed.

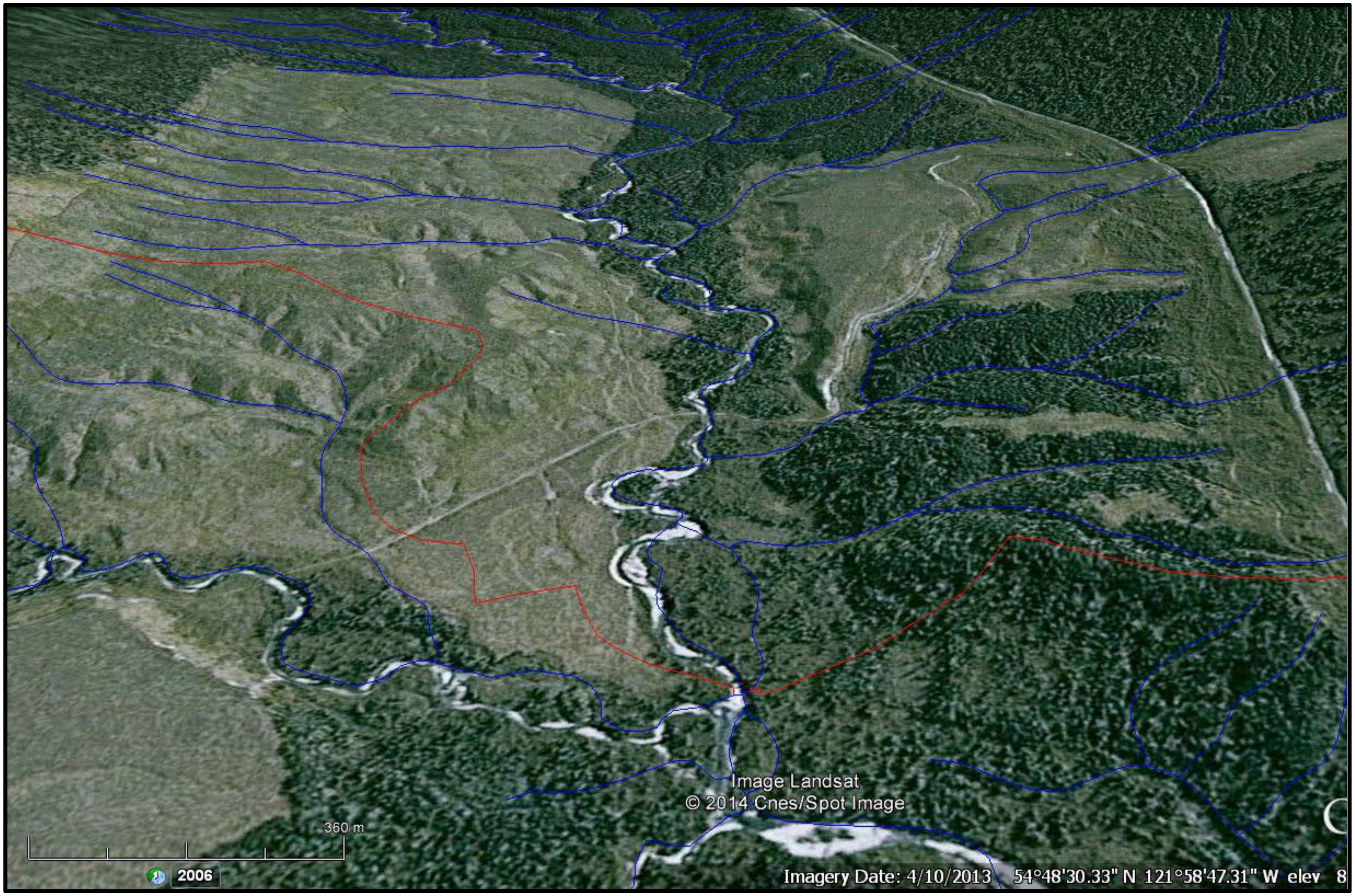

Figure 18. Google Earth image of the lower reaches of the Table River watershed

4.0 METHODOLOGY USED TO ACHEIVE PROJECT OBJECTIVES

COMPUTATION OF WATERSHED SENSITIVITY RELATIVE TO INCREASED PEAK FLOWS

The computation of the watershed sensitivity, relative to the potential for increases in peak flows (PFs), is computed as follows:

PFs= Rs * TOPO * LAT *VERT*CLIM*SYNC* NDTf

Where:

1. **Rs** = The Rosgen stream channel sensitivity score, applied to the lower reaches of the watershed (Rosgen 1996, 2006). This is the most important component of the sensitivity score. Figure 20 (from Rosgen 2006) provides the probability of channel destabilization for different stream channel types based on the amount of disturbance in the watershed (indexed by ECA).

2. **TOPO** = The watershed topography factor. This is related to the general topography of the watershed and addresses the rate of water movement through the watershed

3. **LAT** = The lateral drainage efficiency factor of the watershed (related to the number, size and location of lakes and wetlands in the watershed) This factors relates to the connectivity of the hillslopes to the stream network and the density of streams throughout the watershed.

4. **VERT =** This is the typology factor which considers general soils and bedrock types and their effect on the conductivity of water through the soil , i.e. the proportion of shallow soils over bedrock (fast) vs deep soils over fractured bedrock flow (slow).

5. **CLIM =** The influence of climate type (as indexed by Biogeoclimatic subzones) on potential for increases in peak flows cause by land disturbance. For example a rain-on-snow zone will be much more sensitive than a dry desert type.

6. **SYNC =** The flow synchronization factor. This factor considers the distribution of elevation zones in the watershed and how flows may potentially be desynchronized with a greater distribution of elevation bands. For example a flat watershed, where most of the area generates peak flows at a similar time (i.e. flows are synchronized because most of the watershed is located in one single 300 m elevation band) will be more sensitive to extensive land-use disturbances then will be a watershed that is distributed over several elevation bands.

7. **NDTf** = The dominant natural disturbance type in the watershed. (NDTf). The assumption here is that a lower sensitivity rating will be given to those watersheds where large natural disturbances are frequent and the biological communities may be better adapted to frequent natural changes caused by large disturbances (e.g. wildfires, insect infestations and possibly clearcutting).

The computation of the watershed sensitivity to increased peak flows ((PFs) is based on the sensitivity rating classes and scores provided in the following tables (Table 3 to Table 9)

The Rosgen Stream Channel Sensitivity Score (Rs)

The Rosgen Stream channel classification system (Rosgen 1996, 2006) divides stream channels into 8 basic stream types based on: a) single or multi-thread channels, b) the entrenchment ratio of the channel, c) the width/depth ratio and d) the sinuosity of the channel. The system further classifies channels into 96 sub types based on the dominant channel material. Figure 19 and Figure 20, extracted from the book *Applied River Hydrology* (Rosgen 1996), provide illustrations of the primary delineative criteria for the major stream types. Although most of the criteria are meant to be measured in the field, it is relatively easy (based on extensive professional experience) to infer the approximate values of the delineative criteria from digital orthophotos, maps, and a personal familiarity with the study areas.

Rosgen (1996) also supplies management interpretations for each of the stream types included in the classification system. Figure 20 shows the probability of channel destabilization with increasing forest removal, for each of the Rosgen stream classes. The sensitivity scores, for each of the stream sensitivity classes identified by Rosgen (1996), are provided in Table 3. The USEPA has developed a watershed assessment model based on the concepts of the Rosgen channel classification system (http://www.epa.gov/warsss). This model is called the Watershed Assessment of River Stability and Sediment Supply (WARSSS). It is a comprehensive model that investigates watershed processes at a variety of scales and levels and is used to assess the risks to stream channels caused by land-use activities in the watershed. Although it is more comprehensive then the approach used for this project, it has a lot of similarities. It uses the Rosgen stream types as the basic building blocks of the assessment and defines the risk of outcomes like channel enlargement and bank erosion based on the type and activity level of different hazards in the watershed (e.g. forest removal, roads and riparian logging). This is very similar to the approach used for this project. Figure 21, which has been extracted from the WARSSS procedural handbook, illustrates how the different stream types are used to define risk relative to ECA and Roads. It is obvious from this graph that A1, A2, B1, B2 are the least sensitive channel types, while the G3-G6 and F3-F6 are the most sensitive channel types. The WARSSS system, much like the system used for this project, will identify a larger risk as the condition of a particular channel type deteriorates (e.g. reduced riparian function or geomorphic instability). The Rs for the whole watershed is usually determined by the most sensitive reach, i.e. the “weak link”. If the channel shows signs of instability the sensitivity class is increased by one.

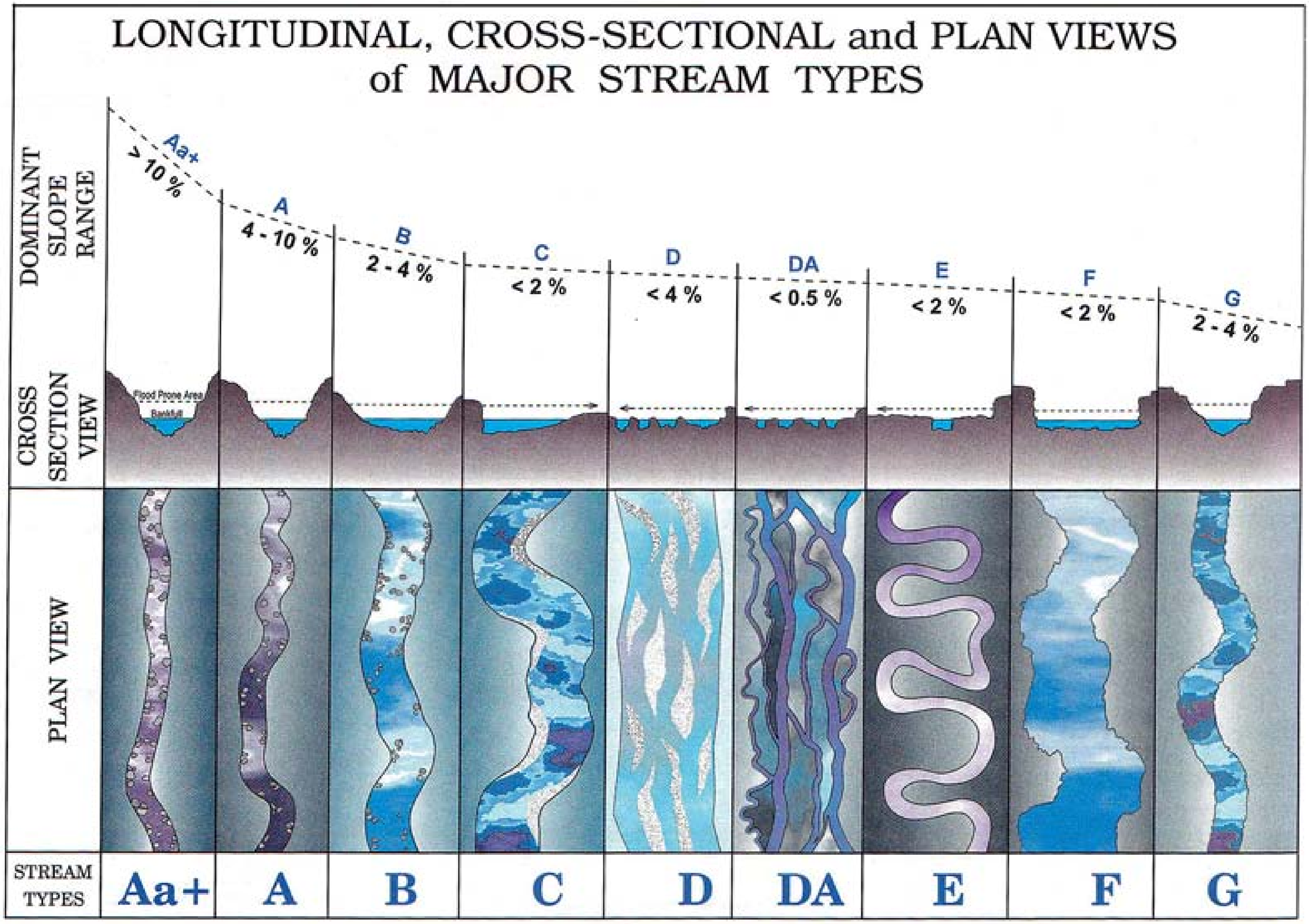

Figure 19. Basic Rosgen stream channel types

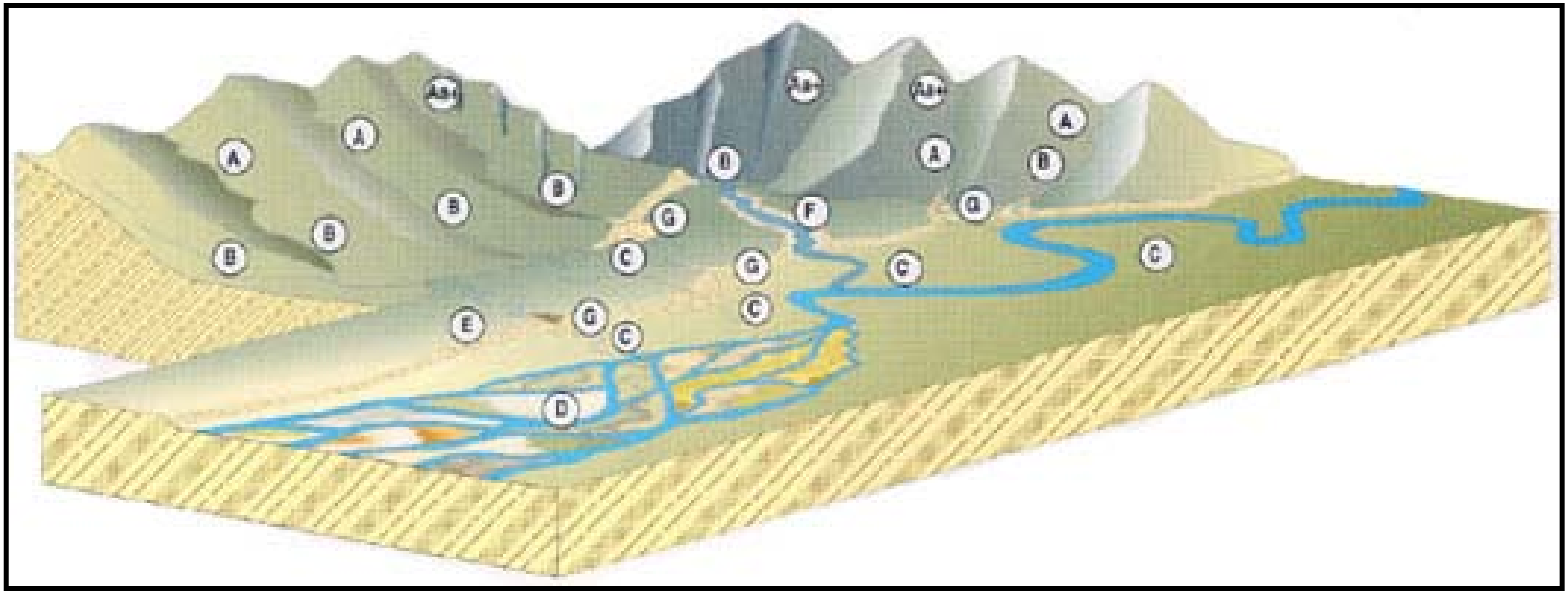

Figure 20. General distribution of different Rosgen stream types across a landscape.

Table 3. Rosgen channel type sensitivity rating table (Rs) (classes based on Rosgen but expaned).

Rosgen Type	SCORE (Rs)	SENSITIVITY CLASS
A1-Stable	1	Low
A1- Lightly unstable	1	Low
A1 - Unstable	1	Low
A2-Stable	1	Low
A2- Lightly unstable	1	Low
A2 - Unstable	1	Low
A3-Stable	4	Very high
A3- Lightly unstable	5	Very high
A3 - Unstable	5	Very high
A4-Stable	4	Very high
A4- Lightly unstable	5	Very high
A4 - Unstable	5	Very high
A5-Stable	5	Very high
A5- Lightly unstable	5	Very high
A5 - Unstable	5	Very high
A6-Stable	5	Very high
A6- Lightly unstable	5	Very high
A6 - Unstable	5	Very high
B1-Stable	1	Low
B1- Lightly unstable	1	Low
B1 - Unstable	1	Low
B2-Stable	1	Low
B2- Lightly unstable	1	Low
B2 - Unstable	1	Low
B3-Stable	1.5	Low
B3- Lightly unstable	2	Moderate
B3 - Unstable	2.5	Moderate
B4-Stable	1.5	Low
B4- stable - out onto inactive fan	2	Moderate
B4- Lightly unstable	2.5	Moderate
B4- Steep banks only	3	High
B4- Lightly unstable onto fan	3.15	Moderate
B4- stable - out onto active fan	3.25	High
B4- steep banks - out onto fan	3.5	High
B4- Failing banks - out onto fan	4	Very high
B4 - Unstable	4	Moderate
B5-Stable	1.5	Low
B5- Lightly unstable	2	Moderate
B5 - Unstable	2.5	Moderate
B6-Stable	1.5	Low
B6- Lightly unstable	2	Moderate
B6 - Unstable	2.5	Moderate
C1-Stable	2	Moderate
C1- Lightly unstable	2.25	Moderate
C1 - Unstable	3	High
C2-Stable	2	Moderate
C2- Lightly unstable	2.25	Moderate
C2 - Unstable	3	High
C3-Stable	3.5	High
C3- Lightly unstable/disturbed	4	Very high

C3 - Unstable/disturbed	5	Very high
C4- Stable - Large	2.5	Moderate
C4/B4 Combo- Stable	3	High
C4- Stable	3.5	High
C4- Stable onto fan	3.8	High
C4- Mostly stable, w disturbed fan	3.9	High
C4- Lightly unstable/disturbed	4	Very high
C4- Lightly unstable w disturbed fan	4.2	Very high
C4- Mod unstable/disturbed	4.5	Very high
C4 - Sig Unstable/disturbed	5	Very high
C5- Stable	3.5	High
C5- Lightly unstable/disturbed	4	Very high
C5 - Unstable/disturbed	5	Very high
C6- Stable	3.5	High
C6- Lightly unstable/disturbed	4	Very high
C6 - Unstable/disturbed	5	Very high
D3-Stable	4	Very high
D3- Lightly unstable/disturbed	4.5	Very high
D3 - Unstable/disturbed	4.8	Very high
D4-Stable	4	Very high
D4- Lightly unstable/disturbed	4.5	Very high
D4 - Unstable/disturbed	4.8	Very high
D5-Stable	3.5	High
D5- Lightly unstable/disturbed	4	Very high
D5 - Unstable/disturbed	4.5	Very high
D6-Stable	3.5	High
D6- Lightly unstable/disturbed	4	Very high
D6 - Unstable/disturbed	4.5	Very high
E3-Stable	2.5	Moderate
E3- Lightly unstable/disturbed	3	High
E3 - Unstable/distrurbed	4	Very high
E4-Swamps-Stable	2	Moderate
E4-Stable	2.5	Moderate
E4-Stable onto fan	2.8	Moderate
E4- Lightly unstable/disturbed	3.2	High
E4 - Unstable/distrurbed	4	Very high
E5-Stable	2.5	Moderate
E5- Lightly unstable/disturbed	3	High
E5 - Unstable/distrurbed	4	Very high
E6-Stable	2.5	Moderate
E6- Lightly unstable/disturbed	3	High
E6 - Unstable/distrurbed	4	Very high
F1-Stable	1	Low
F1- Lightly unstable/disturbed	1.25	Low
F1 - Unstable/Disturbed	2	Moderate
F2-Stable	1	Low
F2- Lightly unstable/disturbed	1.25	Low
F2 - Unstable/Disturbed	2	Moderate
F3-Stable	4	Very high
F3- Lightly unstable/disturbed	4.3	Very high
F3 - Unstable/Disturbed	5	Very high
F4-Stable - Large System	3.8	High
F4-Stable	4	Very high
F4- Lightly unstable/disturbed	4.3	Very high
F4 - Unstable/Disturbed	5	Very high
F5-Stable	4	Very high
F5- Lightly unstable/disturbed	4.3	Very high

F5 - Unstable/Disturbed	5	Very high
F6-Stable	4	Very high
F6- Lightly unstable/disturbed	4.3	Very high
F6 - Unstable/Disturbed	5	Very high
G1-Stable	1	Low
G1- Lightly unstable	1.25	Low
G1 - Unstable	2	Moderate
G2-Stable	1	Low
G2- Lightly unstable	1.25	Low
G2 - Unstable	2	Moderate
G3-Stable	4	Very high
G3- Lightly unstable	4.3	Very high
G3 - Unstable	5	Very high
G4-Stable	4	Very high
G4- Lightly unstable	4.3	Very high
G4 - Unstable	5	Very high
G5-Stable	4	Very high
G5- Lightly unstable	4.3	Very high
G5 - Unstable	5	Very high
G6-Stable	4	Very high
G6- Lightly unstable	4.3	Very high
G6 - Unstable	5	Very high
Lakes	1	Low
Ponds	1	Low

The Watershed Topography Score (TOPO)

It is considered here that a watershed that has a very gentle topography will be less efficient in the transport of water downstream through the watershed and will have a slower “time to peak”, compared to a watershed that is steep with the hill slopes tightly coupled to the stream network. Consequently, a watershed with a gentle topography is considered as less sensitive to increased peak flows and large scale disturbances compared to a very steep watershed that is highly coupled to the hillslopes. The assessment is based on the review of the Google Earth 3 D images, contour maps and the digital orthophotos. The drainage efficiency factors used to “modify” the Rosgen channel sensitivity score are provided in Table 4. Watershed topography rating table (TOPO).Table 4.

Table 4. Watershed topography rating table (TOPO).

Description of the watershed	Topography Factor (TOPO)
Gently rolling with very wide uncoupled floodplains	0.6
Hilly, gentle mountains, generally uncoupled with wide valley flats	0.8
Mountainous with localized steepness	1.0
Generally steep and coupled	1.25
Very steep and tightly coupled	1.40

The Watershed Lateral Drainage Efficiency Score (LAT)

It is considered here that a watershed that has numerous lakes and swamps near the mouth of the river will have more of a buffering capacity for peak flows than a watershed that does not have any lakes or swamps. Consequently, a watershed with no lakes or swamps is considered as being more sensitive to increased peak flows. As the area of lakes/swamps increases throughout the watershed, the sensitivity is considered to decrease. This is an important factor that has the potential to decrease the sensitivity of a watershed substantially. The drainage efficiency factor is used to “modify” the Rosgen channel sensitivity score are provided in Table 5

Table 5. Watershed drainage efficiency rating table (LAT).

Description of Watershed Characteristics relative to abundance of lakes and wetlands	Drainage efficiency and lateral connectivity (LAT)
Numerous lakes, or one big lake, near outlet (big reduction in sensitivity) low drainage density	0.8
Numerous lakes that are scattered throughout watershed, low to moderate drainage density	0.9
Moderate amount of lakes scattered throughout watershed with moderate to high drainage density.	1.0
Few lakes/swamps that are scattered throughout watershed with high drainage density	1.05
No lakes, very high drainage density	1.10

The Watershed Typology Score (VERT)

The typology factor considers general soils and bedrock types and their effect on the conductivity of water through the soil, i.e. the proportion of shallow horizontal flow (fast) vs deep bedrock flow (slow). It is considered that the efficiency of movement of water through the watershed decreases with the depth of porous soils and fractured bedrock.

Table 6. Watershed typology rating table (VERT).

Description of the watershed	Typology Factor Soils and bedrock relative to vertical vs horizontal drainage (VERT)
Very deep porous soils with fractured bedrock	0.9
Deep porous soils with fractured bedrock	0.95
Shallow soils with fractured bedrock or deep soils with solid bedrock	1.0
Moderately shallow soils with solid bedrock	1.05
Very shallow soils and solid bedrock	1.10

The Watershed Flow Synchronization Score (SYNC)

The flow synchronization factor. This factor considers the distribution of elevation zones in the watershed and how flows may potentially be desynchronized with a greater distribution of elevation bands. For example a flat watershed , where most of the area generates peak flows at a similar time (i.e. flows are synchronized) will be more sensitive to extensive land-use disturbances then will be a steeper watershed.

Table 7. Watershed flow synchronization rating table (SYNC)[1].

% of watershed in the same 300 me elevation band	Flow Synchronization Factor (SYNC)
There is no 300 m elevation band that contains more than 10% of watershed	0.85
Only 0 to 10% of watershed is in any given 300 m elevation band	0.90
Only 10 to 20% of watershed is in any given 300 m elevation band	1.00
Only 20 to 45% of watershed is in any given 300 m elevation band	1.05
45 to 75% of watershed is in the same 300 m elevation band	1.15
75 to 95% of watershed is in the same 300 m elevation band	1.25
Almost the entire watershed is in the same elevation band (i.e. very flat watershed)	1.30

[1]Note that the relationship presented in this graph has been summarized using the following equation: SYNC factor = (0.0041*% in same elevation band)+0.8698, which is what is used in the spreadsheet computations.

The Natural Disturbance Type Score (NDTf)

The dominant natural disturbance type in the watershed. (NDTf). The assumption here is that a lower sensitivity rating will be given to those watersheds where large natural disturbances are frequent and the biological communities may be better adapted to frequent natural changes caused by large disturbances (e.g. wildfires, insect infestations and possibly clearcutting).

Table 8. Watershed natural disturbance type rating table (NDTf).

Dominant NDT Type in watershed	Natural Disturbance factor (NDTf)
NDT 5 - Alpine tundra and subalpine park land (less sensitive because better adapted to being disturbed)	0.94
NDT 4 - Frequent stand maintaining fires, (less sensitive because better adapted to frequent disturbance)	0.97
NDT 3 - Frequent stand initiating fires, (a bit less sensitive)	1.0
NDT 2 - Infrequent stand-initiating events (minor increase in sensitivity)	1.03
NDT 1 - Rare stand initiating events (increase in sensitivity)	1.07

The Watershed Peak Flow Climate Generation Score (CLIM)

This indicator refers to the influence of climate type (as indexed by Biogeoclimatic subzones) on potential for increases in peak flows cause by land disturbance. For example a rain-on-snow zone will be much more sensitive than a dry desert type.

Table 9. Watershed climate type rating table (CLIM).

BEC Zone	**Weight for BEC Peak Flow Generation Index**		**Justification for Peak Flow Generation Weight Selection**
	Rank **1**= Logging in this zone generates the biggest increases in peak flows **14**= Logging in this zones causes the least effect on increases in peak flows	**Score (CLIM)** (Score is scaled from 0 to 1, where 1 is biggest impact and 0 would be no impact at all)	
MH	High	1.1	Deepest snowpack and rain on snow zones
ICH	High	1.1	Wet climate with potentially lots of snow, not that much different than MH
ESSF	High	1.1	Deep snowpacks and thus the effect of logging on snow accumulation and melt can be significant. Not that much different than ICH and ESSF
MS	High	1.1	Climate is wet and snowy (less than ESSF, but more than SBS)
SBS	High	1.1	Not a huge annual precipitation, but significant snowpack
CWH	Moderate	1.0	Lots of rain, but not much snow. Thus effects of tree removal are less, but still significant
CDF	Moderate	1.0	Lots of rain, but virtually no snow
SWB	Moderate	1.0	Although winters are long, snowpacks are not that deep.
BWBS	Low-Mod	0.85	Although winters are long, snowpacks are not that deep.
SBPS	Low	0.65	Very dry and low snowpack, but completely forested.
IDF	Low	0.65	Most of the zone is relatively dry with generally more rain than snow.
PP	Very Low	0.30	Very dry and low snowpack, not much logging potential in PP
BG	Very Low	0.30	Minimal logging in this zone
AT	Very Low	0.30	No logging in this zone

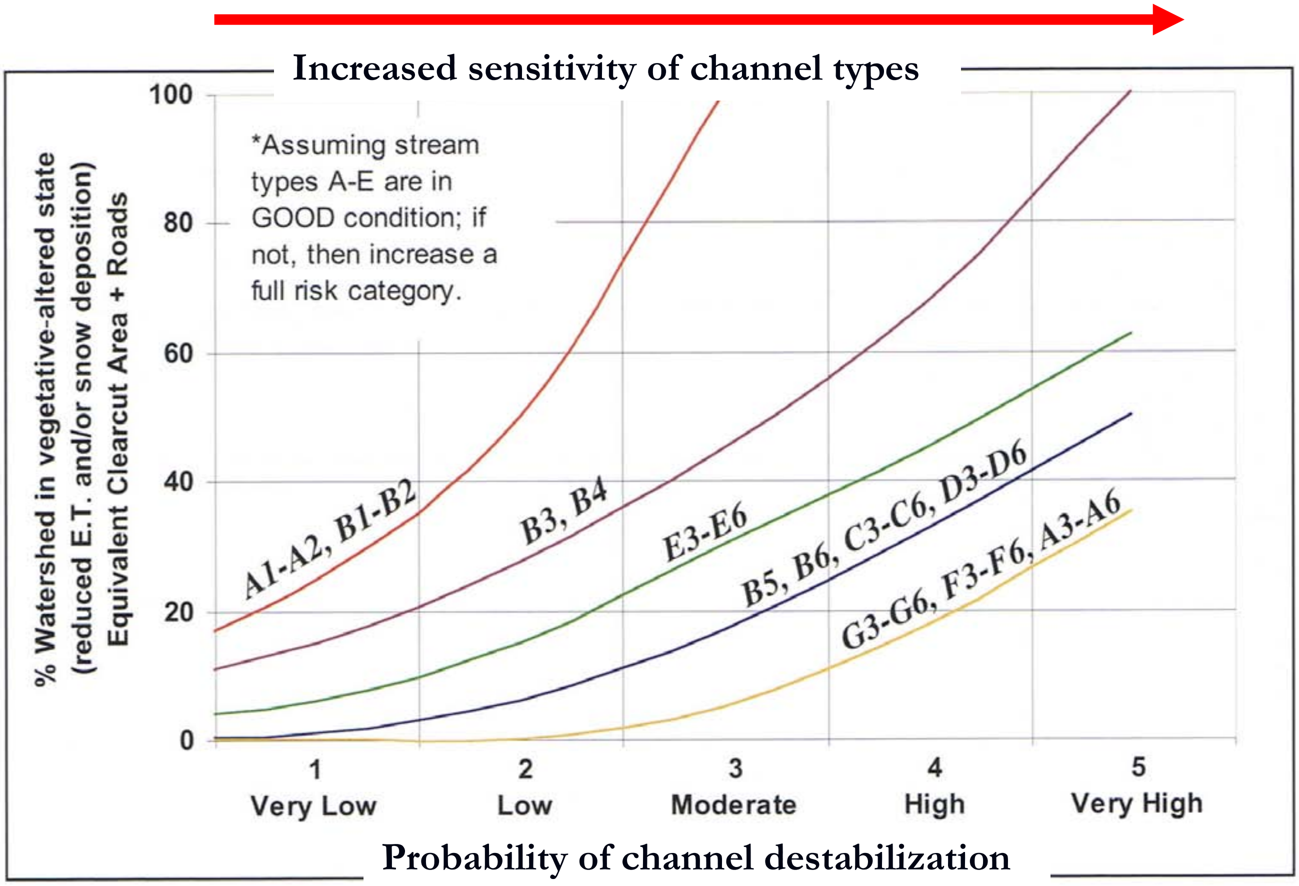

Figure 21. Probability of stream channel destabilzation and accelerated bank erosion associated with increases in equivalent clearcut area, for different Rosgen stream types (adapted from Rosgen 2006).

Table 10. Determination of the peak flow sensitivity rating class based on the sensitivity scores.

Sensitivity Rating	Sensitivity Score
Extreme	greater than or equal to 8.0
Very High	5.0 to 8.0
High	3.8 to 5.0
Moderate	2.8 to 3.8
Low	1.8 to 2.8
Very Low	less than 1.8

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