

Addressing Climate Change Risks and Opportunities: Hydrology

Climate Workshop
March 10, 2015

John Rex, PhD, P.Ag.
Research Hydrologist
Omineca Region



Outline

- Background: climate change and development effects on hydrology
- Omineca research products
 - Watershed Health Project
 - Omineca Hydrology Model



Hydrology & Climate Change

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Extension Note

MARCH 2008

R.G. Pike, D.L. Spittlehouse,
K.E. Bennett, V.N. Egginton,
P.J. Tschaplinski,
T.Q. Murdock, and
A.T. Werner

A Summary of Climate Change Effects on Watershed Hydrology¹

The climate of British Columbia is changing, and with these changes will come many adjustments in watershed hydrology and, ultimately, in the use of water-related resources. Yet, because British Columbia is hydrologically diverse, the local responses to these anticipated changes will differ.

Historical Trends in Temperature and Precipitation

Analysis of British Columbia climate data for the last 100 years indicates an overall rise in air temperatures for all seasons, with the greatest warming occurring in the winter. This warming has been greater in northern British Columbia than in the southern and coastal regions. Trends in annual precipitation across British Columbia for the last century are more varied than for temperature. The increase in average annual precipitation is more spatially varied than for temperature, with larger increases occurring in regions with comparatively low annual



precipitation. During the last 50 years there has been an increase in the occurrence of extreme wet and extreme dry conditions in the summer and a decrease in winter snowpack.

Historical Trends in Glacier Recession and Streamflow

Most British Columbia glaciers are out of equilibrium with the current

¹ This summary was extracted with permission from: Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Egginton, P.J. Tschaplinski, T.Q. Murdock, and A.T. Werner. 2008. Climate change and watershed hydrology Part I – Recent and projected changes in British Columbia. Streamline Watershed Management Bulletin. Vol. 11, No. 2. Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Egginton, P.J. Tschaplinski, T.Q. Murdock, and A.T. Werner. 2008. Climate change and watershed hydrology Part II – Hydrologic implications for British Columbia. Streamline Watershed Management Bulletin. Vol. 11, No. 2.

Please refer to these documents for more information and full citations.

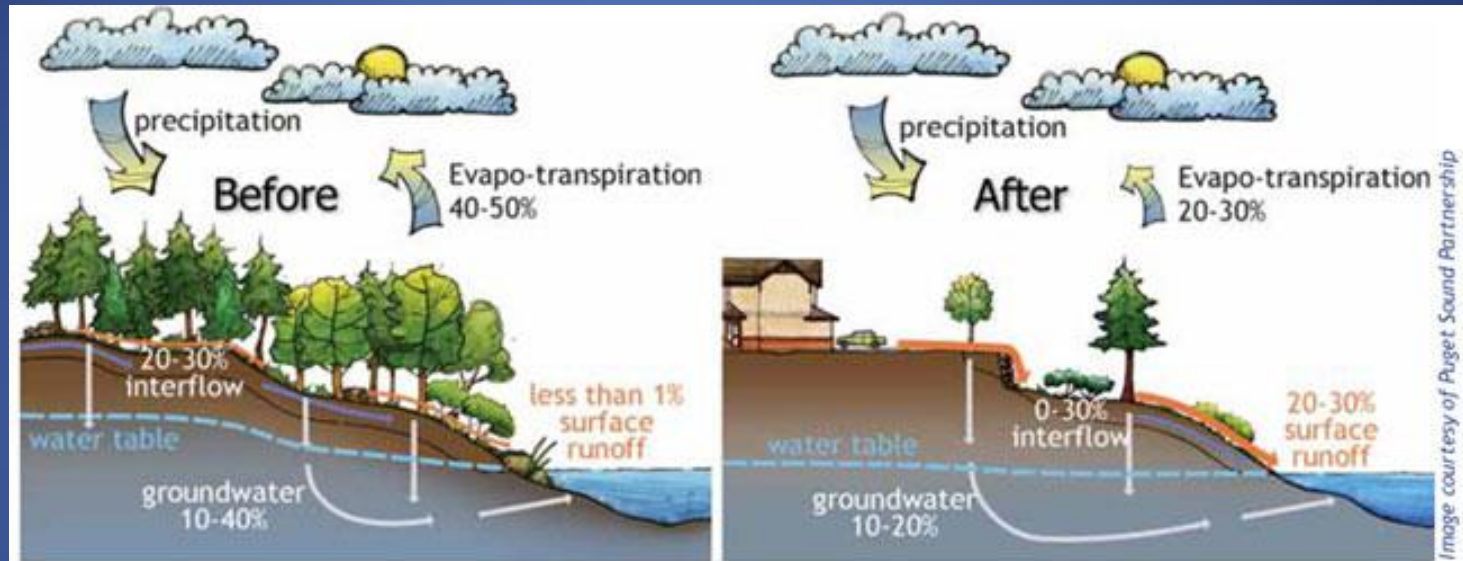
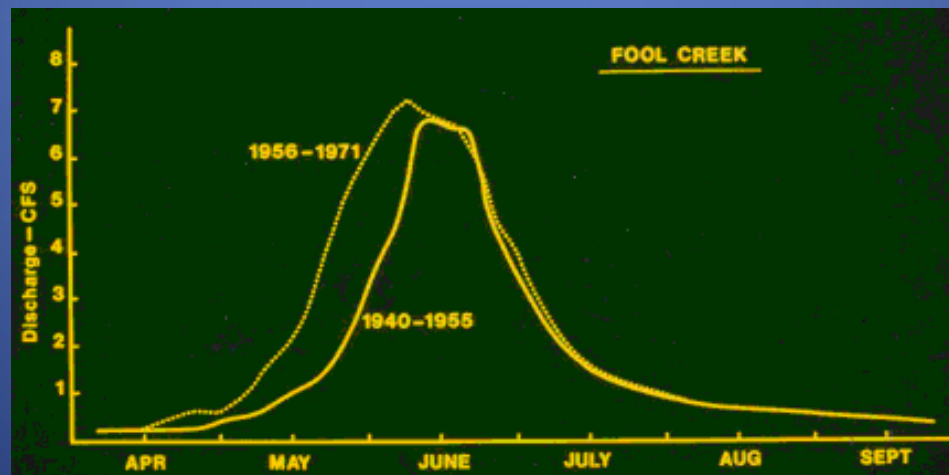


Ministry of Forests and Range
Forest Science Program

- Increased atmospheric evaporative demand
- Altered vegetation composition affecting evaporation and interception
- Increased stream and lake temperatures
- Increased frequency and magnitude of storm events and disturbances
- Accelerated melting of permafrost, lake ice, and river ice
- Decreased snow accumulation and accelerated snowmelt
- Glacier mass balance adjustments
- Altered timing and magnitude of streamflow

Hydrology and Resource Development

- Water Quantity



Hydrology and Resource Development

- Water Quality – Physical and chemical changes

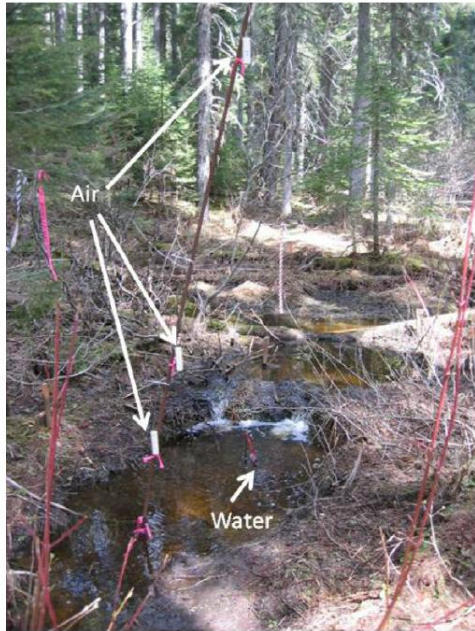
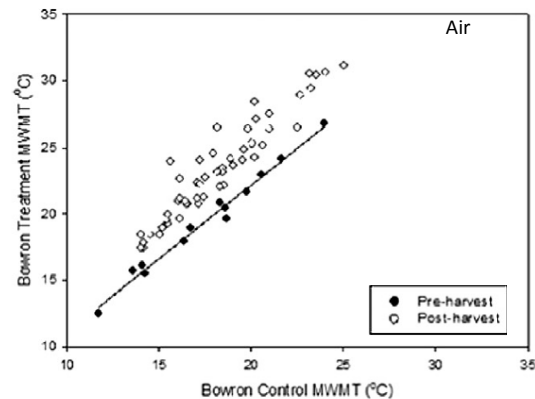
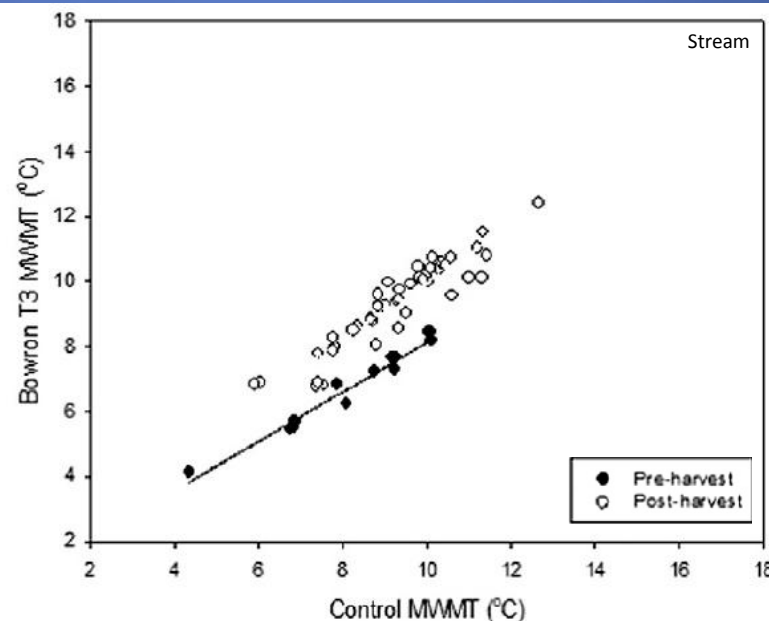


Fig. 2. Study stream showing placement of air temperature probes at 0.5, 1.0, and 2.5 m along with the water temperature probe in the thalweg.

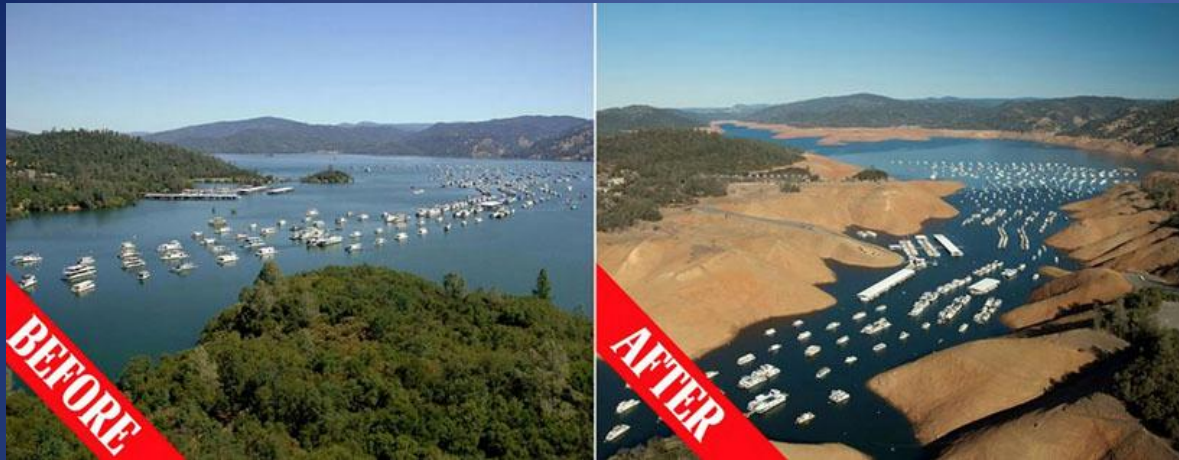
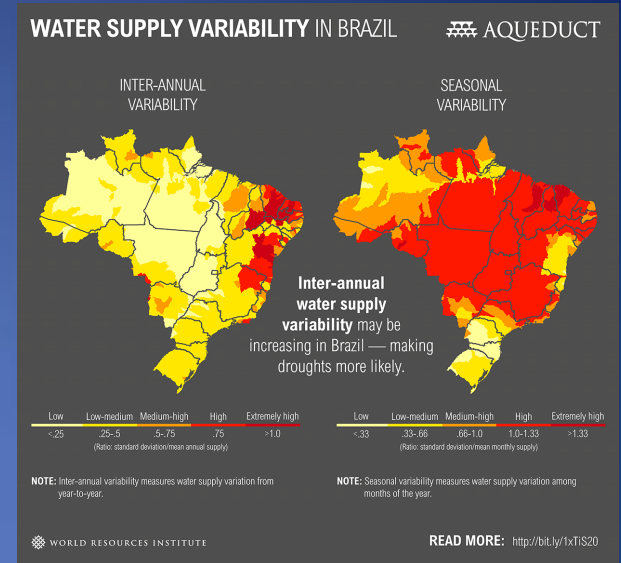
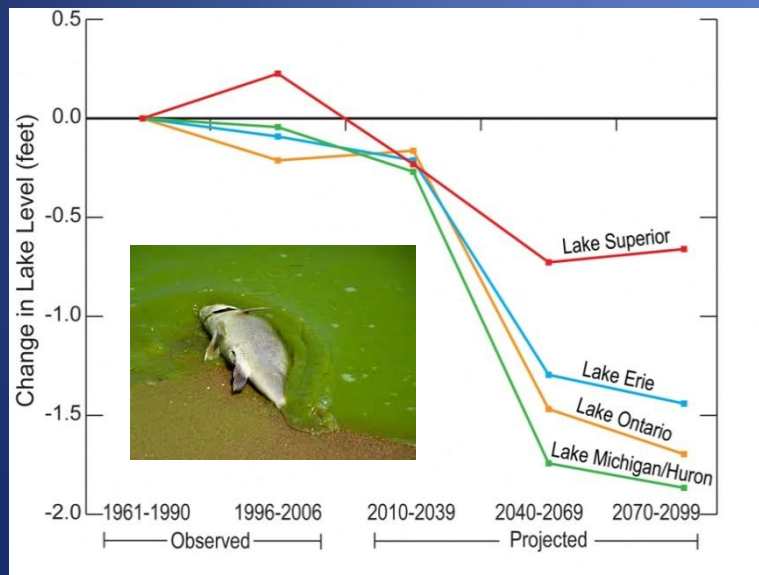
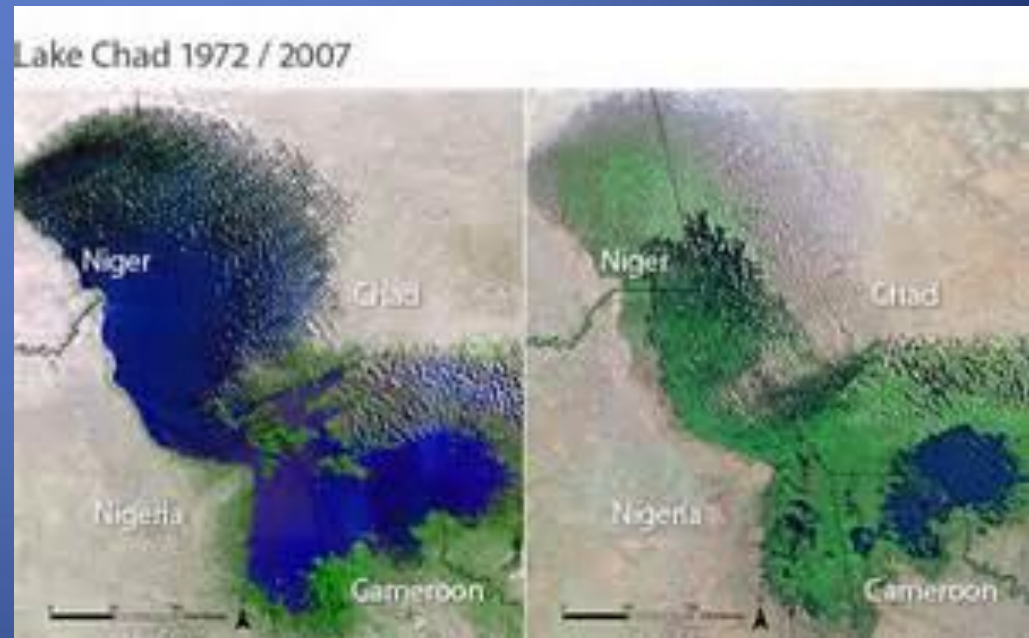


http://www.for.gov.bc.ca/hre/ffip/Stuart_Takla.htm



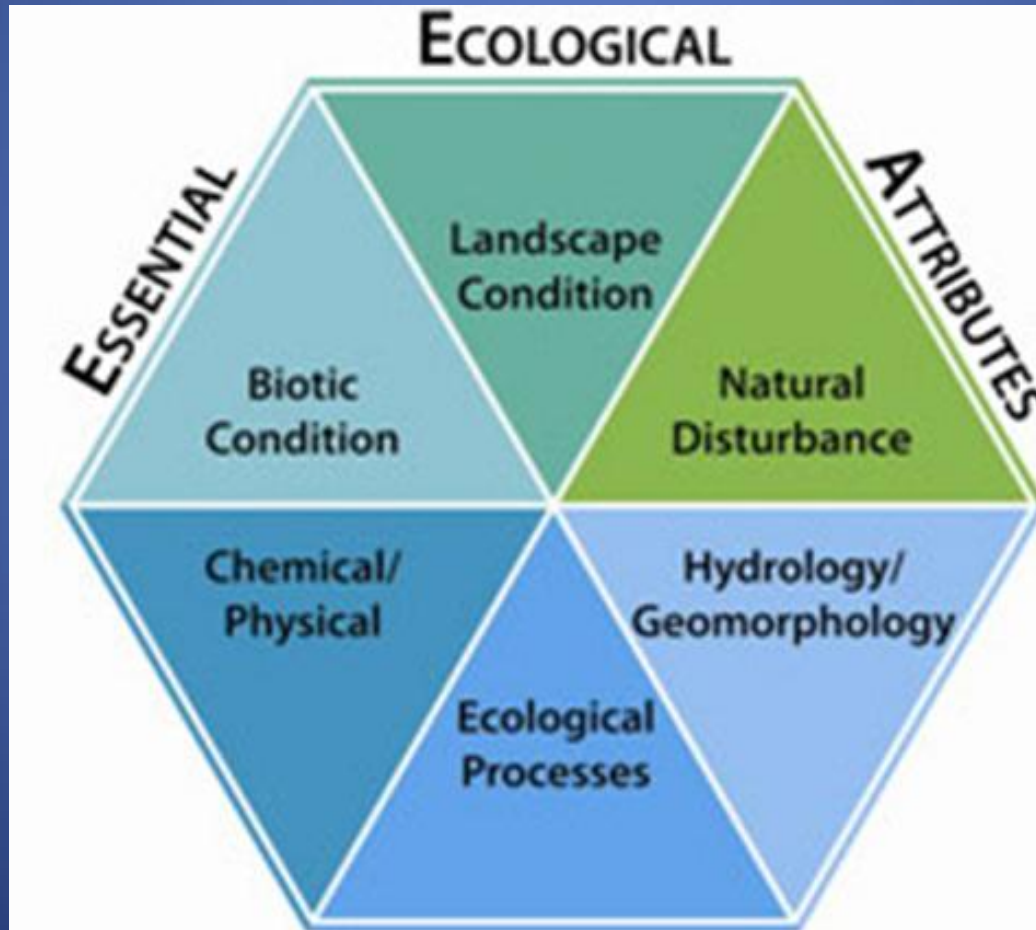
Source: Fish-Forest interaction webpage, Jnl. Forest Ecology and Management

Global Issue



Sources:
 EPA, World Resources Institute, UNESCO,
 Southbay Residential, Niagra at large

Regionally: Watershed Health Project Omineca Region

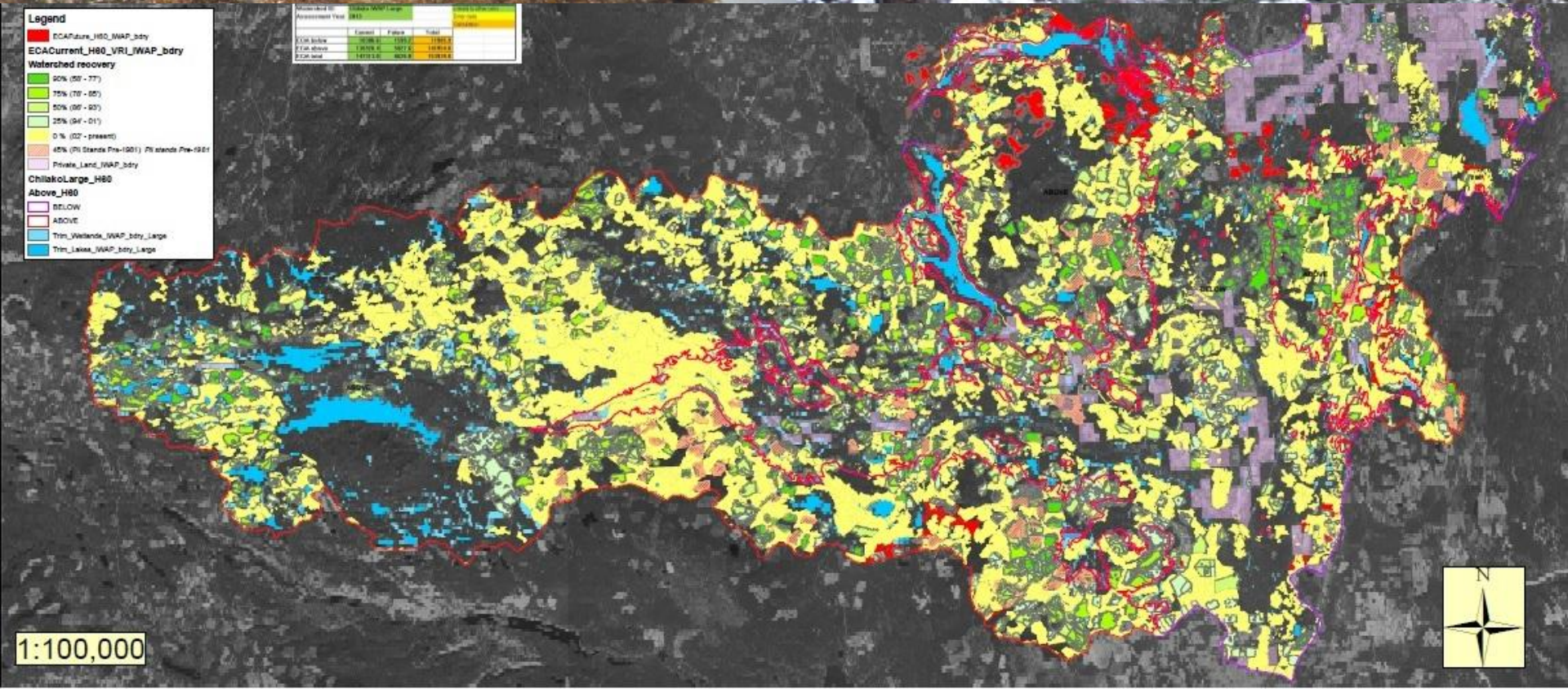


Topics

- Why?
- Project Framework
- Risk Assessment Process
- Demonstration Results
- Validation Process
- Timeline



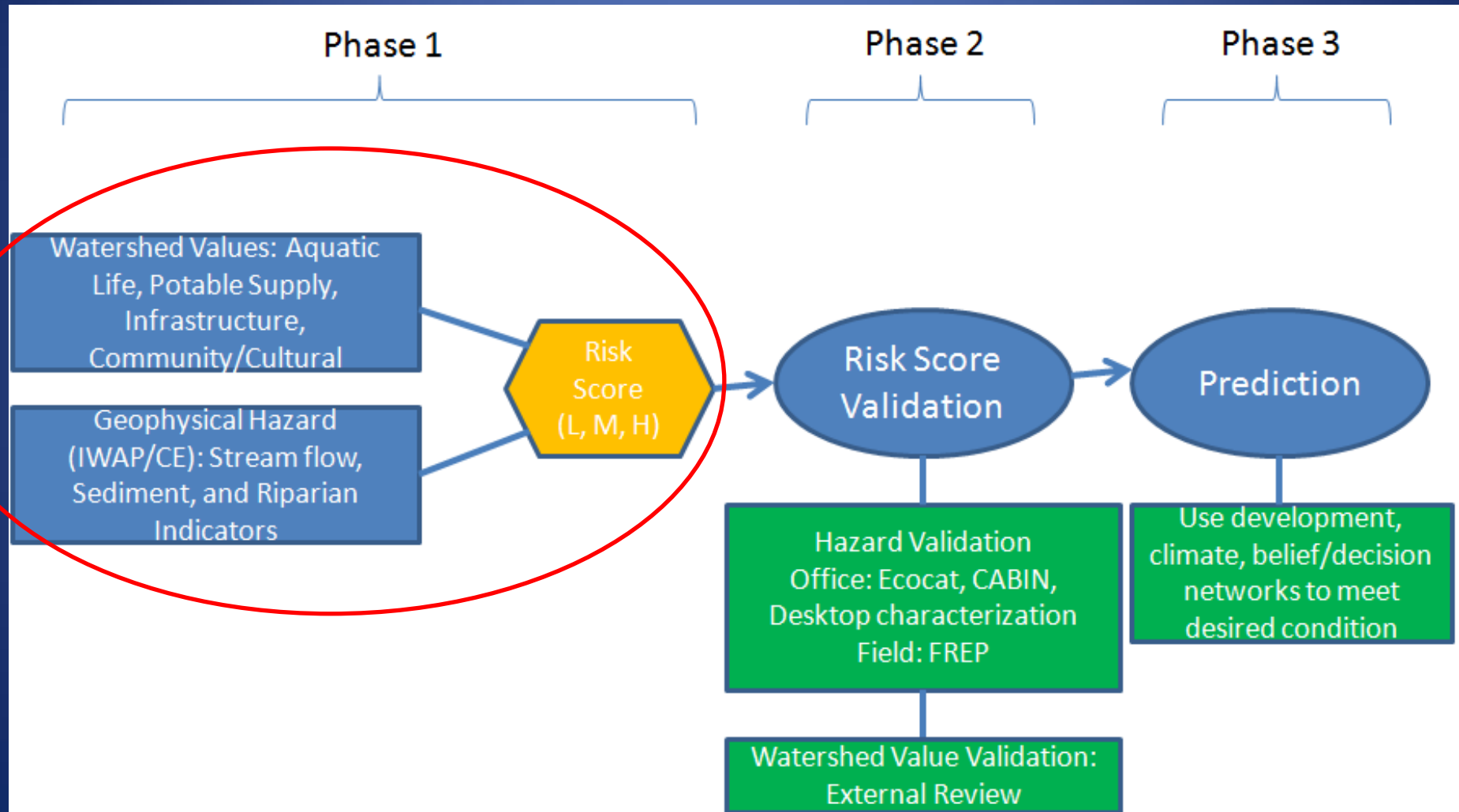
Why



Team (Extended)

- Collaborative FLNRO effort:
 - Representation of all resource districts including stewardship, tenures, GIS, and BCTS.
 - Regional GIS team,
 - Regional resource specialist, land base stewardship biologists, and research hydrologist,
 - Director Resource Management.
- Other involved or interested agencies:
 - External consulting agencies,
 - Government and NGO collaborators or cooperative agencies.

Framework



Assessment Process: Geophysical

- Based on IWAP and Thompson –Okanagan Cumulative Effects Project (Doug Lewis, Bill Grainger, and Michael Milne).
- Three hazard indices: stream/peak flow, sediment, and riparian.
- Hazard indices consider watershed sensitivity to hazard, land-use effect, attenuation.
- Hazard score identified as low to high, relative measure.

Stream/Peak Flow

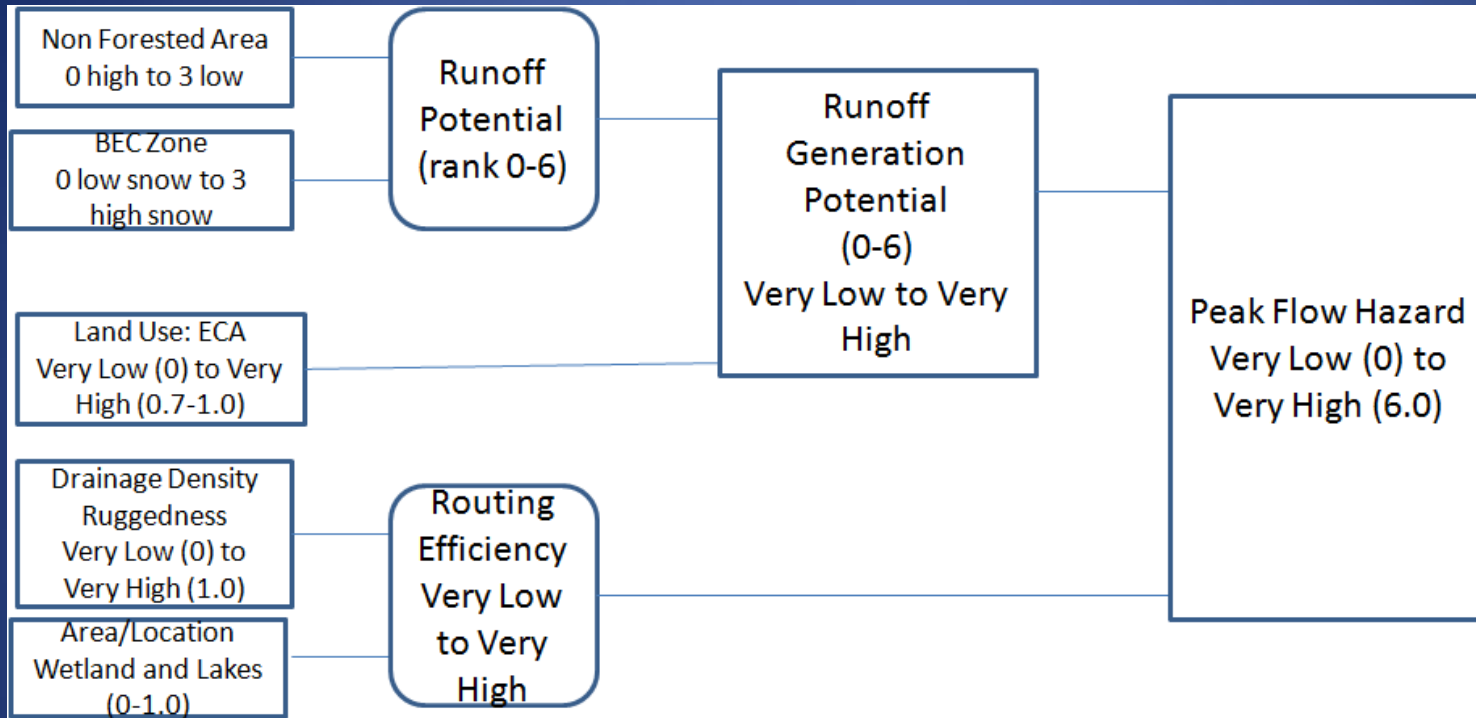
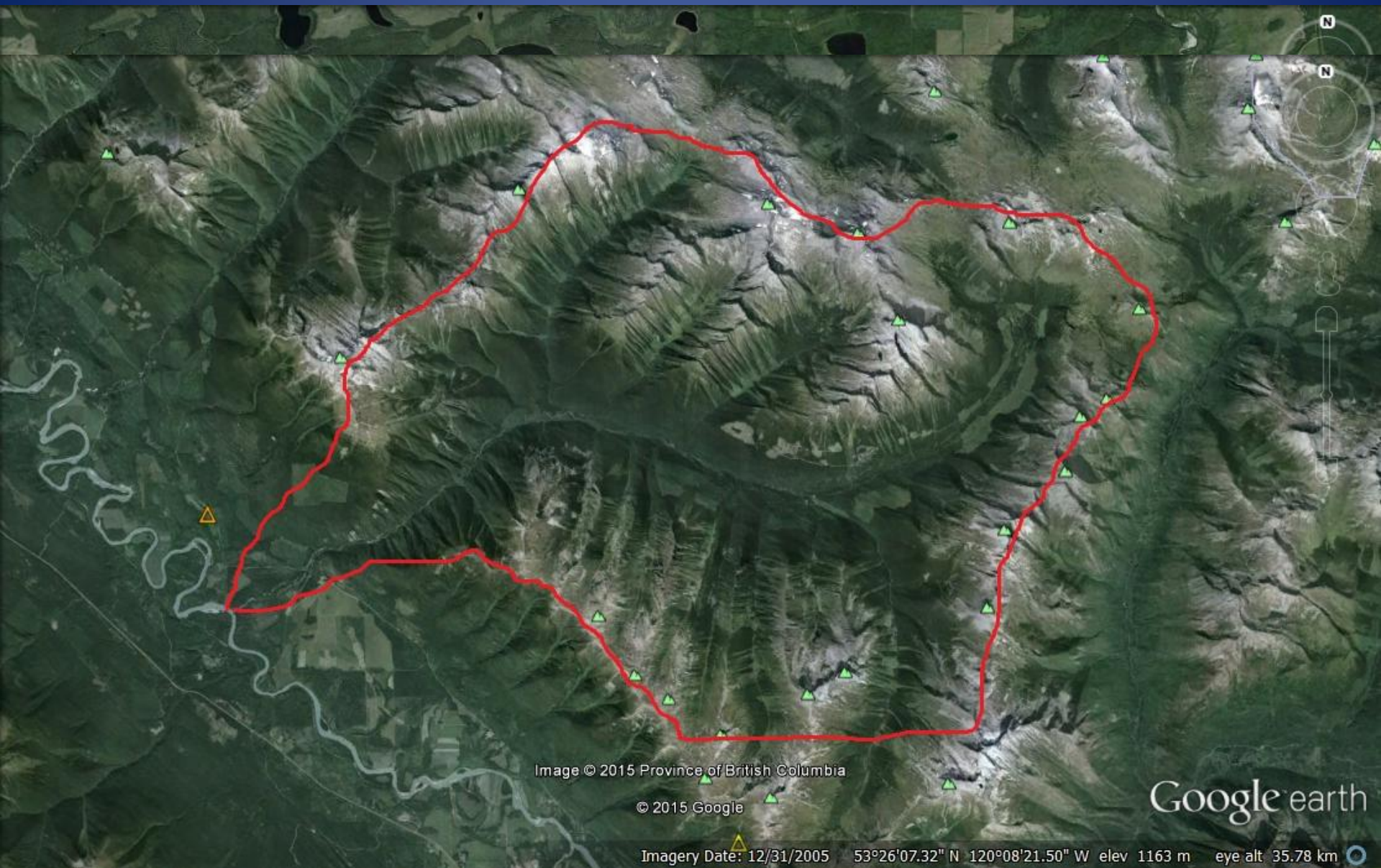


Table 7. Peak Flow Hazard Rating matrix derived from Runoff Generation Hazard and Routing Efficiency ratings.

		Routing Efficiency Ratings				
		Very Low	Low	Mod	High	Very High
Runoff Generation Potential Hazard	Very Low	VL	VL	L	L	M
	Low	VL	L	L	M	H
	Mod	L	L	M	H	H
	High	L	M	H	H	VH
	Very High	M	H	H	VH	VH



Watershed boundaries drawn for example not for accuracy

Sediment

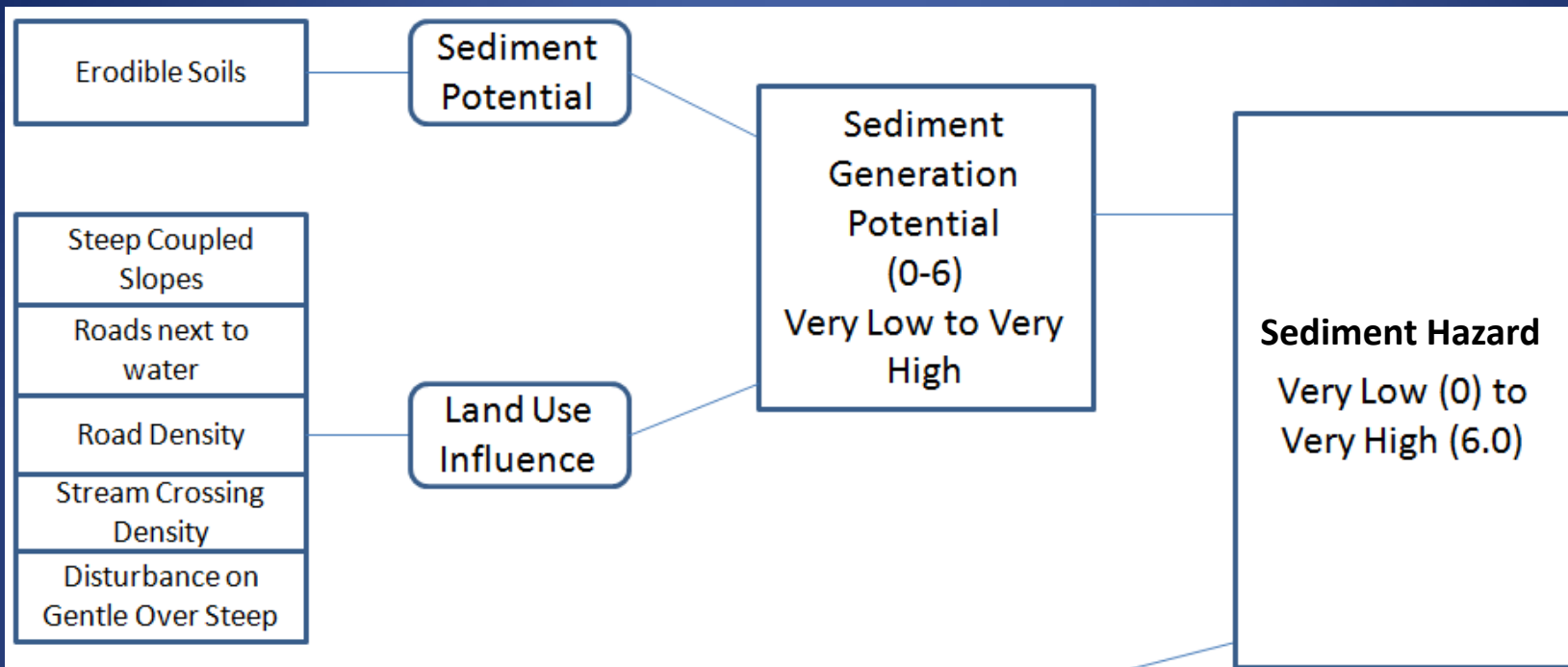


Table 7. Sediment hazard rating based upon generation hazard and routing efficiency ratings.

		Routing Efficiency Ratings				
		Very Low	Low	Mod	High	Very High
Sediment Generation Potential	Very Low	VL	VL	L	L	M
	Low	VL	L	L	M	H
	Mod	L	L	M	H	H
	High	L	M	H	H	VH
	Very High	M	H	H	VH	VH

EXTREMELY HIGH
(4.7+ mi./sqmi.)
Upper Coeur d' Alene 0406
Actual Density 10.85 mi./sqmi.



HIGH
(1.7 - 4.7 mi./sqmi.)
Methow 11
Actual Density 2.06 mi./sqmi.



ROAD DENSITIES

By ICBEMP SubSample Watersheds

LEGEND

 Streams

 Roads

MODERATE
(.7-1.7 mi./sqmi.)
South Fork Salmon 1501
Actual Density 1.34 mi./sqmi.



VERY LOW
(.02-.1 mi./sqmi.)
Example
Actual Density .08 mi./sqmi.

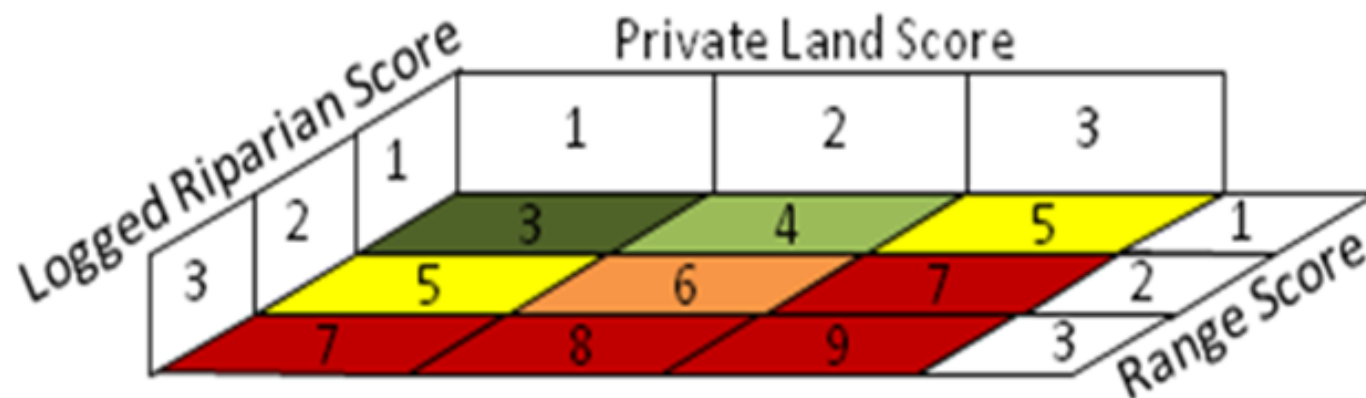


LOW
(.1-.7 mi./sqmi.)
Methow 56
Actual Density .3 mi./sqmi.

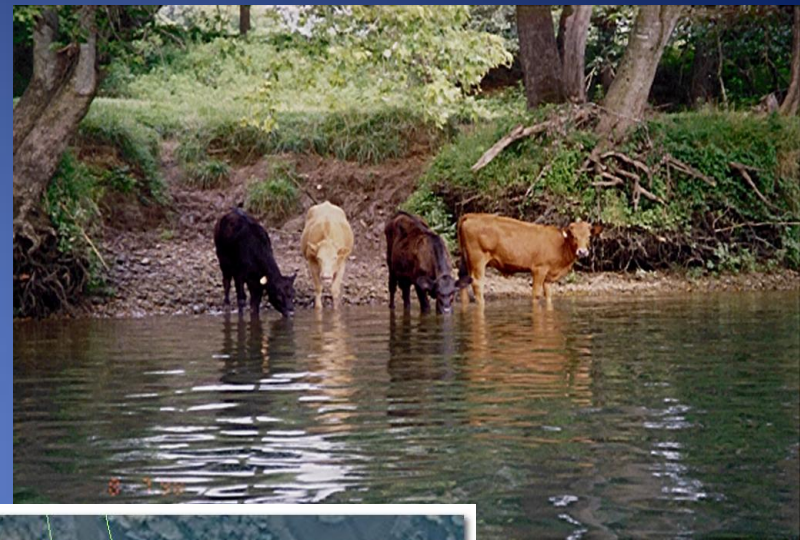
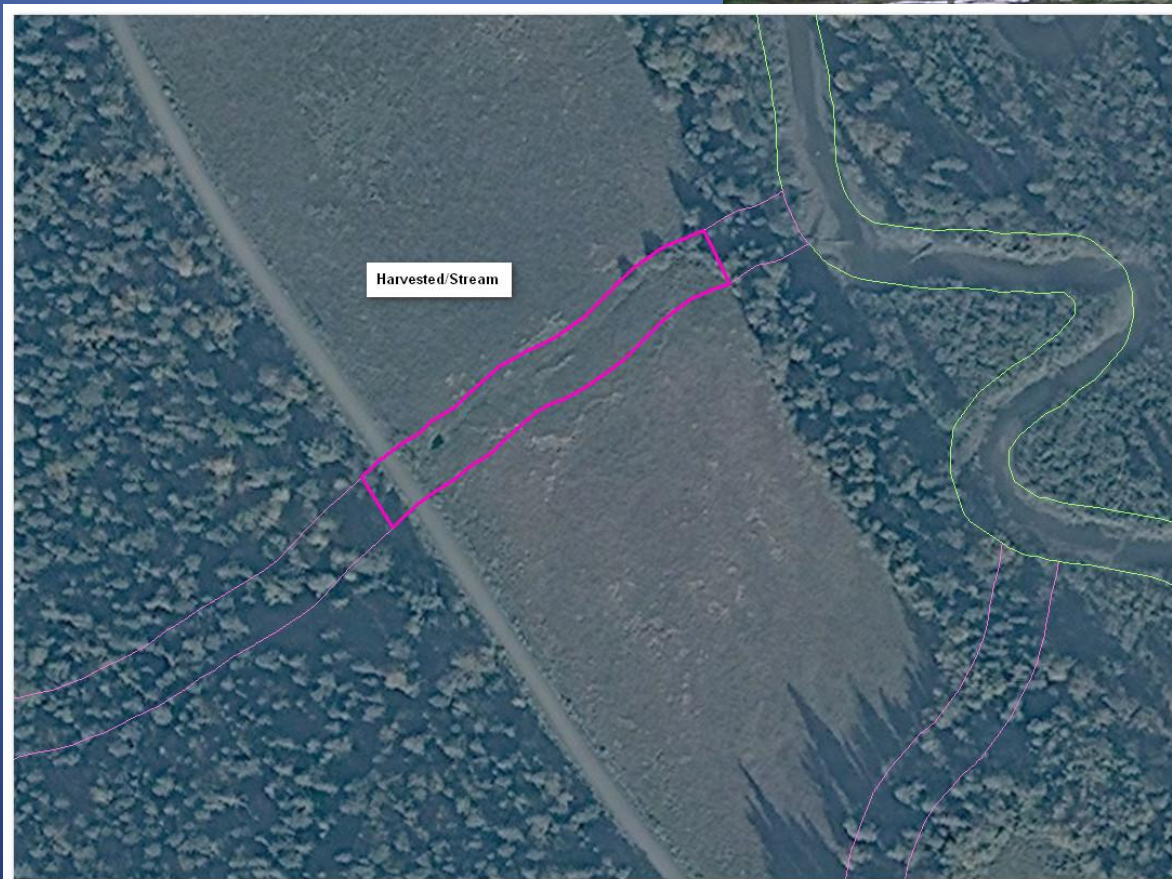


Riparian

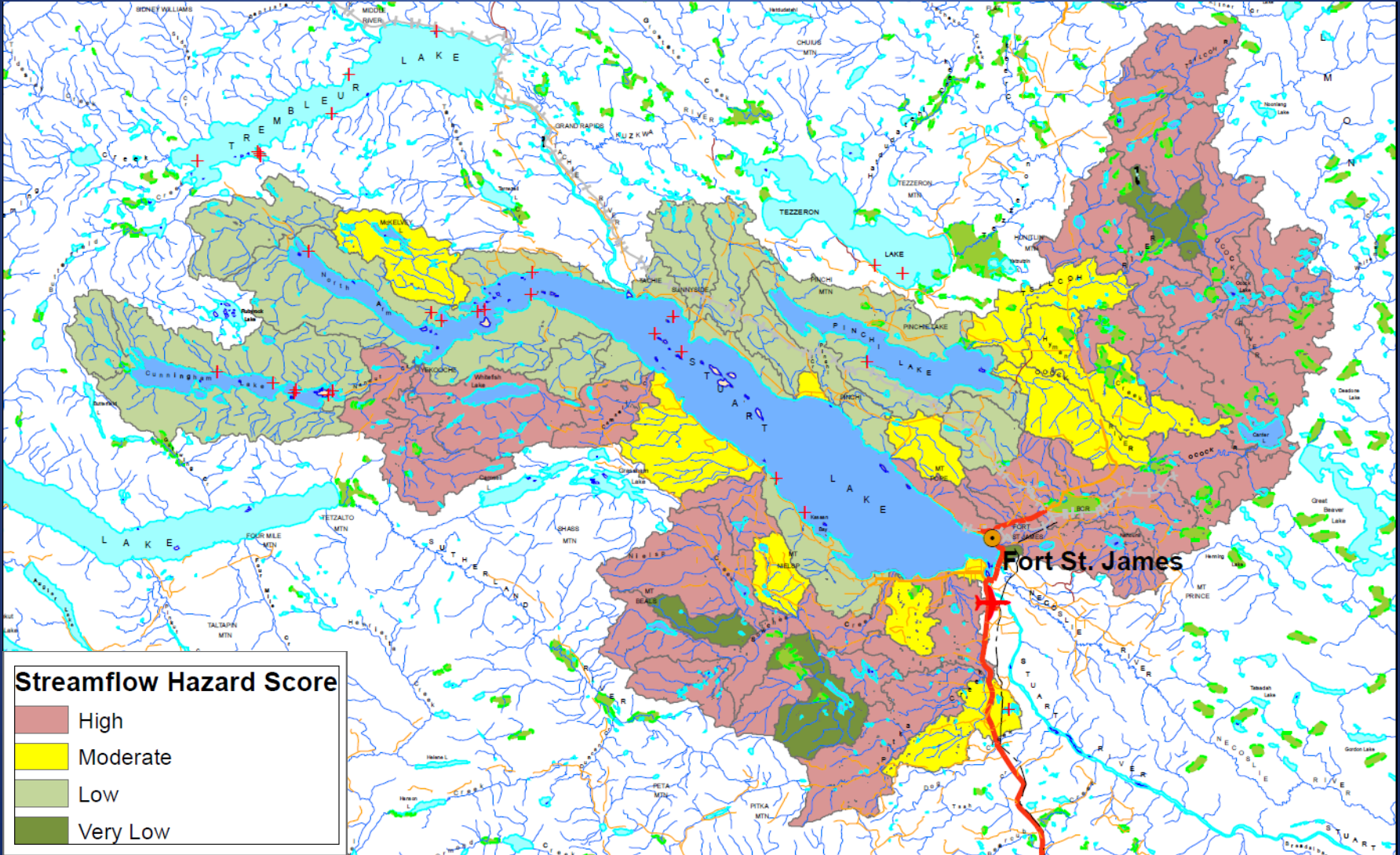
Private Land	<20%	21-40%	>40%	Percentage of total stream length within or adjacent to private land
Logged Riparian	<20%	21-40%	>40%	percentage of total stream length within or adjacent to cutblocks
Range	<40%	40-70%	>70%	percentage of total stream length within active range



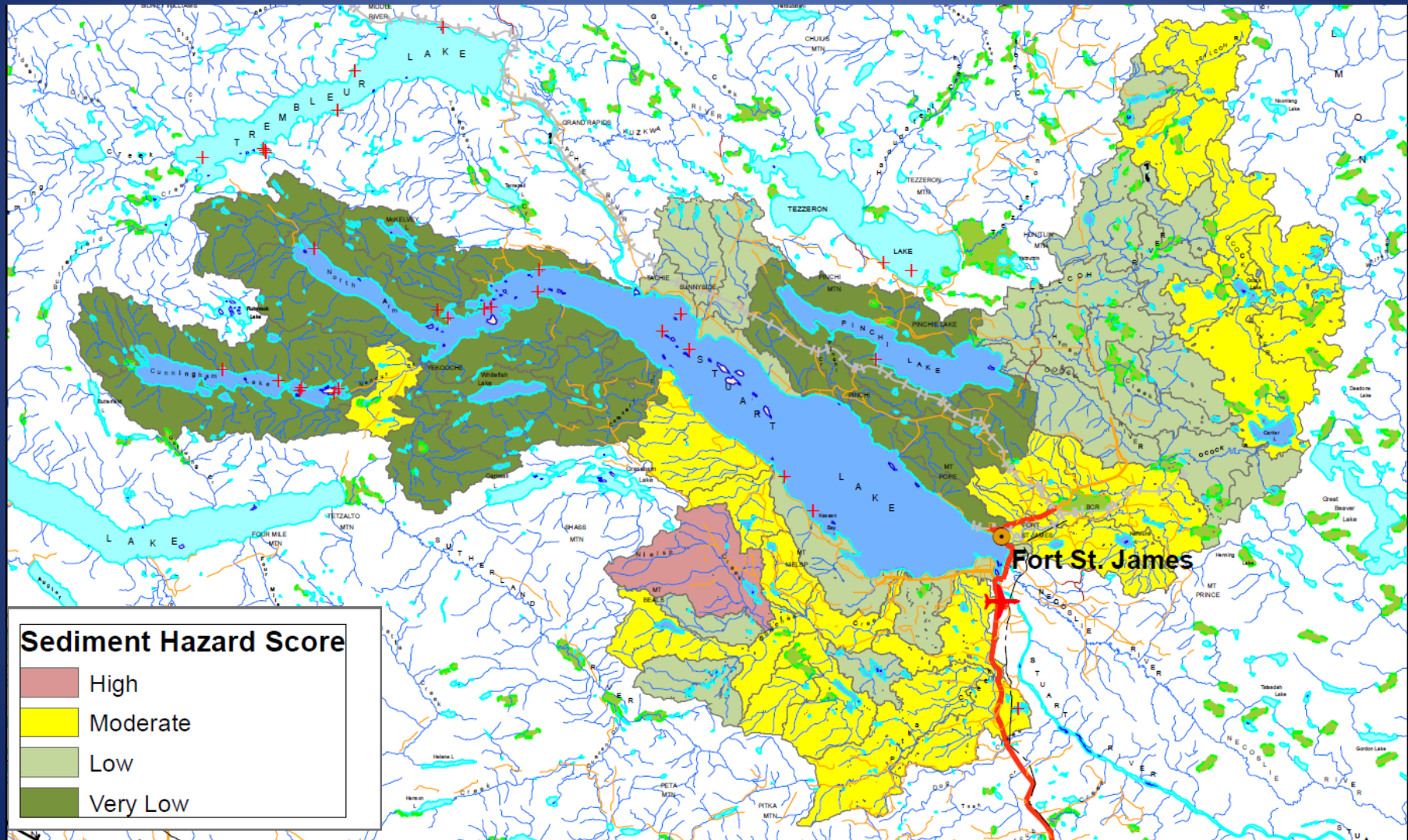
Riparian hazard matrix used to derive a riparian hazard rating from the combined scores of three land use indicators



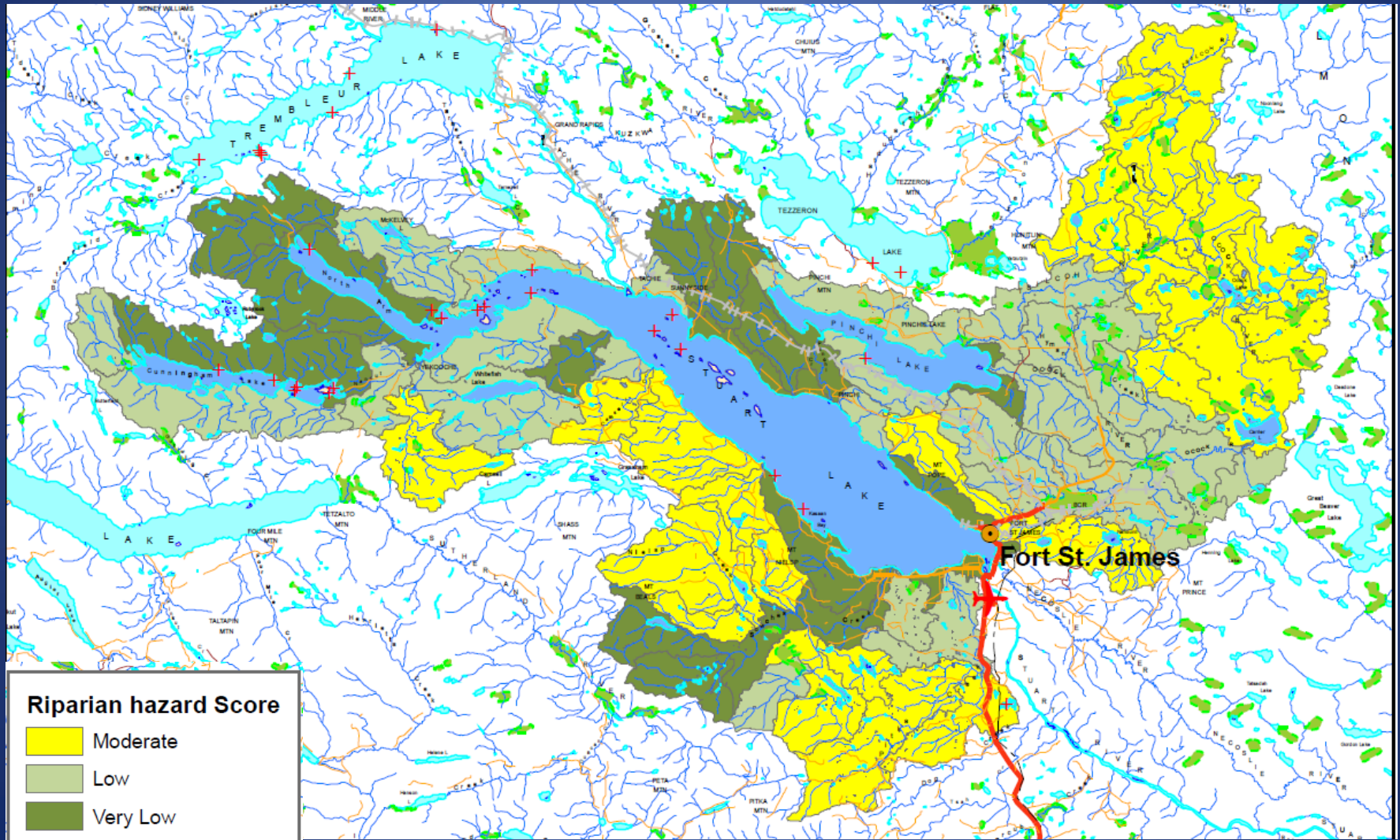
Sample Results: Stuart Lake Peak Flow (Demonstration Only)



Sediment Hazard (Demonstration only)

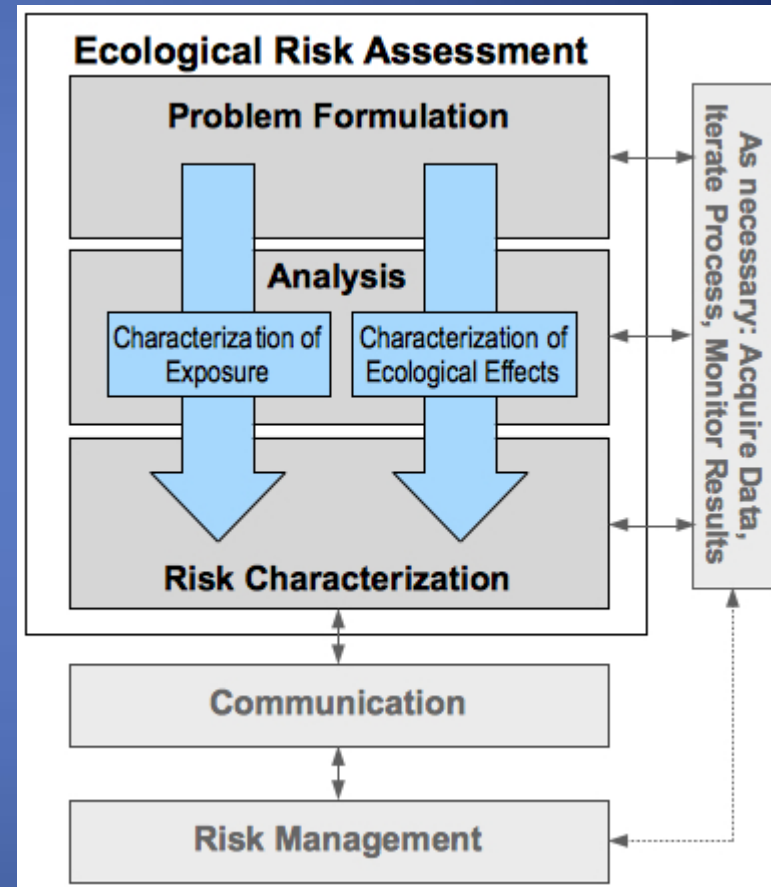


Riparian Hazard (Demonstration Only)



Risk Assessment

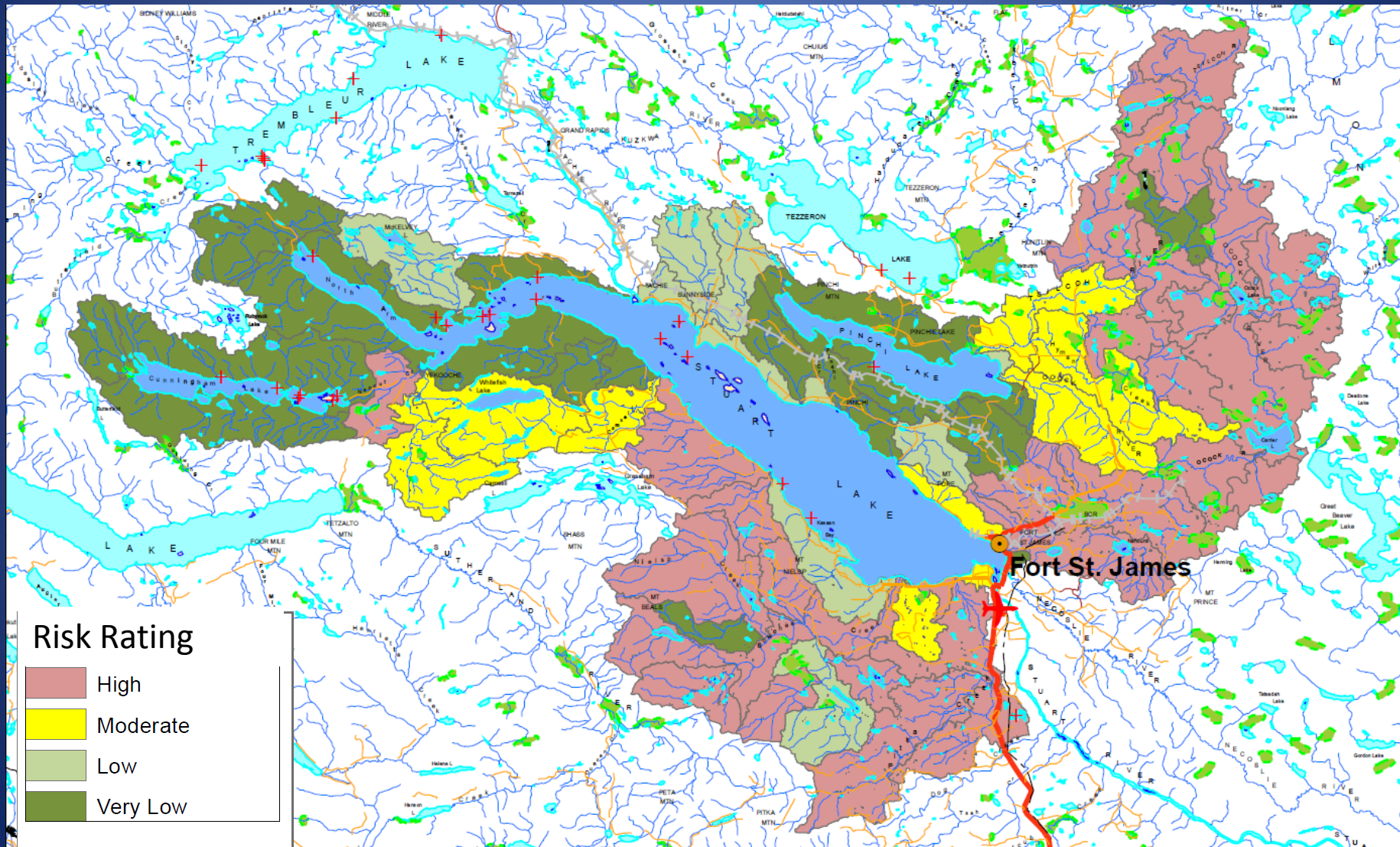
- Classic Definition:
 - Risk= Hazard * Consequence
 - We have three geophysical hazards
 - Level of consequence is determined by the value being managed.
- Aquatic based values include potable supply, aquatic life, community/culture, and infrastructure



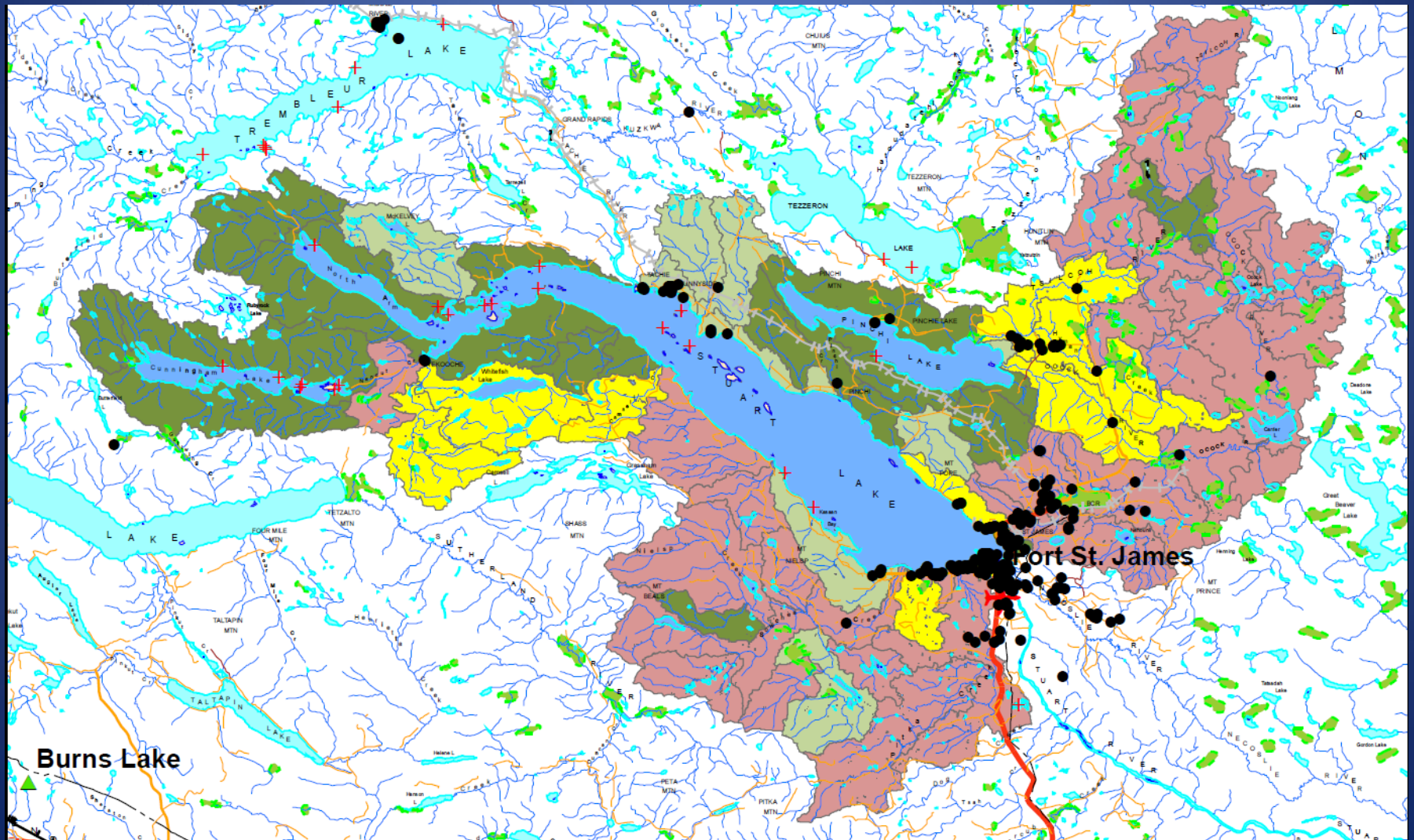
Risk Assessment: Potable Supply

		Peak Flow						
		Very Low	Low	Mod	High	Very High		
Sediment Hazard	V Low	VL	VL	L	M	H	Very Low	
	Low	VL	L	M	H	H	Low	
	Mod	L	M	H	H	H	Mod	
	High	M	H	H	H	VH	High	
	Very High	H	H	H	VH	VH	Very High	
								Riparian Hazard

Risk Assessment: Aquatic Life and Potable Supply (Demonstration Only)

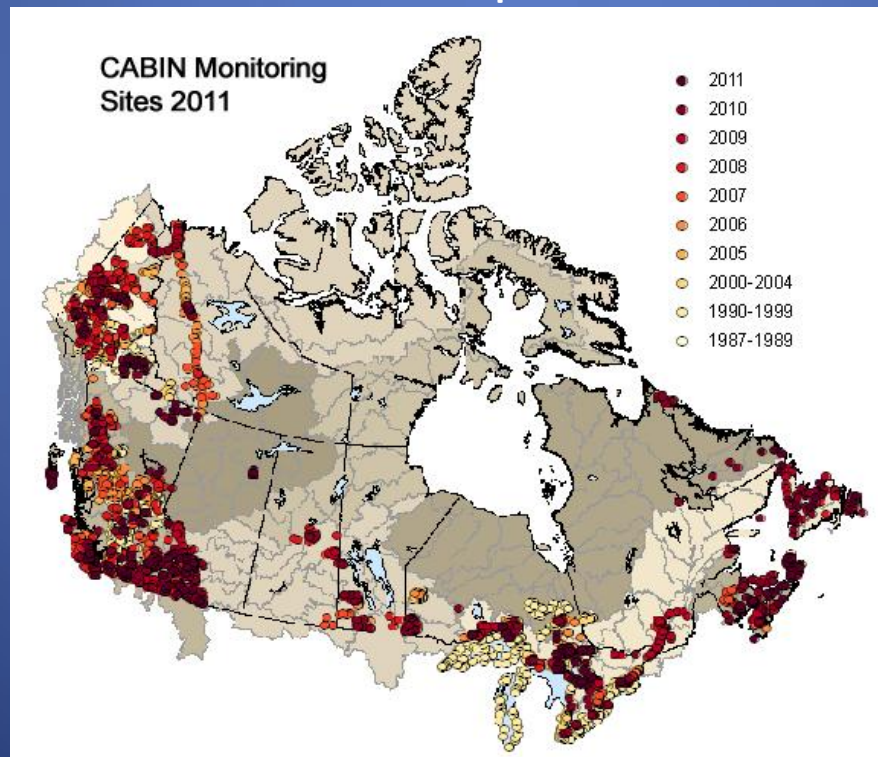


Risk Assessment: Water License POD (Demonstration only)



Validation Assessment

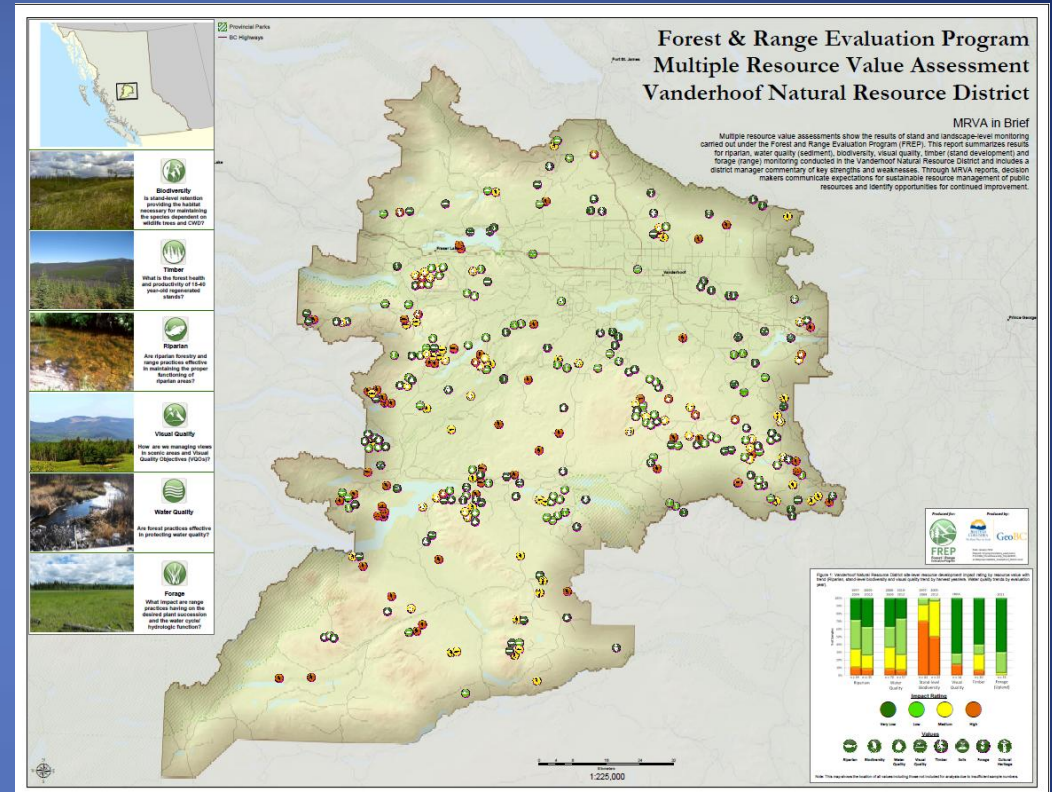
- Objective: identify validity of GIS assessment
- Approaches:
 - Office-based includes Watershed Characterization, CABIN, existing FREP data
 - Field-based includes FREP protocols



2013



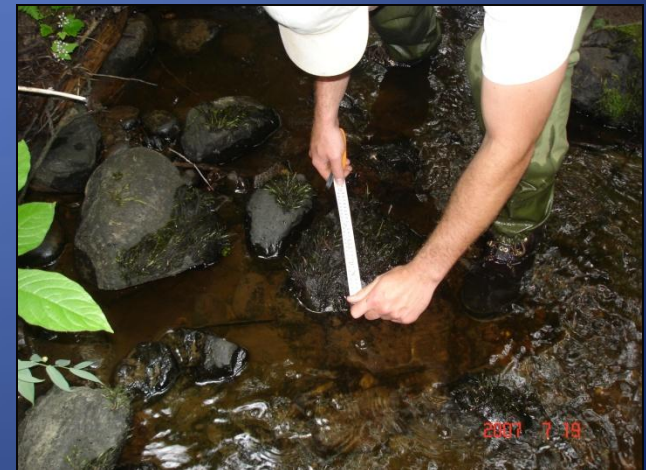
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- 1.1 Information Resources.....
- 1.2 Previous Studies
- 1.3 Maps
- 1.4 Air Photos/Remotely Sensed Images.....
- 1.5 Watershed Climate
- 1.6 General Hydrology and Drainage Characteristics
- 1.7 Sediment, Stream Channels, and Sediment Yield Potential.....
- 1.8 Land Uses and Natural Disturbances Checklist

Field-Based: FREP Stream/Riparian

- The evaluation has 15 indicator questions:
 - Stream indicators
 - 1. Channel bed disturbance
 - 2. Channel bank disturbance
 - 3. Large woody debris processes (jams)
 - 4. Channel morphology
 - 5. Aquatic connectivity
 - 6. Fish cover diversity
 - 7. Moss abundance and condition
 - 8. Fine sediments
 - Riparian indicators
 - 9. Aquatic invertebrate diversity
 - 10. Windthrow frequency
 - 11. Riparian soil disturbance
 - 12. LWD supply
 - 13. Shade and bank microclimate
 - 14. Disturbance increaser plants
 - 15. Vegetation vigour, form, and structure



Key characteristics of healthy streams and their riparian habitat

Field-Based: FREP WQEE



Road Related

- 1 All road stream crossings (bridge and culvert) Some streams may be missing from TRIM maps and, upon discovery of such streams in the field, will be added to sites requiring evaluation.
- 2 Inter-drainage culverts. Road segments located within 20 meters of stream or lake, or where there is a chance that road drainage reaches the natural water body.
- 3 Road generated slope failure. Any failure either immediately above or below road. (These will not generally be known until the field visit).

Harvesting Related

- 4 Harvesting/yarding within or adjacent to riparian zone.
- 5 Skidder/mechanized harvester trails in proximity to riparian zone.
- 6 Harvesting generated slope failure (all new failures within or below cutblock).
- 7 Other forestry harvesting disturbances resulting in bare, unvegetated soil.

Silviculture Related

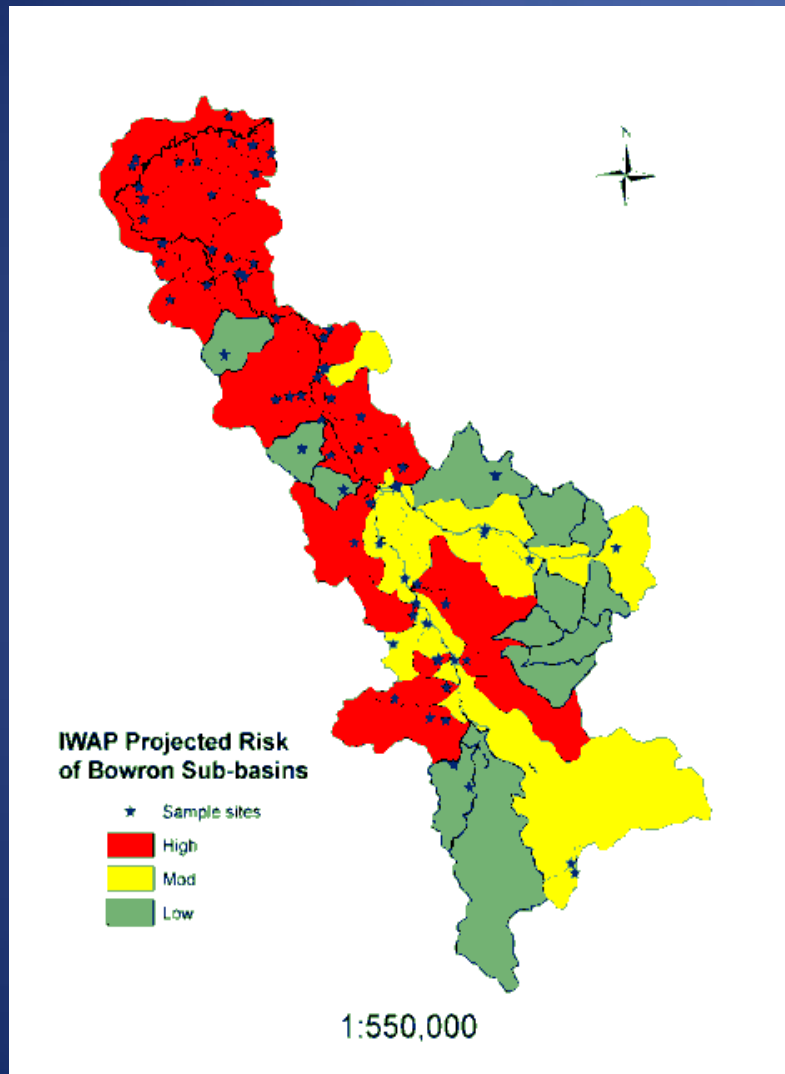
- 8 Silvicultural-related-activities leading to water quality degradation.

Livestock Related

- 9 Livestock presence noted within riparian zone and stream channel. Where livestock presence is noted, the site will require further evaluation using Range Checklist Indicator Sheet. (Form 3)

Sampling Design

- Selected watersheds will each be assessed using office and field-based technique.
- Stratified Random Sampling:
 - Strata – Watershed Risk Class
 - Randomly select watersheds in each class.
 - Randomly select transects/stream reaches.



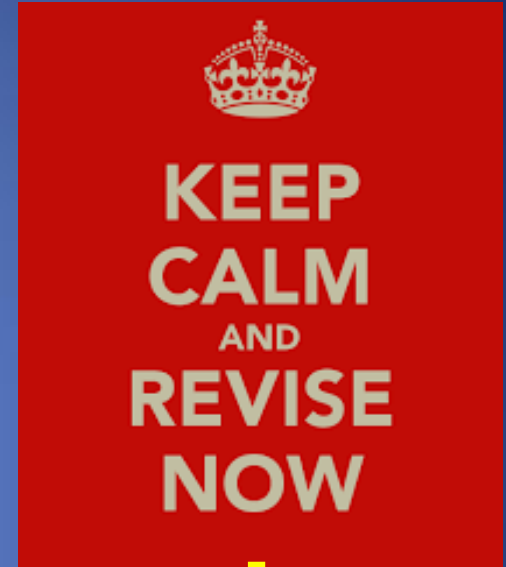
Implications: Potential Outcomes



Existing GIS model
effectively
predicted field
conditions



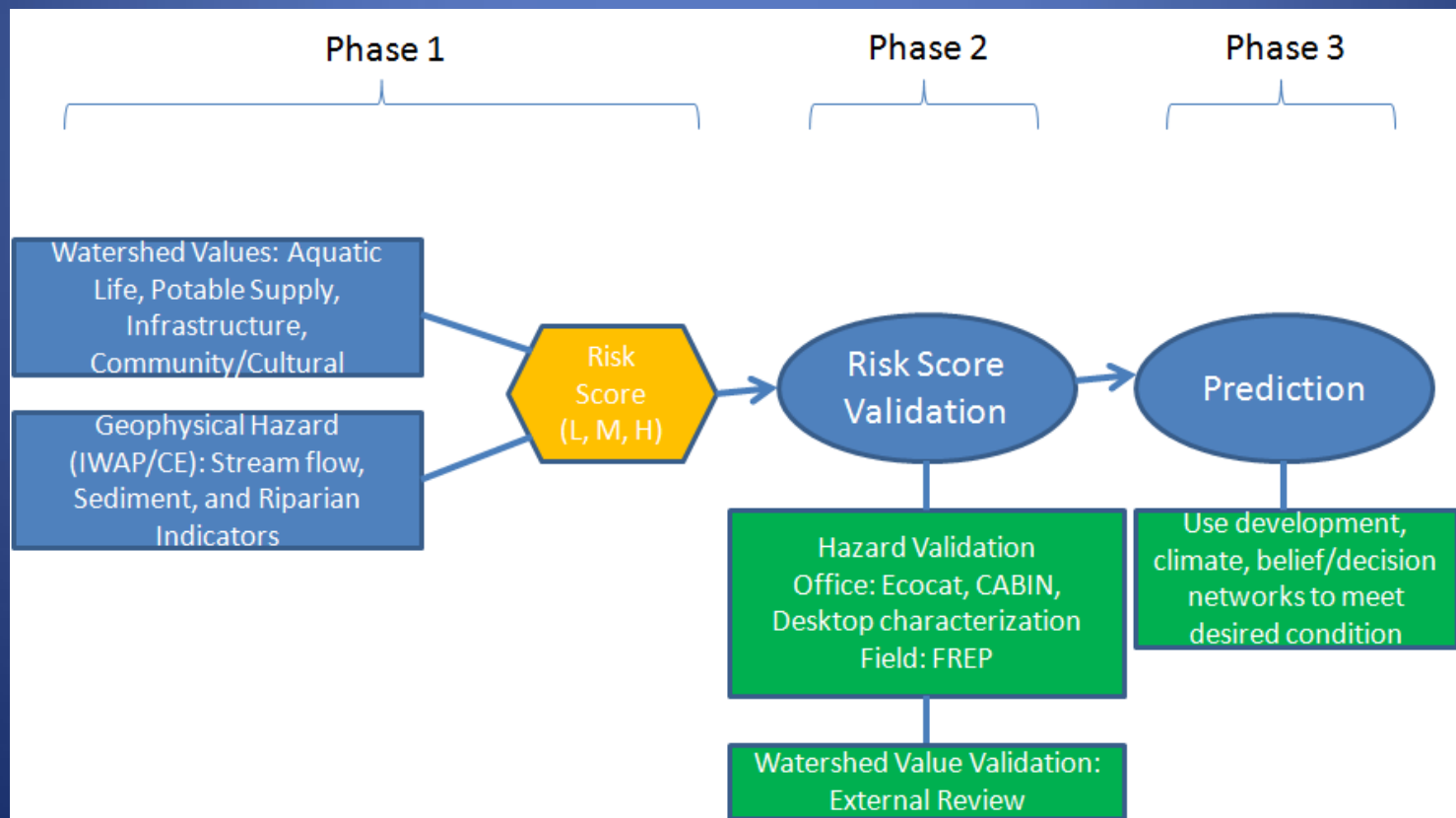
Assessment
identified need for
re-weighting the GIS
variables or addition
and/or removal of
factors



Significant revision and
potentially more
validation assessment

Applications

- Identifying baseline conditions – Spring 2016,
- Potential future conditions,
- Engaging discussion and stimulating planning.



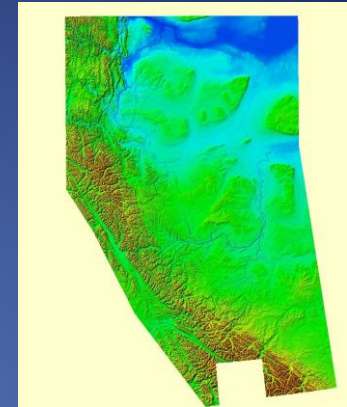
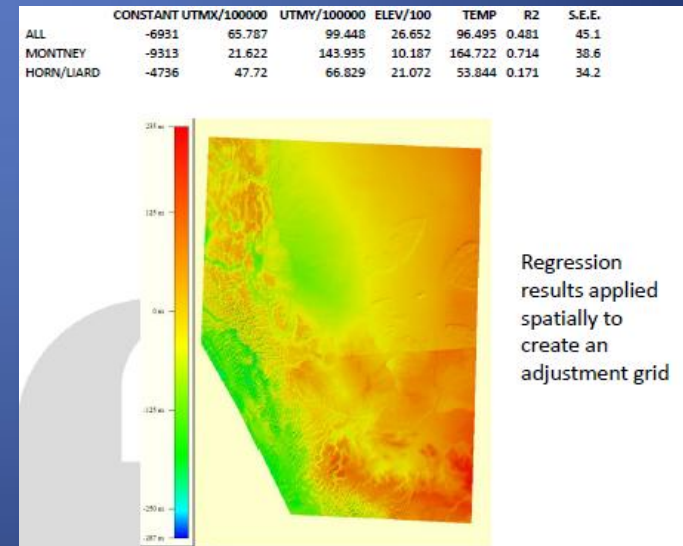
Omineca Hydrology Model

- Building upon success of the Northeast and Northwest Water Tools (OGC -Allan Chapman, Foundry Spatial- Ben Kerr, and FLNRO- Dave Wilford & Scott Jackson)
- Models monthly discharge and identifies environmental flow needs as well as existing allocations.



Process Overview

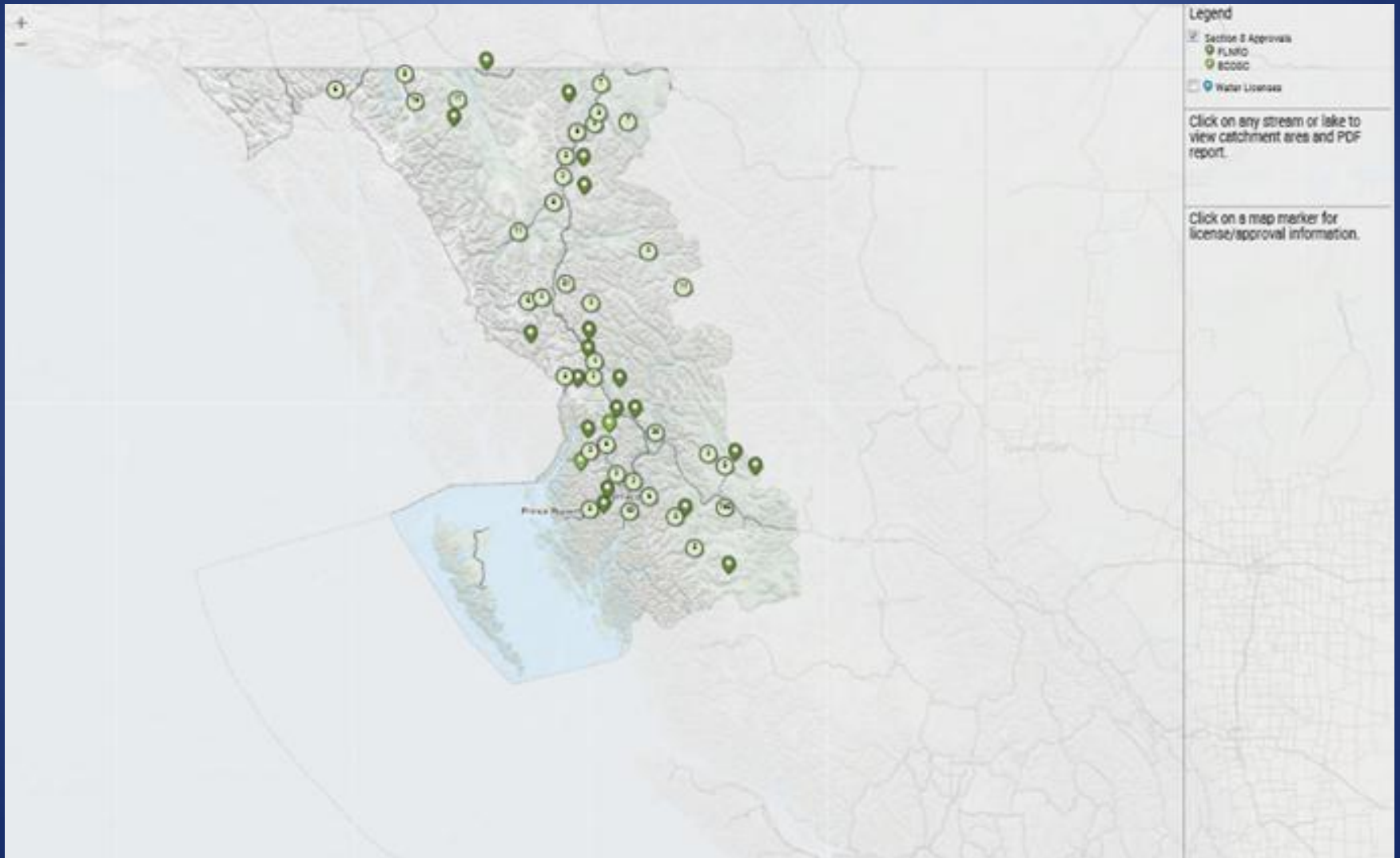
- Water balance model using: topography, climate, evapotranspiration, vegetation, hydrometric information (123 gauged basins in BC and Yukon).
- Region specific regressions used to adjust for difference between modeled and actual runoff.
- Validation process identified a mean error <3%, predicted monthly runoff within $20\% \pm 80\%$ of time.



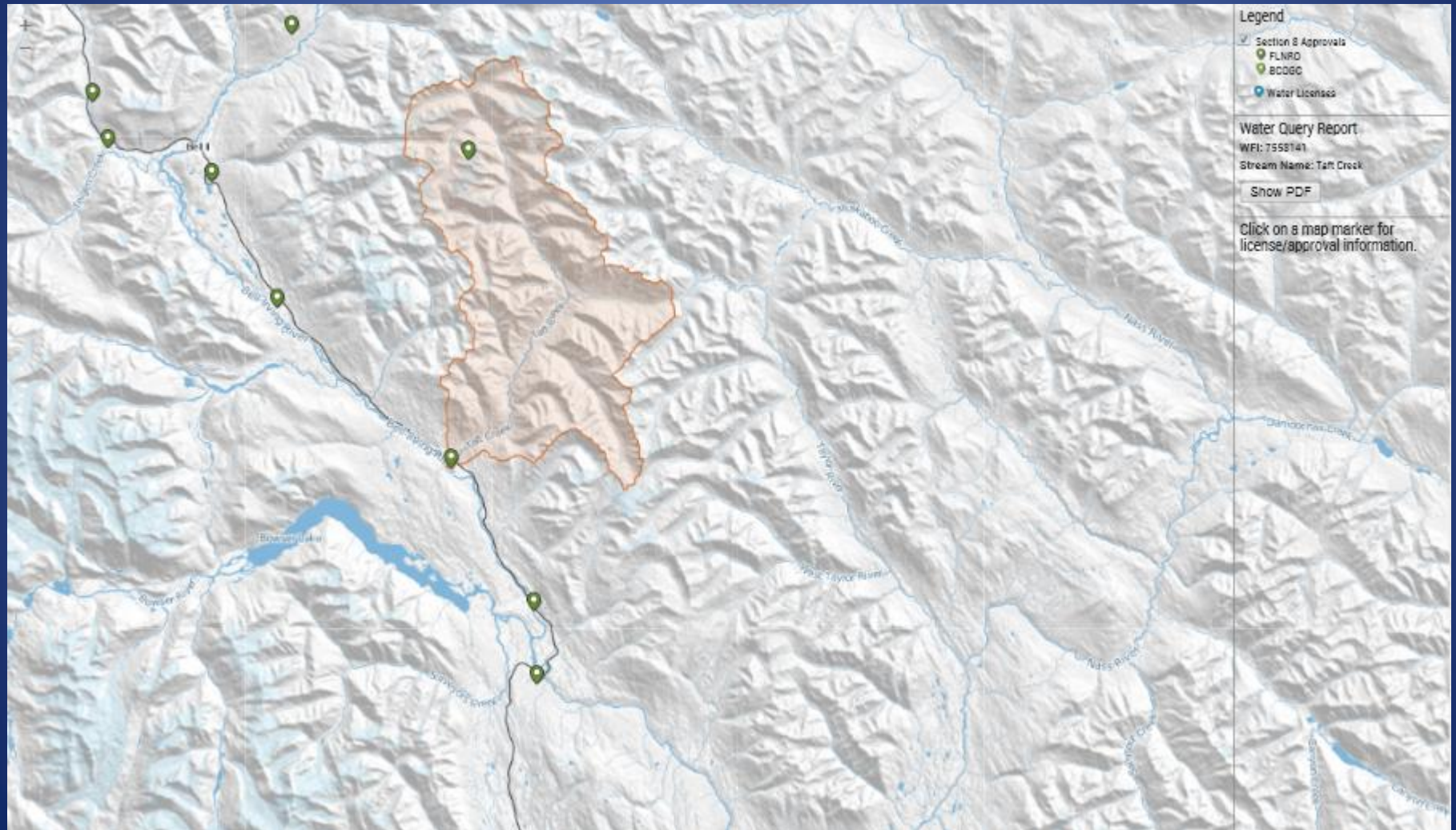


<https://www.bcogc.ca/public-zone/water-information>

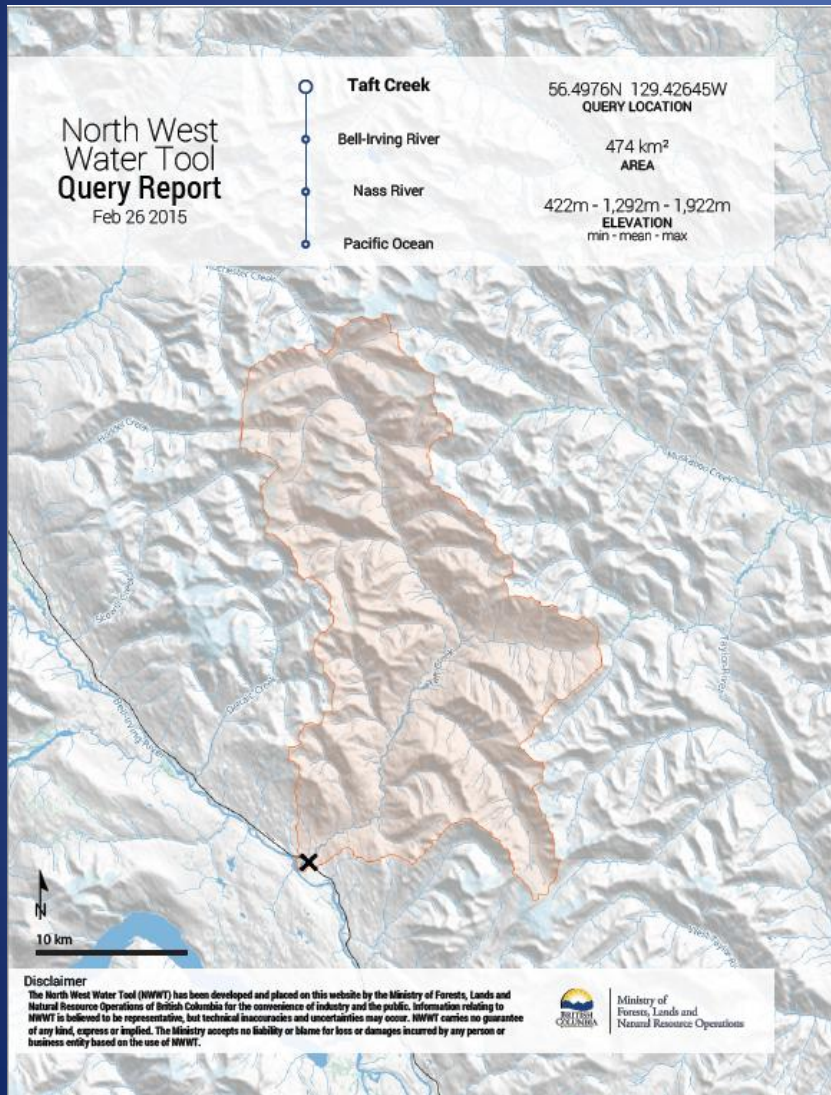
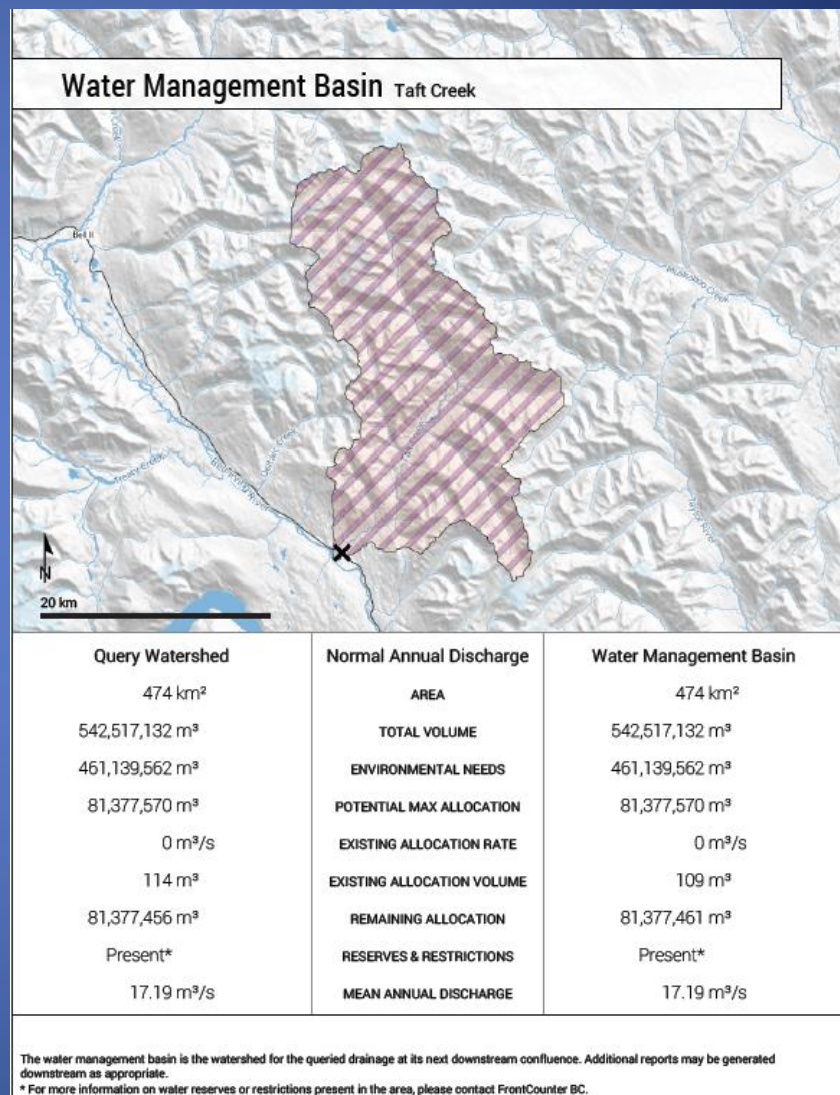
Northwest Water Tool



Select Watershed

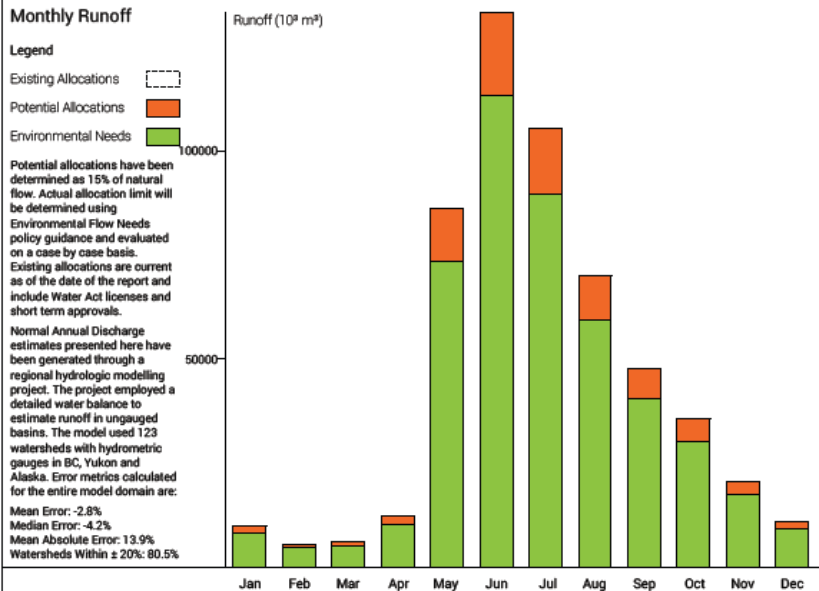


Watershed Report



Hydrology and Environmental Flow Needs

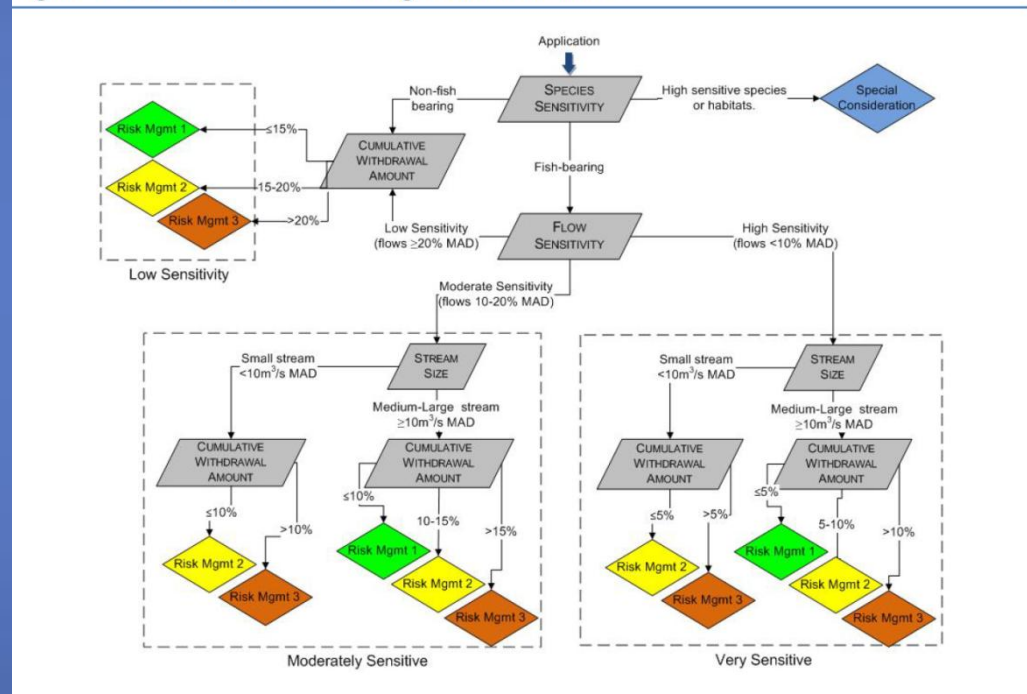
Modelled Hydrology



ENVIRONMENTAL NEEDS (10^6 m^3)	8235.7	4686.2	5190.8	10313.5	73297.1	111313.2	89603.5	59412.1	40569.4	30144.0	17443.2	9112.8
POTENTIAL ALLOCATION (10^6 m^3)	1453.4	827.0	916.0	1820.0	12934.8	19964.3	15812.4	10484.5	7159.3	5319.5	3078.2	1608.1
EXISTING ALLOCATIONS (10^6 m^3)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
REMAINING ALLOCATION (10^6 m^3)	1453.4	827.0	915.9	1820.0	12934.8	19964.3	15812.4	10484.5	7159.3	5319.5	3078.2	1608.1

Monthly estimates of runoff presented here have been generated through a regional hydrologic modeling project. The model used 123 watersheds with hydrometric gauges in BC, Yukon and Alaska. Basin physical characteristics were used to determine the distribution of runoff in individual months, and combined with the results of the annual modeling process which employed a detailed water balance to estimate runoff volumes in individual months.

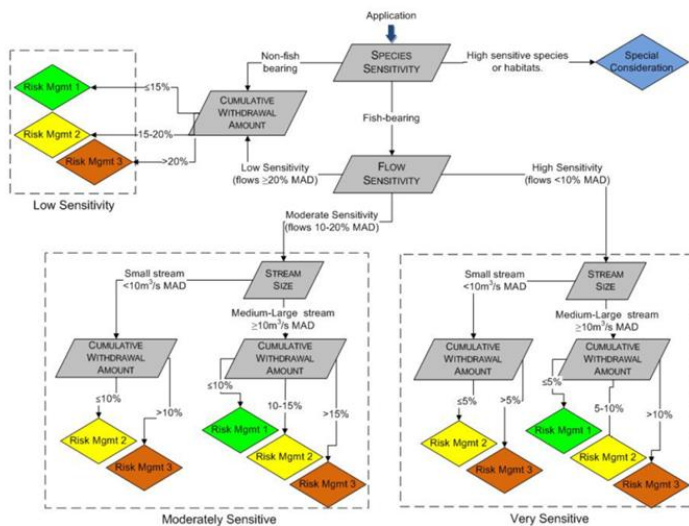
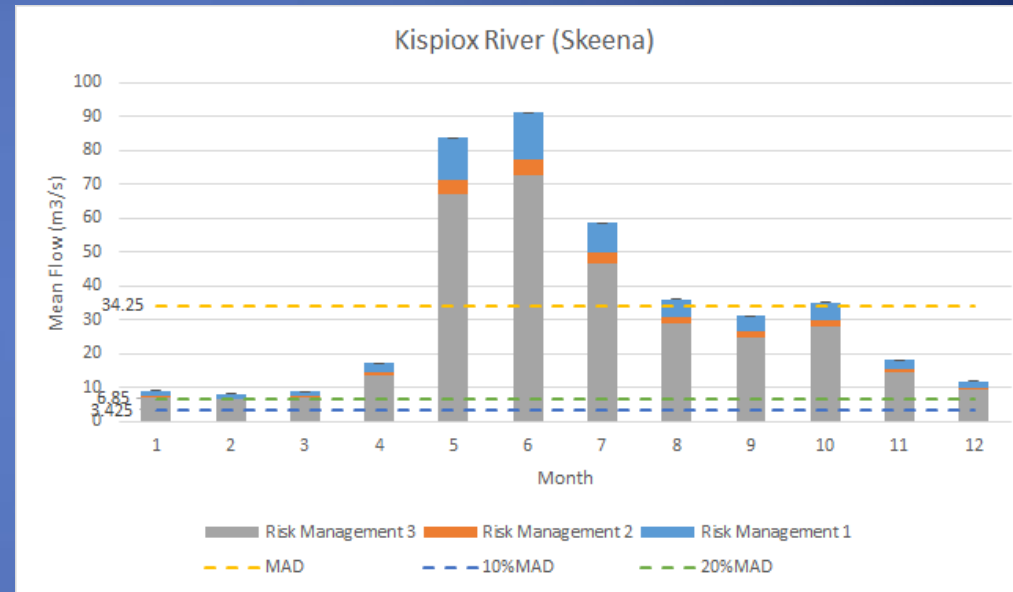
Figure 1. Environmental Risk Management Framework



BC Environmental Flow Needs Policy, 2014

Environmental Flow Need Output Sample

Figure 1. Environmental Risk Management Framework



Allocation and Land Use

Existing Allocations

BC Water Act - Water Licenses - 0 Licenses, 0 m³ Total Annual Volume

Licensee	Number	POD	Priority Date	Quantity	Flag
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BC Water Act - Short Term Approvals (Section 8.) - 1 Approval, 114 m³ Total Annual Volume

Licensee	Number	POD	Start Date	End Date	Quantity
Billabong Road & Bridge Maintenance Inc Road Maintenance (02146) from 1 all Creek	A610437*	437	2014-03-20	2015-11-30	113.65 m³/year

Water License Flag Description

N : Non-Consumptive (license volumes not used in calculations)

T : Total demand one POD

P : Multiple PODs for PUC/qty at each are known/PODs on same source

M : Max licensed demand for purpose/multiple PODs/qty at each POD unknown

D : Multiple PODs for PUC/qty at each are known/PODs on different sources

For more information on water licenses:

Water License Query Tool: http://a100.gov.bc.ca/pub/wtrwase/water_licenses.input

Scanned Water License Directory: http://www.env.gov.bc.ca/wsd/water_rights/scanned_license_dir/

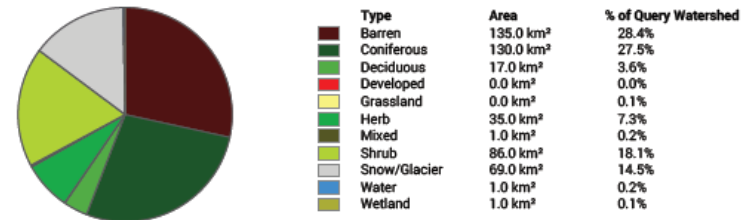
*BC Ministry of Forests, Lands and Natural Resource Operations is statutory decision maker.

**BC Oil and Gas Commission is statutory decision maker.

Land Cover and Regional Hydrology

Land Cover

The land cover characteristics of the query watershed are presented in the pie chart below. Differences between individual classes in canopy closure, evapotranspiration, and infiltration rates influence hydrologic characteristics in the watershed including total annual runoff, time to outlet, and flood and drought flow conditions. The land cover components have been determined using data from Canadian (Geobase 2009), US (Selkowitz 2011), and multi-government commission (CEC 2013) datasets.



Hydrometric Stations in Water Management Basin - 0 Stations

The Inventory of Streamflow in the Skeena Region (Obedkoff 2001) was published by the BC Ministry of Environment to present summary data and analysis of streamflow in the Skeena Region. A recent revision of the report (Ahmed and Jackson, 2013) includes updated data beyond 2000 and a new normal period of 1981-2010. Within this report, summary streamflow statistics and graphs are included which provide for more accurate estimates of streamflow parameters in ungauged basins in the Region. The table below presents a portion of the data included in the report, for hydrometric gauges found within the Water Management Basin the subject query of this report is in. The full report is available at <http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportid=40801>

Station	Name	Area	Median Elev	Annual Runoff	10 Yr Flow Ratio	10 Yr - 7 Day Low Flow
		km²	m	mm	HighAvg	LowAvg
						U/s/km²
						Jun - Sep
						Annual

Ahmed, A., Jackson, S. Inventory of Streamflow in the Skeena Region. Knowledge Management Branch, BC Ministry of Environment.

CEC. 2013. North American Land Change Monitoring System Land Cover 2005. Commission for Environmental Cooperation, Montreal QC.

Geobase. 2009. Land-cover, circa 2000-Vector. Centre for Topographic Information, Earth Sciences Sector, Natural Resources Canada.

Obedkoff, W. 2001. Streamflow in the Skeena Region. Water Inventory Section, Resources Inventory Branch, BC Ministry of Environment, Lands and Parks.

Selkowitz D.J., Stehman S.V., 2011. Thematic accuracy of the National Land Cover Database (NLCD) 2001 land cover for Alaska. Remote Sensing of Environment, 115 (6), pp. 1401-1407.

Climate

The climate of the query watershed has been characterized using ClimateWNA (Wang 2012). In the left hand column, charts are presented for the reference time period 1961-90. In the right hand column, three illustrative climate change scenarios have been selected to estimate a range of potential future change in the query watershed. (Murdock 2011)

The A1B scenario describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The technological emphasis of A1B is a mix between fossil and non-fossil energy sources.

The A2 scenario describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

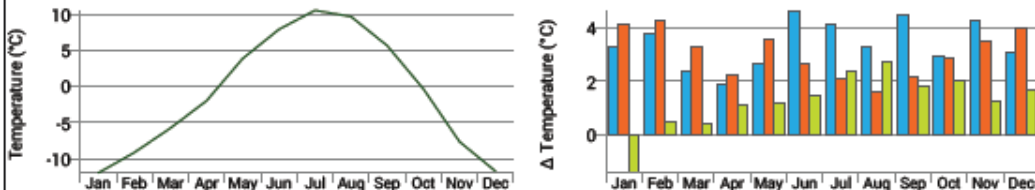
The B1 scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

Normal (1961 - 1990)

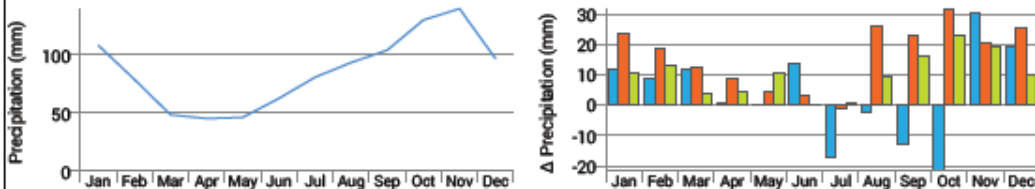
Predicted Change (2040 - 2070)

■ A1B Scenario ■ A2 Scenario ■ B1 Scenario

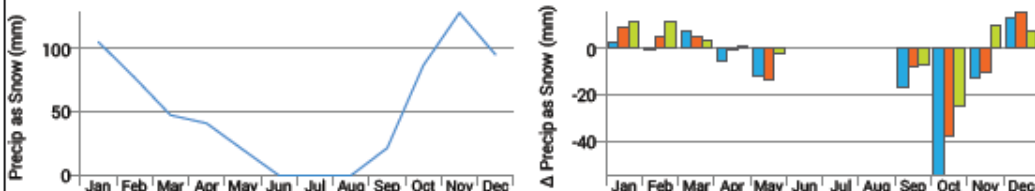
Monthly temperatures are presented as averages of the monthly mean temperature for the query basin as a whole. Projected changes in temperature may affect the hydrology in the watershed by influencing the time of freeze and thaw, evapotranspiration rates, form of precipitation, and vegetation composition, among other factors.



The precipitation in the query watershed is shown as an average unit precipitation for the watershed. Changes in precipitation timing and amount may affect the hydrology in the watershed by influencing the timing and magnitude of peak and low flow conditions. These changes may affect availability of water for environmental flow needs and human use, and modify the physical characteristics of river channels and associated needs for engineered structures.



Precipitation as snow in the query watershed is presented as an average unit precipitation for the query basin as a whole. Changes in the amount of precipitation as snow may affect winter snowpack volumes and associated melt related hydrology in the spring. An increase in rain-on-snow events may be associated with elevated natural hazard risk from avalanche or other slope stability failures.



Climate

- Normals provided,
- Three climate scenarios based on:
 - Rapid global economic and population growth,
 - Slower regionally based economic and population growth.
 - Hybrid of growth and adoption of resource efficient technology.

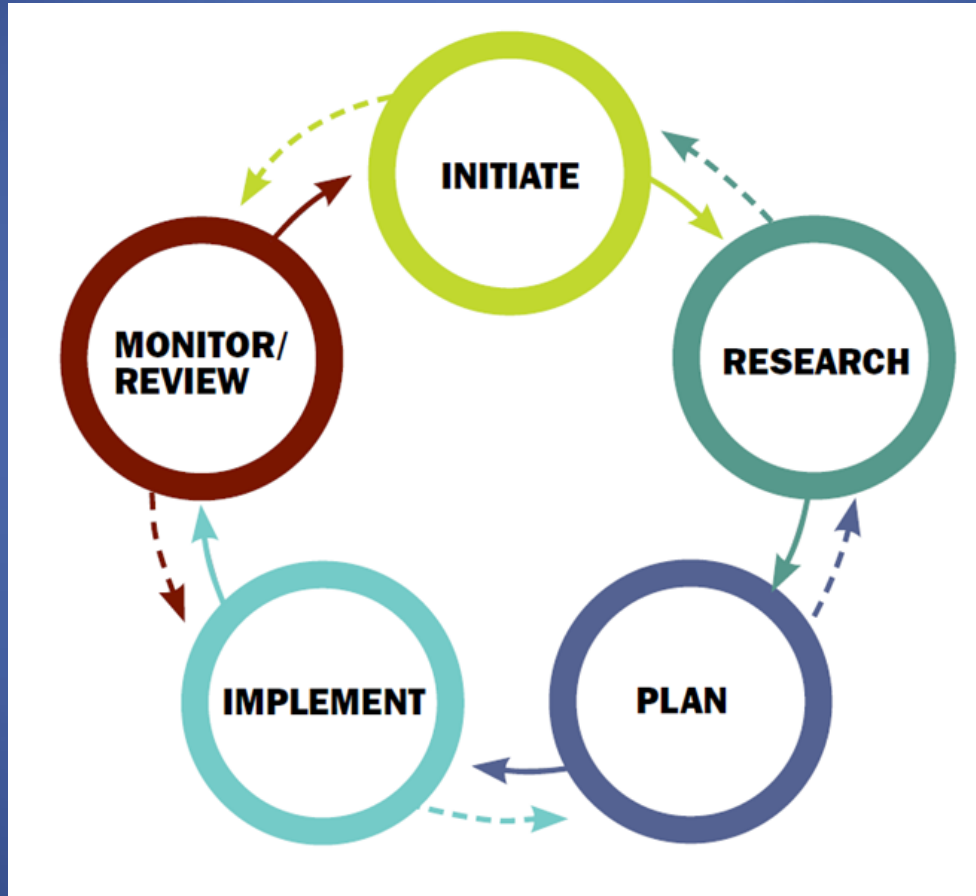


Application of Tools

- Reviews and permitting,
- Watershed management and planning,
- Informing public and others,
- Forecasting.



Planning and Adaptation



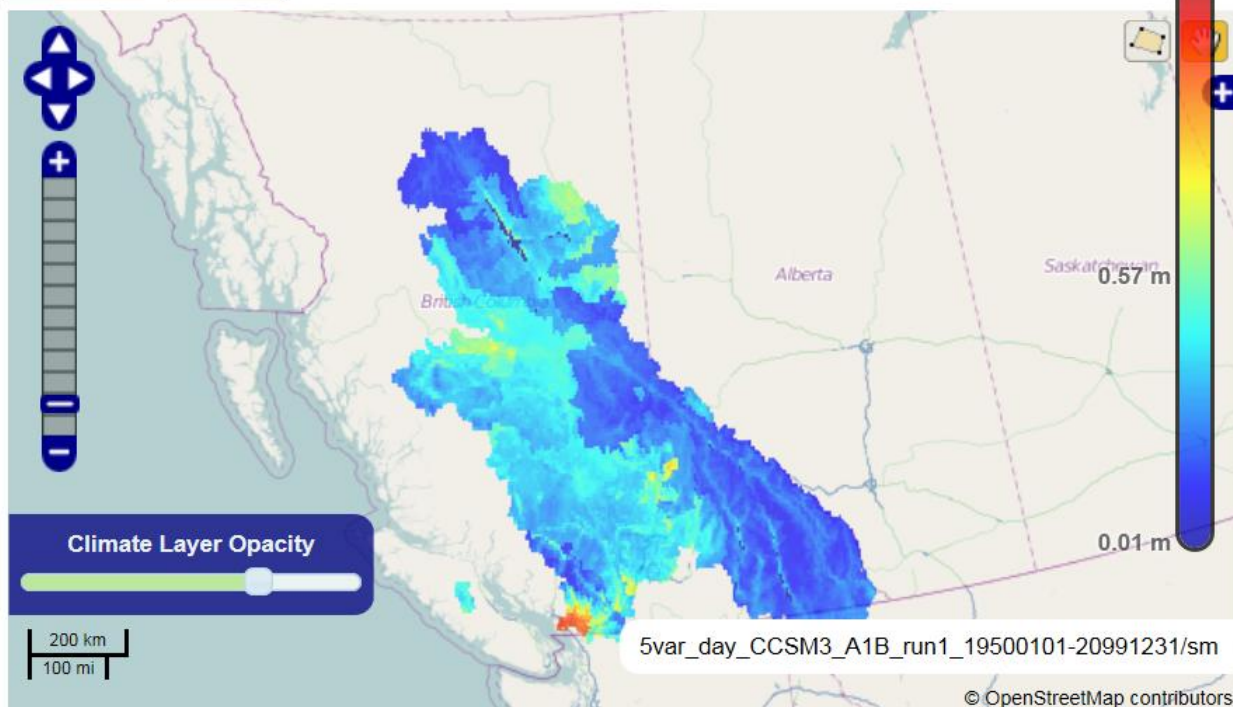
PCIC Gridded Hydrologic Model Output



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Gridded Hydrologic Model Output

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Dataset Selection

A1B	[+]
A2	[+]
B1	[+]
historical	[+]

Download Data

Date Range

1950/01/01 to 2100/01/01

Output Format

NetCDF [?]

PCIC Data Portal version 2.2.4 [Terms of Use](#)

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-136.68813, 53.25996

<http://www.pacificclimate.org/data/gridded-hydrologic-model-output>

Questions

