

CURRENT CONDITION AND 10-YEAR HISTORIC TREND ANALYSIS OF HYDROLOGIC HAZARDS IN THE OKANAGAN TIMBER SUPPLY AREA

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B.C. Ministry of Forests, Lands and Natural
Resource Operations



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Executive Summary

A hydrologic hazard assessment was completed to evaluate watershed conditions in the Okanagan Timber Supply Area (Okanagan TSA). The assessment uses a GIS indicator-based assessment procedure to evaluate the likelihood of harmful or hazardous changes (hydrologic hazards) related to streamflow, sediment generation and delivery, and riparian function. Hazard ratings for streamflow, sediment and riparian function are analyzed and reported using a hierarchical structure of assessment units (AUs) including: Sub-basins, Basins, Watersheds, Large Watersheds or Super-Watersheds. These hazard assessment results can be used as part of a risk-based approach to evaluate risk to downstream values such as fish habitat, water quality, people and property, infrastructure or aquatic biodiversity. The hazard assessment was completed for 2003 and 2016 respectively, using indicator data, and qualitatively discusses factors and uncertainties that may affect potential future hazards.

Historic 10-year trend and current condition results indicate an increase in the number of AUs with *High* and *Very High* hazard ratings for streamflow, sediment and riparian function from 2003 to 2016. The number of AUs with *High* and *Very High* Riparian function hazard increases the most in this time period, followed by streamflow hazard. Hazards increased greatest in the southern portion of the TSA; although hazards are generally lower than adjacent TSAs in the Thompson Okanagan Region. The primary factor contributing to elevated riparian and streamflow hazard is extensive Mountain Pine Beetle (MPB) induced mortality of pine-dominated forests and salvage of MPB-affected forests over the past decade in the middle to southern portion of the Kamloops TSA. These factors result in elevated equivalent clearcut areas (ECA) and harvesting adjacent to streams in higher elevation Sub-basins, Basins and Watersheds. Upstream harvesting-related effects on riparian buffers accumulate with livestock grazing and private land use to contribute to increased likelihood of reduced riparian function in larger watersheds. The current streamflow and riparian hazards are expected to persist for the next 20-30 years, at minimum, until regeneration of harvested areas occurs, and recovery of hydrologic function of forests and riparian vegetation returns.

These results suggest that unintended outcomes resulting from the cumulative effect of historic and current land use likely have occurred in the Okanagan TSA. These outcomes may result in long standing ecologic consequences (impact to fish habitat, aquatic ecosystem health, and water quality) through a higher likelihood that harmful hydrologic changes could impact the provision of key ecosystem services important for human well-being (e.g. clean drinking water, flood regulation). These outcomes could also have direct, and potentially severe, socio-economic consequences to downstream values (e.g. injury and/or loss of human life, damage to property and/or infrastructure) through a higher likelihood of harmful hydrologic change (e.g. severe flooding or debris flow events).

To address these potential negative outcomes will require field-based assessment by qualified professionals in individual watersheds to support operational-level mitigation actions. Actual conditions in any given watershed can vary from those derived from this Strategic GIS-based assessment as a result of site-level factors not considered in GIS indicators and ratings. Although outcomes of this assessment are consistent with field-based monitoring of stream functioning condition completed throughout the Thompson-Okanagan Region over the past three years, the potential consequences to downstream values have not been assessed by qualified professionals in the field. Thus, further field-based investigation by qualified professionals to assess risk to downstream values and provide operational -level decisions and mitigation actions is recommended.

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1. Assessment Approach

This assessment of hydrologic hazard is part of a risk-based approach as described in Lewis et al. (2016), where risk is the product of hazard and consequence defined by the risk equation; **Risk = Hazard x Consequence**. In this assessment, only the hazard side of the risk equation is reported. These hazard ratings are then intended to be used with consequence ratings derived for downstream ecological and socio-economic values to derive risk ratings (Figure 1). *Consequence* refers to the change, loss or damage to a value(s) (e.g. human life, private or public property, water intakes, infrastructure, fish habitat etc.) that may result from hazardous occurrences. Consequence ratings are the measurement or expression of the potential loss or damage to downstream values, and the specific elements at risk comprising those values.

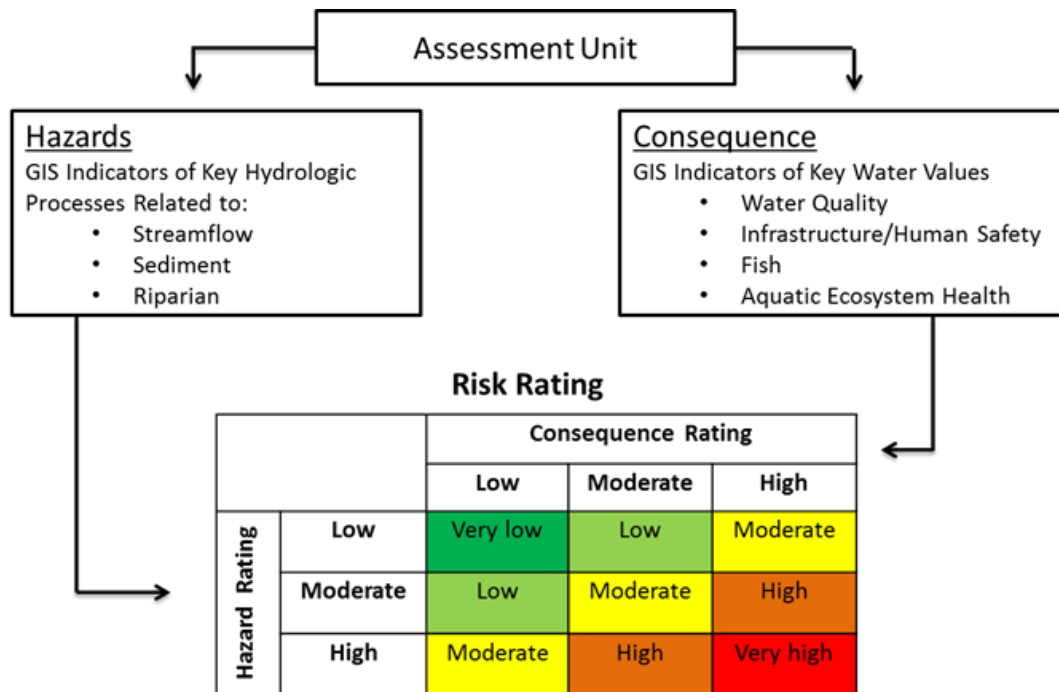


Figure 1. A qualitative risk matrix illustrating how hazard ratings from this assessment can be used with consequence ratings for both ecological and socio-economic values. From Lewis et al. (2016).

This assessment provides hydrologic **Hazard Ratings** as an expression of the likelihood of hazard occurrence. Three hydrologic hazards commonly used to evaluate watershed condition that are considered in this assessment include:

- 1) **Streamflow** effects – increases the frequency and magnitude of hydro-geomorphic events (floods, bank erosion, channel instability, debris floods and debris flows),
- 2) **Sediment** generation and delivery – reduced water quality as a result of sediment or other deleterious material input to streams from roads, landslides or other upslope sources, and
- 3) **Riparian Function** – reduced channel bank stability, stream shading and large woody debris inputs

A five-class hazard rating scheme is used by applying the qualitative terms (*Very Low*, *Low*, *Moderate*, *High*, and *Very High*) to express the likelihood of a harmful event (hazard) occurring (Table 1). The 5-class rating scheme can be adapted to a 3-class rating scheme (*Low*, *Moderate*, *High*) by combining *Very Low* and *Low* into a single *Low* rating, and *High* and *Very High* into a single *High* rating as applied in Figure 1.

Table 1. Terminology used to describe hazard ratings. From Lewis et al., 2016.

Rating	Definition	Probability of Occurring (%)
Very Low	Highly Unlikely	<10%
Low	Unlikely	<33%
Moderate	May	33-66%
High	Likely	>66%
Very High	Very Likely	>90%

1.1 Assessment Scenarios and Reporting

Hydrologic hazard ratings are reported for two time periods:

- **Historic condition to 2003** – historic condition includes existing levels of forest harvesting, road networks and other land use activities. Historic condition was re-created to 2003 using archived datasets.
- **Current condition (2016)** – current condition includes existing levels of forest harvesting, road networks and other land use activities. Current condition includes vegetation resource inventory (VRI) information with updated consolidated cutblocks to January 2016.

In addition to the historic and current condition, factors potentially affecting future condition are qualitatively discussed, but were not modelled at this time.

1.2 Confidence in the Assessment Outcomes

Strategic-level GIS indicator-based assessments, such as used in this report, have particular uncertainties inherent with human behaviour, the broad-scale of application, the generalizations and assumptions used to characterize the complex systems involved, and information and data limitations (Lewis et al. 2016). Thus, an estimate of the confidence in the assessment of historic, current and future condition is reported, as are sources of uncertainty potentially affecting the outcomes consistent with Lewis et al., (2016).

1.3 Assessment Units

This assessment uses a hierarchical reporting structure of Large Watersheds, Watersheds, Basins, Sub-Basins and Residual Units, collectively referred to as Assessment Units (AU), following the methodology of Lewis et al. (2016). The assessment includes 546 AUs that cover most of the Okanagan TSA area, including 276 in the North Okanagan and 270 in the South Okanagan (Figure 2 Left).

For reference, the assessment area includes a number of large watershed units that flow into Shuswap and South Thompson River system. In the northern portion of the TSA, the Seymour River, Eagle River, Salmon River and Scotch Creek flow directly into Shuswap Lake. The Shuswap River upstream of Sugar Lake, Cherry Creek and Bessette Creek flow into the Shuswap system north of Vernon. In the southern portion of the TSA, the Ashnola River system flows into the Similkameen River west of Osoyoos (Figure 2 Right). Not shown in Figure 2 (Right), but that are included in the analysis, are numerous basins and watersheds of management interest that flow directly into Okanagan Lake.

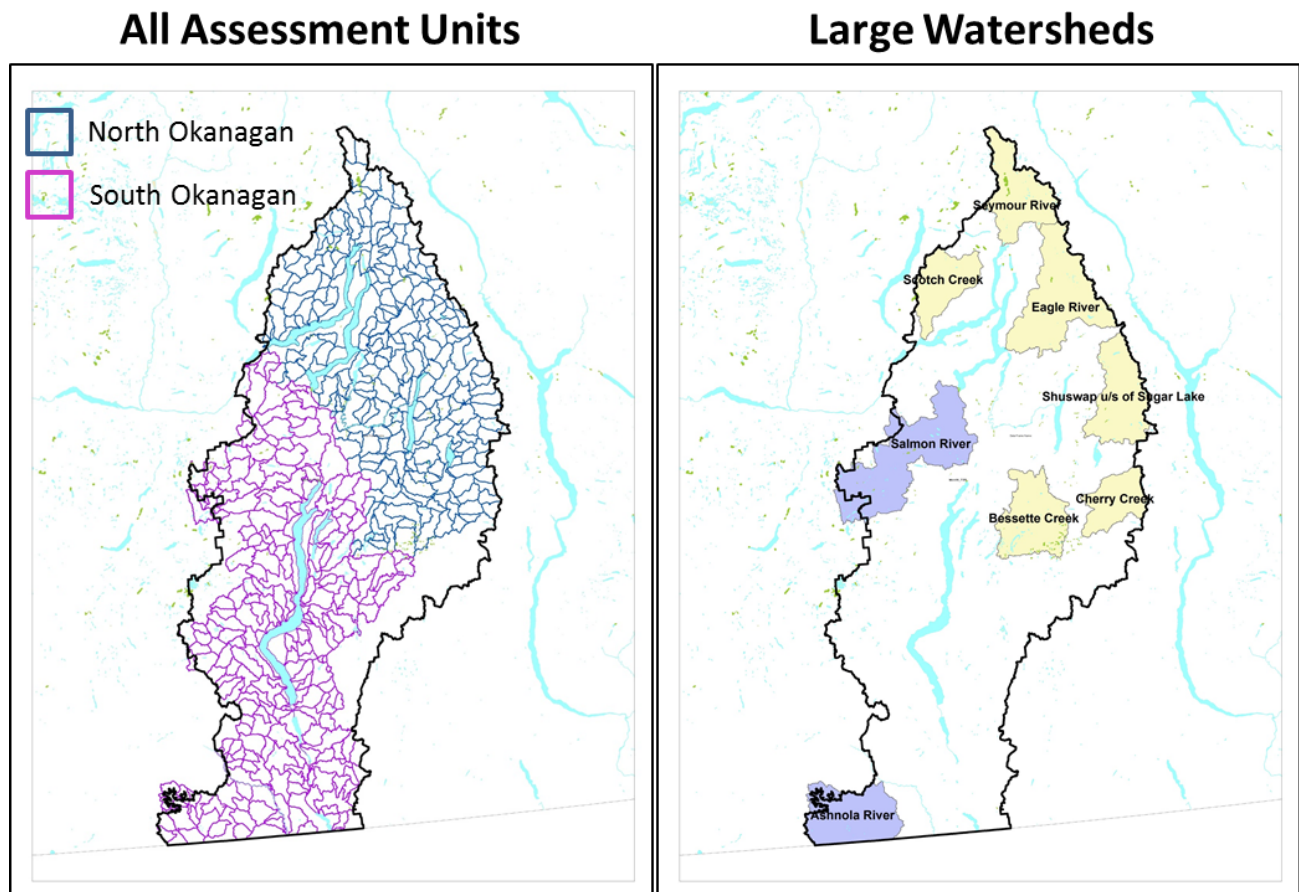


Figure 2. Map illustrating the extent of all Assessment Units (AUs) included in the Okanagan TSA Hydrologic Hazard Assessment (pink and blue outlines – left), and Large Watersheds (right) that are part of the AU reporting structure as reference for major systems included in the assessment.

2. Assessment Results

2.1 Current Condition and Historic Trend

2.1.1 Streamflow Hazard

The number of AUs with *Moderate*, *High* and *Very High* Streamflow hazard in the Okanagan TSA increased slightly from 2003 to 2016 with a greater change in the South Okanagan AUs. The number of AUs rated *Low* and *Very Low* declined (Figure 3; See Appendix 1 and 2).

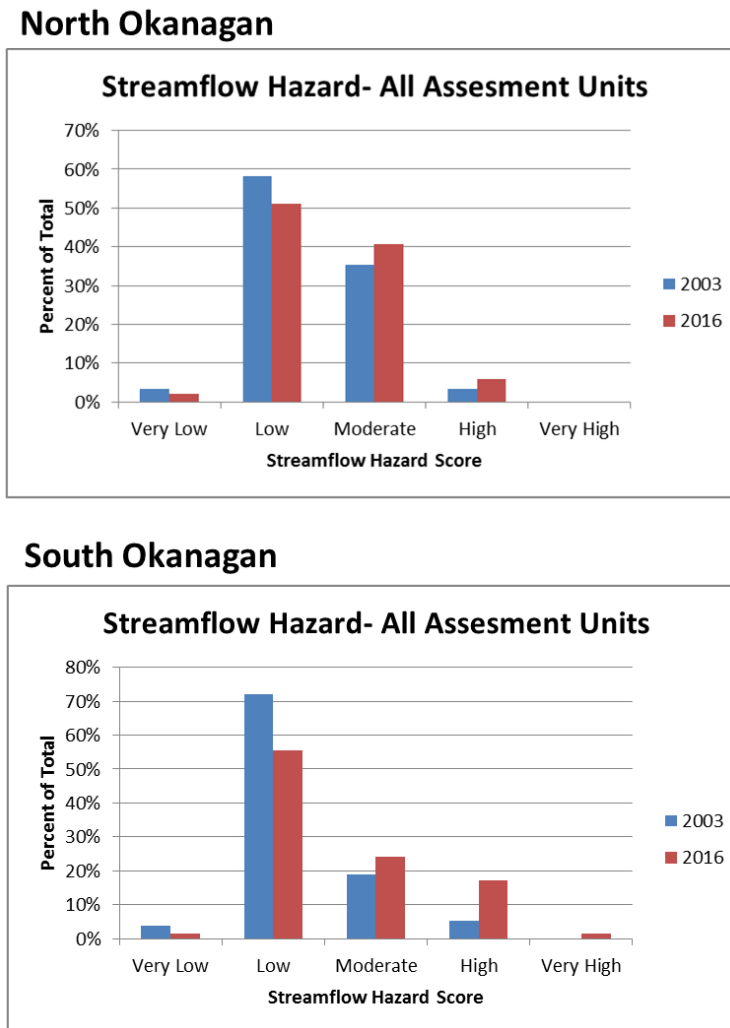


Figure 3. Change in streamflow hazard for all AUs (residual units not included) in the North (N = 276 AUs) and South (N = 270 AUs) Okanagan TSA from 2003 and 2016.

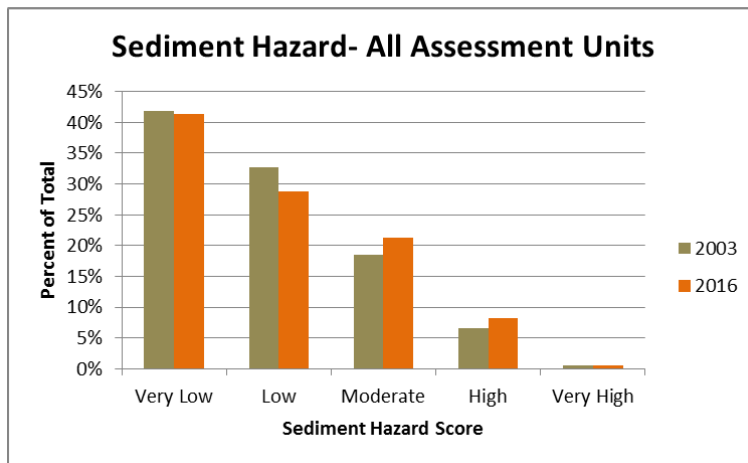
These results suggest more AUs are likely to experience an increased frequency and magnitude of potentially harmful hydro-geomorphic events (floods, bank erosion, channel instability, debris floods and debris flows). This change is due to an overall increase in equivalent clearcut area (ECA) following Mountain Pine Beetle (MPB) induced mortality of pine-dominated forests and extensive salvage of these affected forests over the past decade, particularly in the South Okanagan. The greatest increases between 2003 and 2016 occurred in upper elevation sub-basins, basins and watersheds in the southern portion of the TSA (See

Appendix 1 and 2). However, a previous MPB outbreak and MPB salvage in the 1980s and 1990s, and reduced severity of the current MPB outbreak, likely reduced the extent of mature pine-dominated forest affected by the current MPB outbreak. Thus, the forested area affected by the recent MPB outbreak and salvage may have been reduced compared to adjacent TSAs (e.g. Merritt TSA) that experienced much greater MPB salvage and resulting increases in streamflow hazards. The combined effects of extensive salvage logging across several smaller basins also accumulated to increase streamflow hazard in some watersheds and larger watersheds (Appendix 1 and 2).

2.1.2 Sediment Hazard

The number of AUs with *Moderate*, *High* or *Very High* Sediment hazard in the Okanagan TSA showed a small increase between 2003 and 2016 in the North Okanagan compared to the South Okanagan (Figure 4; See Appendix 3 and 4).

North Okanagan



South Okanagan

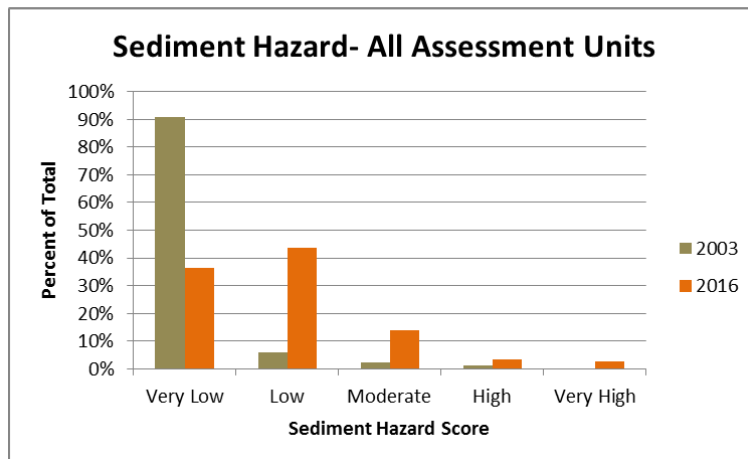


Figure 4. Change in sediment hazard for all AUs (residual units not included) in the North (N= 276 AUs) and South (N=270 AUs) Okanagan TSA from 2003 and 2016.

These results indicate that only a small number of AUs are moderately or highly likely to experience potentially harmful levels of sediment. In the South Okanagan, the increase in sediment hazard from 2003 to 2016 is due to an increase in roads close to water, roads on steep slopes (>50%) connected to water

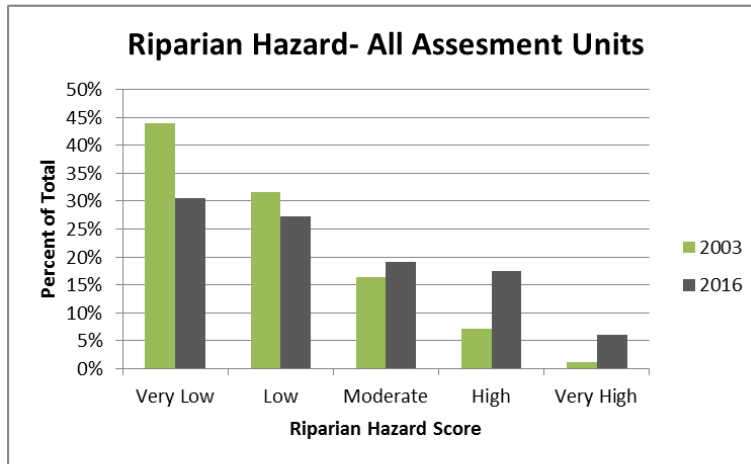
bodies and harvesting on gentle terrain over steep slopes connected to water bodies. These small changes are likely due to an expanding road network along small streams in upper elevation sub-basins, basins and watersheds associated with MPB salvage logging in the southern portion of the TSA rather than development of new major roads systems along low, valley-bottom rivers.

The Okanagan TSA has an extensive, well-developed existing road network, so large changes in road-related sediment effects based on new road development were not anticipated. The increase in the amount of new roads measured in GIS may not reflect actual sediment generated and delivered in this time period because of changes in level of industrial use, road maintenance. Increased industrial use associated with MPB salvage during the past decade could result in increased sediment generation and delivery. However, upgrading of old or existing (pre-Forest Practices Code era) roads to improved current standards may have offset potential increases.

2.1.3 Riparian Function Hazard

The number of AUs with *High* and *Very High* Riparian function hazard in the Okanagan TSA increased from 2003 to 2016. In the North Okanagan <10% of AUs rated as *High* and *Very High* hazard in 2003 compared to close to 25% of AUs in 2016 (Figure 5, See Appendices 5 and 6). In the South Okanagan, riparian hazard was greater overall in 2003 due to a higher proportion of private land and range tenures. In the South Okanagan <35% of AUs are rated as *High* and *Very High* hazard in 2003 compared to >50% of AUs in 2016 (Figure 5, See Appendix 3). These results suggest a larger portion of AUs in the South Okanagan are more likely to experience loss of riparian function such as bank stability, stream shading or LWD inputs. This increase from 2003 to 2016 is primarily driven by an increase in the proportion of total stream length with harvesting adjacent to streams (within 30 metres) particularly in Sub-basins and Basins where extensive salvage of MPB-affected forests occurred in the middle to southern (See appendices 5 and 6). This upstream harvesting combined with existing private land and livestock grazing effects in watersheds and large watersheds to result in significant increases in Riparian Function hazard at this scale.

North Okanagan



South Okanagan

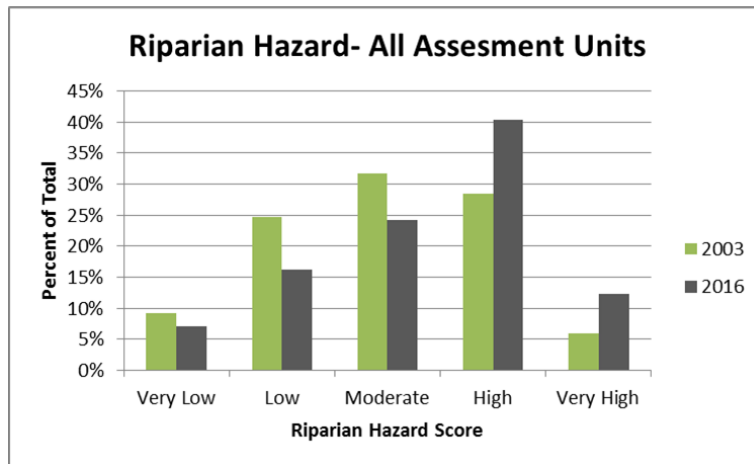


Figure 5. Change in riparian hazard for all AUs (residual units not included) in the North (N= 276 AUs) and South (N=270 AUs) Okanagan TSA from 2003 and 2016.

2.2 Projected Future Condition

2.2.1 Streamflow Hazard

Future changes in streamflow hazard will largely depend on the amount and spatial distribution of new forest harvesting or forest clearing associated with other resource sector activity or land use.

Future conditions that will contribute to a stable to declining streamflow hazard:

- The future average annual cut (AAC) in the TA may decline as salvage of MPB-affected forests subsides, and coupled with regeneration of existing harvested areas, should result in decreases in the rate of hazard as compared to that experienced over the past decade.
- Harvesting directed into lower elevation Douglas-fir forests will have less effect on streamflow as these areas contribute less snowmelt to spring peak flow events.

The current streamflow hazard is expected to persist for a minimum of 20-30 years until forest regenerate and recover hydrologic function. Future conditions that will contribute to increasing streamflow hazard may include:

- Future harvesting directed into AUs with increased hydrologic response potential such as the interior wetbelt and wetbelt transition areas in the middle to northern portion of the TSA , could increase streamflow hazard.
- Uncertainty regarding the location, extent and severity of future natural disturbance such as wildfire.

2.2.2 Sediment Hazard

Future sediment hazard, as expressed using the GIS-based indicators used in the assessment procedure, will depend on the spatial distribution of new road building associated with forest sector development and other resource sector or land use. However, actual sediment generation and delivery on the existing road network will likely have a greater effect across the TSA, and will depend on future use and road management practices.

Future conditions that will contribute to a stable to declining sediment hazard on the existing road network:

- Decreased industrial use of existing road networks.
- Deactivation or rehabilitation of existing roads.
- Opportunities to improve older road infrastructure (pre-Forest Practices Code era) as forest harvesting directed into mid-term non-pine dominated forest types (dry Douglas-fir in the south and wetter Interior Cedar Hemlock (ICH) and Engelmann Spruce Subalpine Fir (ESSF) forest in the northern portion of the TSA).

Future conditions that will contribute to increasing sediment hazard on the existing road network:

- New roads and harvesting in steeper more landslide prone terrain (wetter ICH and ESSF forest in the north of the TSA).
- Non-forest sector increase in industrial road use and – particularly in valley bottoms adjacent to major river corridors (e.g. pipeline expansions).
- Increased uncontrolled recreational (Off-Road Vehicle) use of existing road network.
- Increased uncontrolled livestock access to stream networks associated with existing expanded road networks.

2.2.3 Riparian Function Hazard

Future riparian hazard will depend on the amount and spatial distribution of forest sector development and other resource sector or land use in or adjacent to riparian areas.

Future conditions that will contribute to a stable to declining riparian hazard:

- Improved retention and protection of riparian vegetation during forest harvesting, particularly on small streams (S5-S6).
- Riparian restoration projects on private land.
- Improved livestock management practices to minimize uncontrolled livestock access and grazing in riparian areas.

Current riparian hazard is expected to persist for a minimum of 20-30 years until riparian vegetation in harvested areas regenerate and recovers hydrologic function. Future conditions that will contribute to increasing riparian hazard:

- Expansion of private-land clearing of riparian corridors or livestock grazing.
- Non-forest sector industrial expansion along valley bottoms riparian corridors (e.g. pipeline or highway expansions).
- Increased uncontrolled livestock access to stream networks due to loss of natural range barriers in areas where extensive MPB salvage has occurred.

2.3 Confidence in Hazard Ratings

2.3.1 Streamflow Hazard

A Moderate to High Confidence rating is applied to the results of the historic and current condition assessment for streamflow hazard.

The following factors contribute to increased confidence in the assessment results:

- Moderate to High confidence that model structure adequately captures both watershed characteristics and disturbance-related effects that contributes to an altered peak flow regime. High confidence is based on existing research, and recent validation of GIS-indicators with field-based monitoring.

The following sources of uncertainty contribute to a reduced confidence in the assessment:

- Moderate certainty in VRI data accurately capturing existing amount of forest harvesting and extent of hydrologic recovery of regenerating stands.

2.3.2 Sediment Hazard

A Moderate Confidence rating is applied to the results of the Sediment hazard rating used in the historic and current condition assessment of sediment hazard.

The following factors contribute to increased confidence in the assessment results:

- High certainty that model structure (indicators used to reflect road and harvesting related likelihood of sediment generation and delivery) adequately captures potential sediment sources.

The following sources of uncertainty contribute to a reduced confidence in the assessment:

- Moderate certainty regarding actual impacts of roads on. The model currently assumes all roads equally contribute sediment, however sediment generation and delivery can vary depending on substrate, road location, construction, maintenance and use.
- Moderate - Low certainty in the erodible soils indicators (1:2 million coarse scale). Improved digital soil mapping can help capture locations of erodible soil types to improve information on sediment generation potential.

2.3.3 Riparian Function Hazard

A Moderate to High Confidence rating is applied to the results of the historic and current condition assessment of Riparian Function hazard.

The following factors contribute to increased confidence in the assessment results:

- High certainty in that the private land indicator reflects well-documented private land impacts in the literature and validation of private-land related effects from existing channel assessments and field-based monitoring in the Kamloops TSA.

The following sources of uncertainty contribute to a reduced confidence in the assessment:

- Moderate certainty related to the logging adjacent to streams indicator. Monitoring results from the Forest and Range Evaluation Program (FREP) show a high proportion of impact of forest and range practices on functioning condition of small streams (1-3 metres). These impacts are assumed to accumulate within a larger stream network based on the extent of harvesting adjacent to streams. However, actual knowledge is limited and will require further field-based investigations to corroborate this assumption,
- Moderate certainty in the livestock grazing indicator. Livestock related impacts can vary depending on livestock numbers, accessibility of streams and extent and type of management practices used to minimize livestock impacts to streams. However, field-based watershed assessments in the area have identified livestock impacts. Further field-based investigation and refinement of the indicator will improve accuracy.

3. Discussion and Conclusions

The increase in likelihood of changes in all three hydrologic hazards suggests that unintended outcomes resulting from the cumulative effect of historic and current land use are likely to occur in the Okanagan TSA. The unintended outcomes of these changes may include increased frequency and magnitude of potentially harmful hydro-geomorphic events (e.g. floods, debris floods, flows, bank erosion) and harmful conditions (reduced water quality, loss of spawning and rearing habitat for fish).

These outcomes may have long-standing ecologic consequences (impact to fish habitat, aquatic ecosystem health, and water quality) impacting the provision of key ecosystem services important for human well-being (e.g. clean drinking water, flood regulation). These outcomes could also have direct, and potentially severe, socio-economic consequences to downstream values (e.g. injury to and/or loss of human life, damage to property and/or infrastructure) due to a higher likelihood of harmful hydro-geomorphic events (e.g. severe flooding or debris flow events).

To address the increased likelihood for harmful unintended outcomes to occur, as suggested by this strategic-level GIS assessment, field-based watershed-level risk assessments, completed by qualified professionals, are necessary to inform resource use and development decisions across multiple sectors. GIS indicator-based assessment procedures, as applied in this assessment, while useful for strategic

level planning decisions in large management units (TSA's, Resource Districts), should not be used alone to make operational decisions or set management targets at the individual watershed level.

Outcomes of this strategic-level GIS indicator-based assessment are consistent with field-based monitoring of stream functioning condition completed throughout the Thompson-Okanagan Region over the past three years (Lewis, 2016), however the potential consequences to downstream values in specific watersheds have not been assessed by qualified professionals in the field. Actual conditions in any given watershed can vary from those derived from this procedure as a result of site-level factors not considered in GIS indicators and ratings.

The risk to ecological or socio-economic values (fish, fish habit, public safety, water quality, public and private infrastructure, etc.) resulting from hazardous changes in watershed processes can also vary based on spatial location and vulnerability (including any existing mitigation measures in place) of those elements. Thus, further field-based investigation by qualified professionals to assess risk to downstream values and provide operational -level mitigation recommendations is recommended. This strategic-level GIS-based approach should not replace the use of qualified professionals and field-based assessments in individual watersheds to support operational-level decisions.

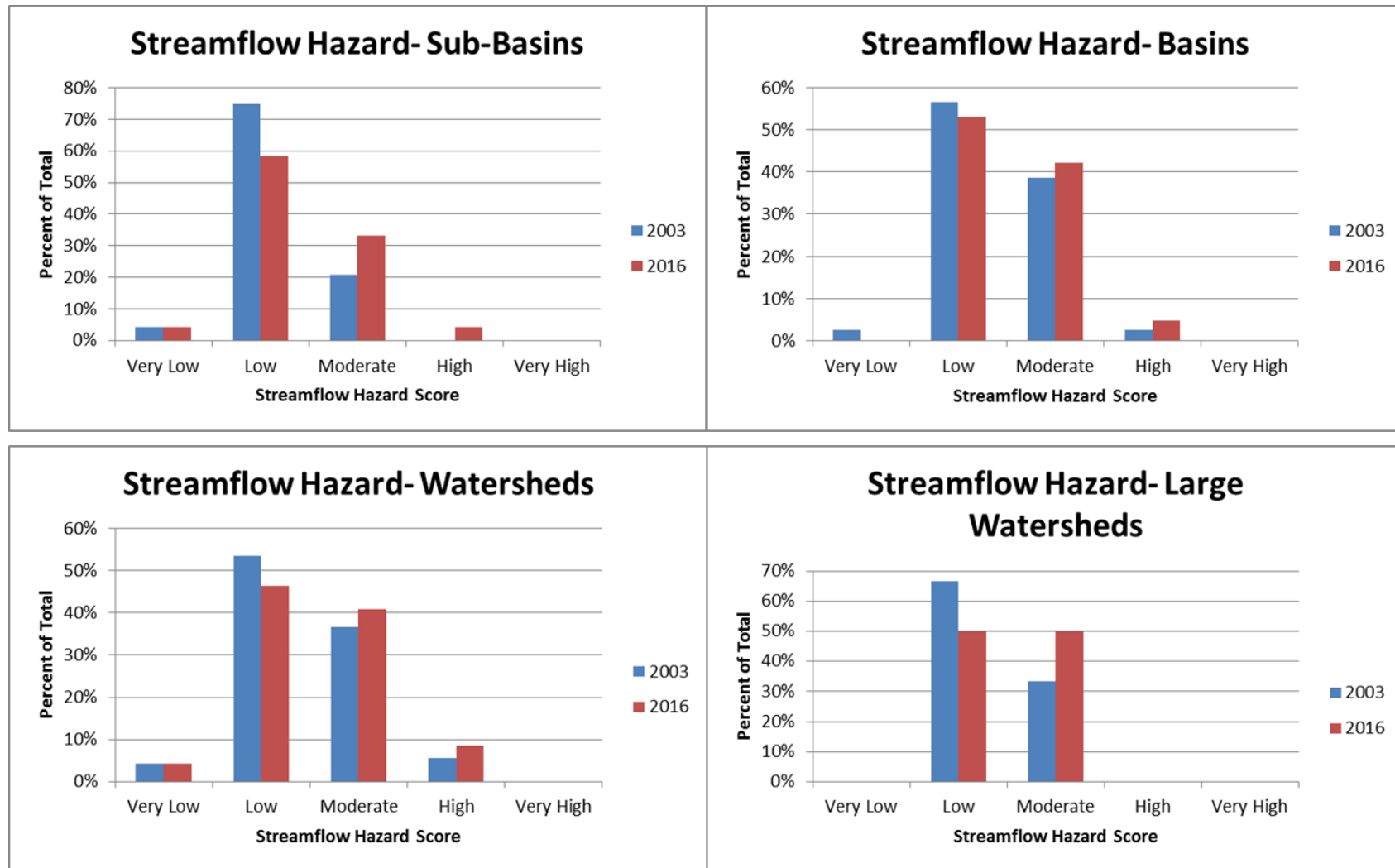
In the future, hydrologic hazard across the TSA may vary over time. The expected reduction in annual harvest in the Okanagan TSA, as salvage of MPB-affected stands subsides, is expected to mitigate some hazards with re-growth and recovery of hydrologic function in harvested or naturally disturbed forests. However, the spatial distribution of future harvesting and road building, particularly into non-pine dominated watersheds that may be more sensitive to forest harvesting, has the potential to maintain or elevate hydrologic hazards in some parts of the TSA.

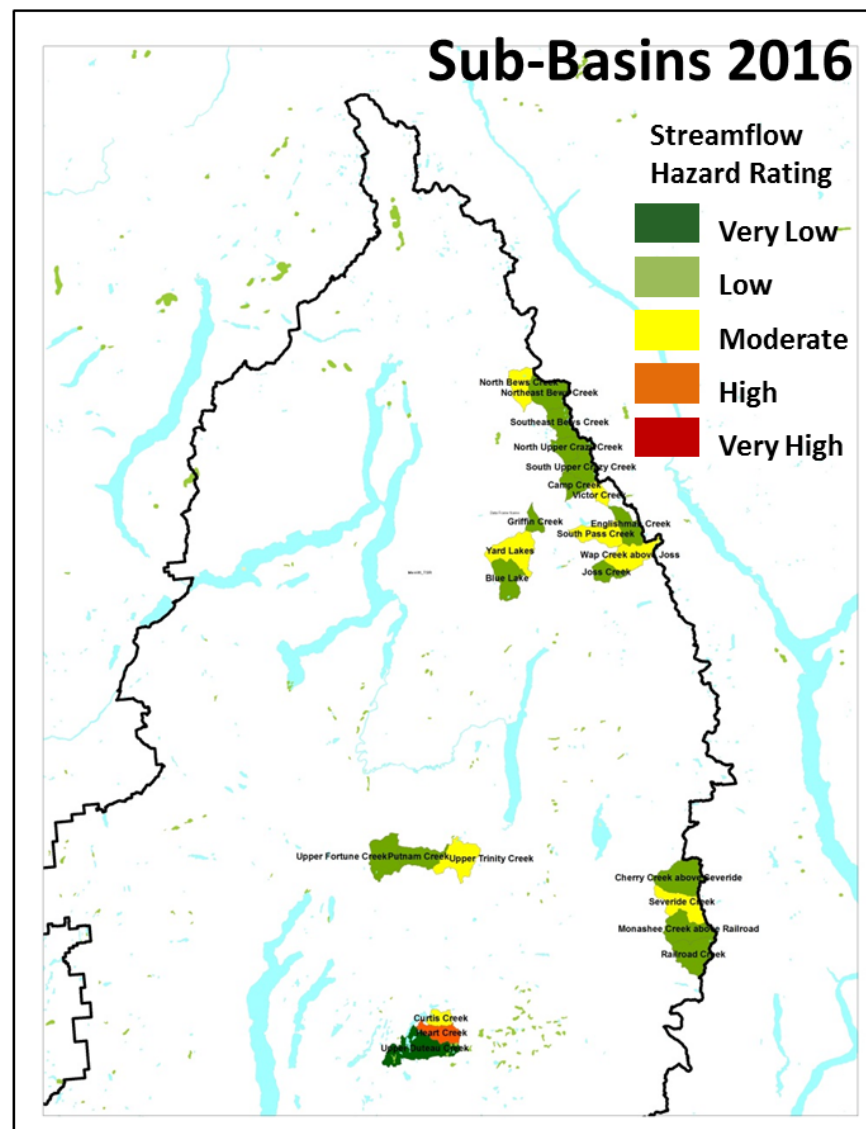
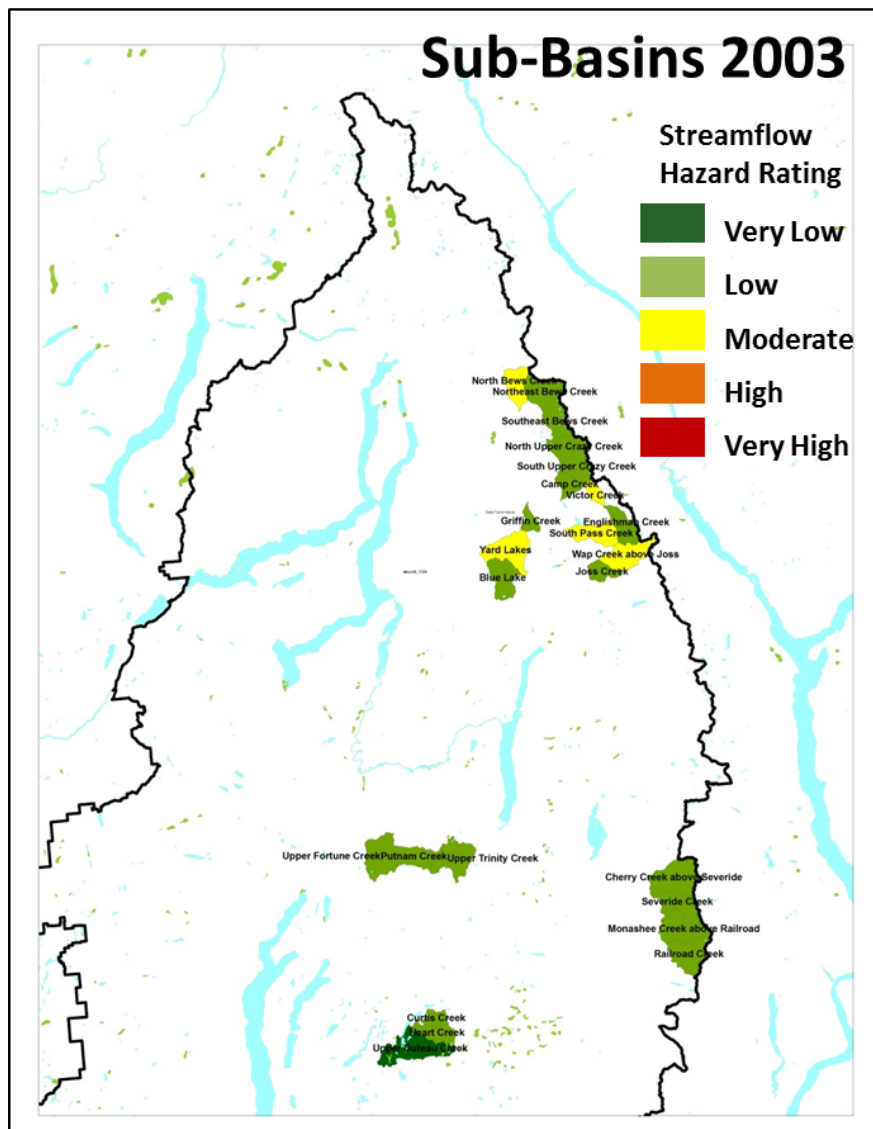
Ongoing resource sector practices and land use may also prolong, increase or expand the existing hydrologic hazards and potential impacts to watershed condition, depending on the timing and spatial location of development activities and natural disturbances. Forward looking assessments that consider future land use, completed at both strategic levels, and within individual watersheds can be used to evaluate options to address and mitigate future unintended outcomes.

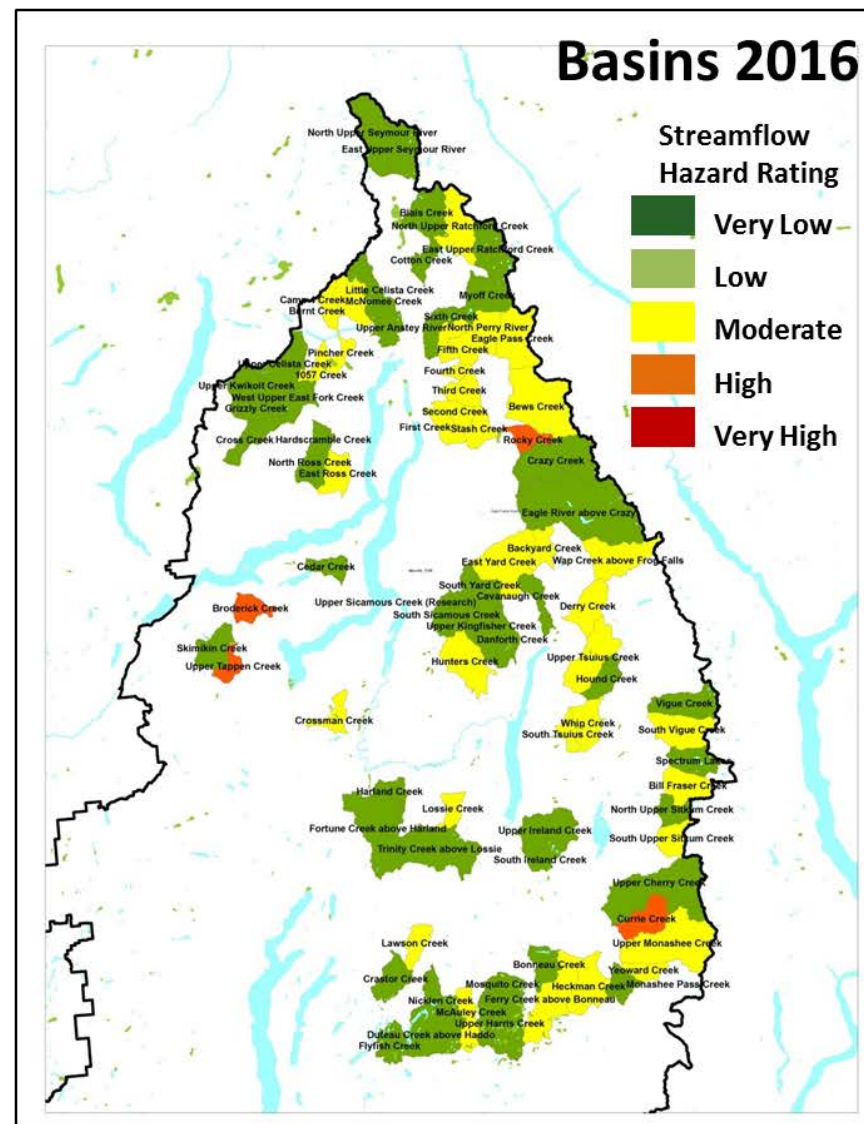
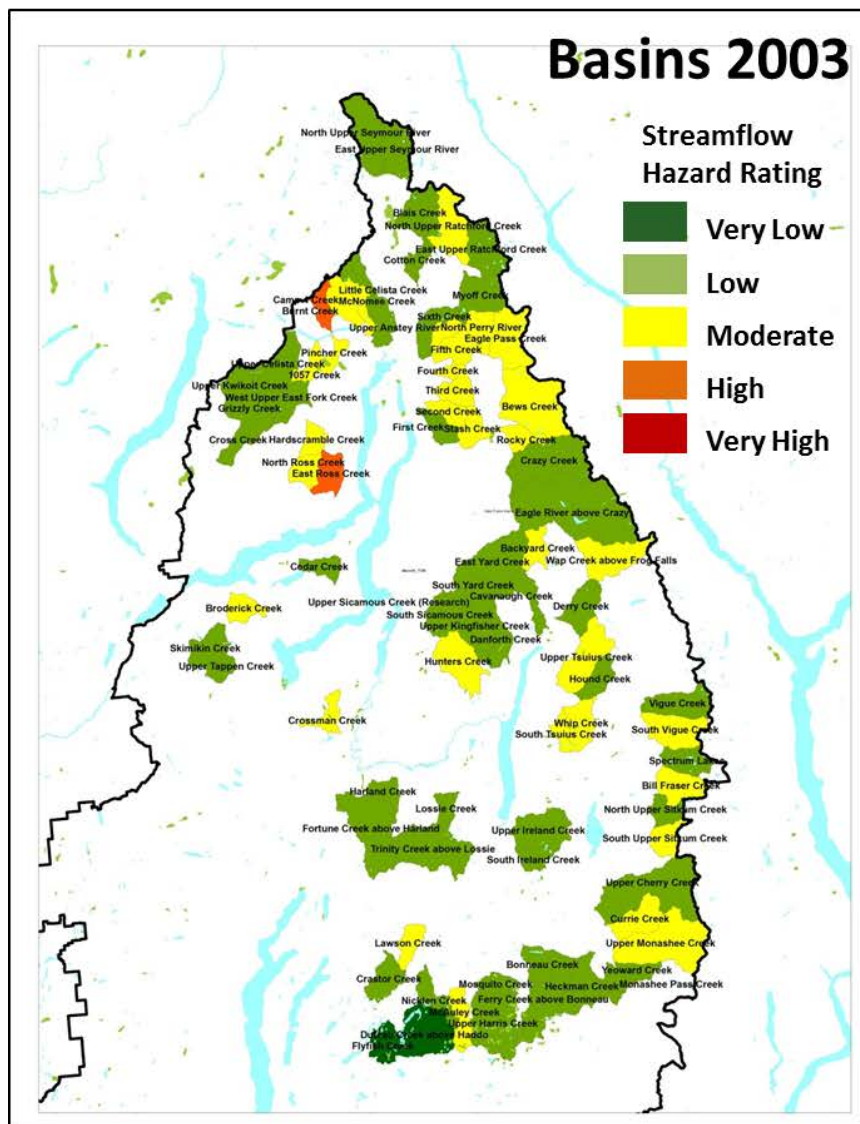
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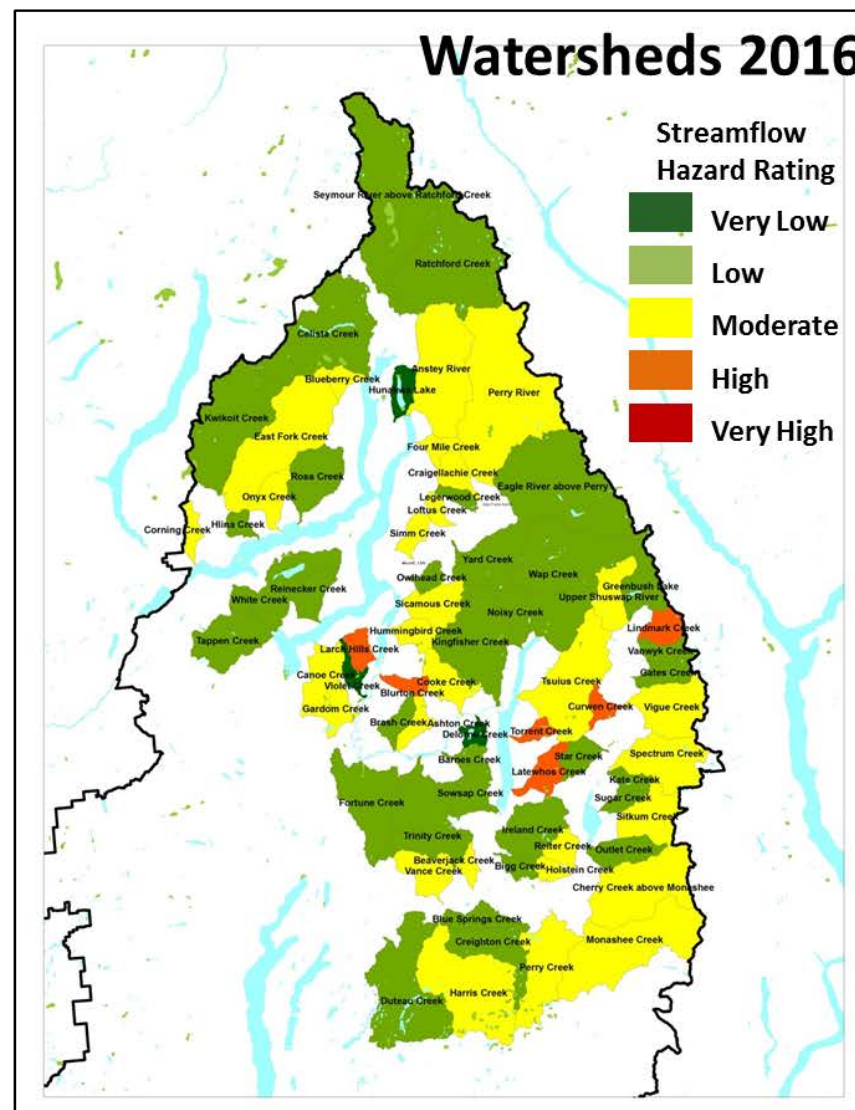
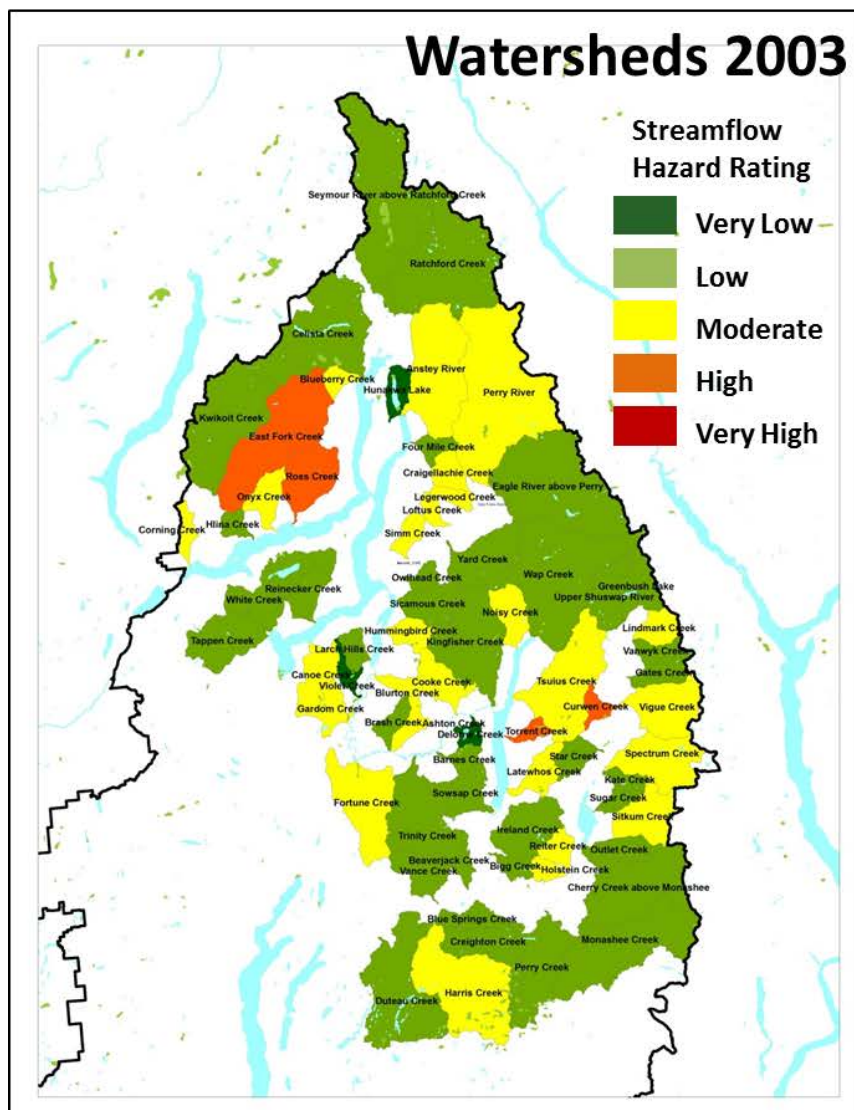
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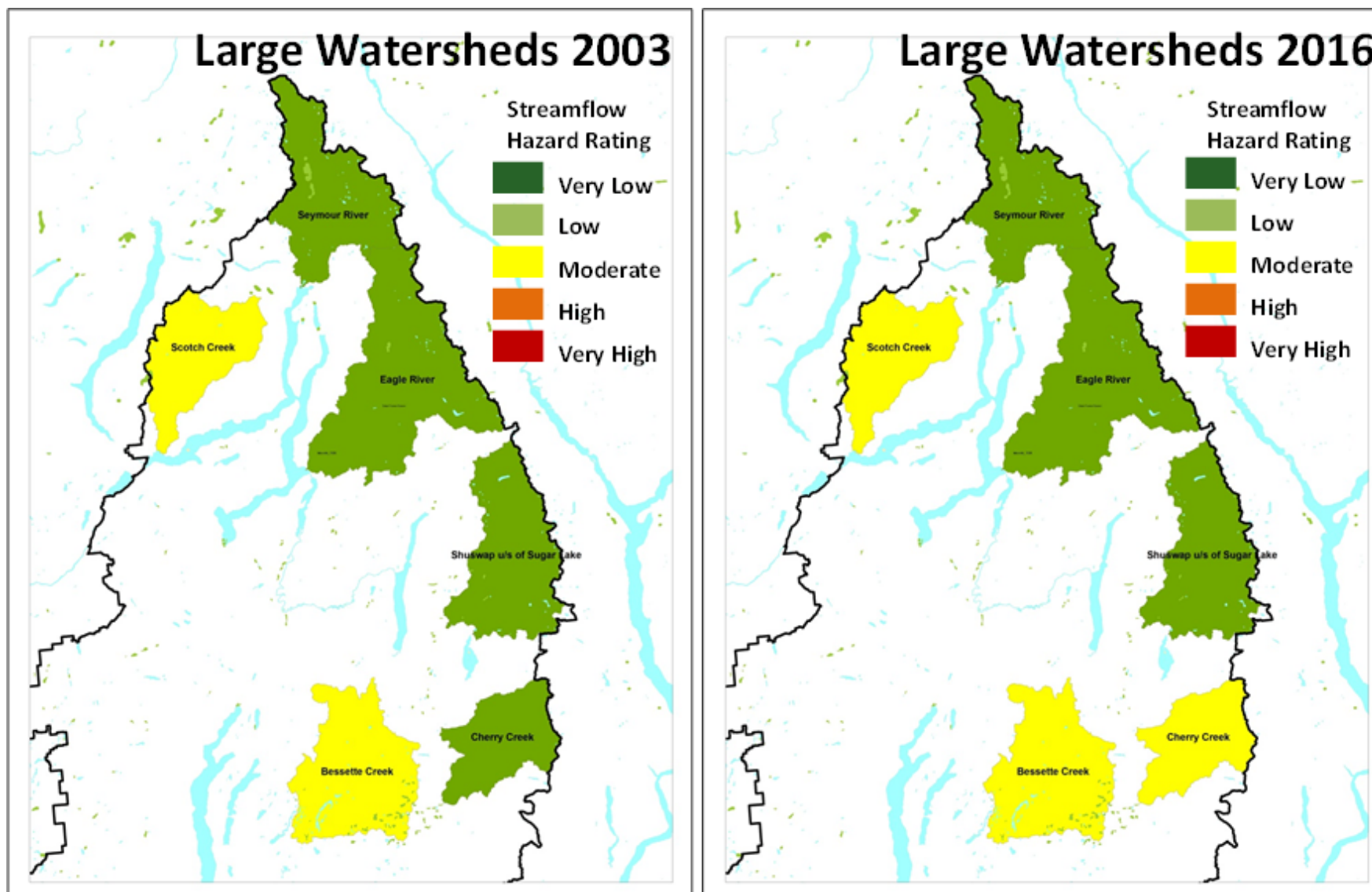
Appendix 1 – North Okanagan Streamflow Hazard Summary Statistics and Maps





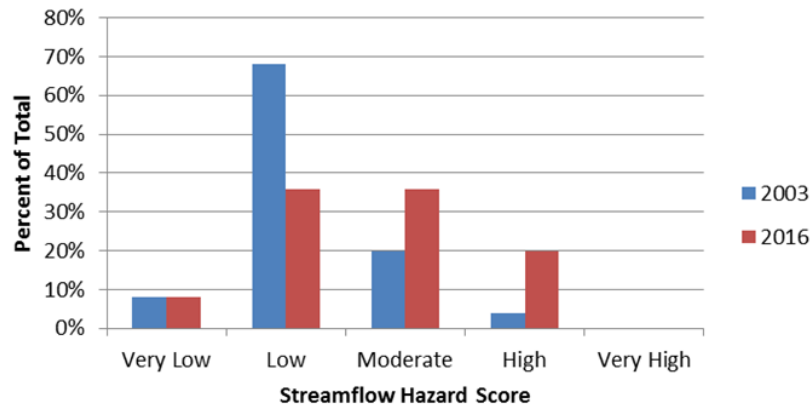




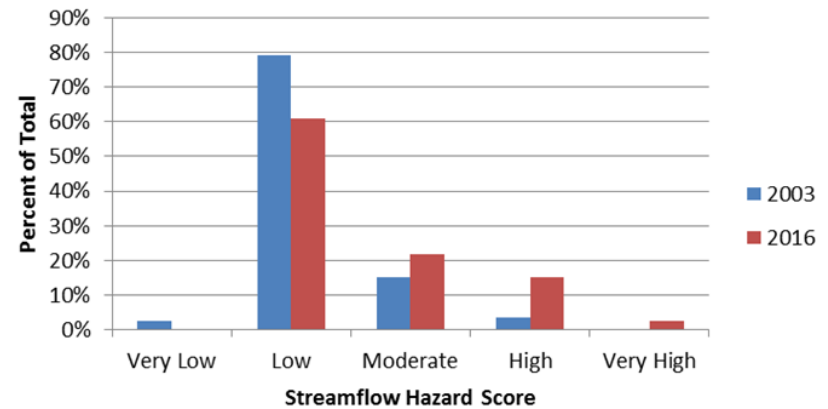


Appendix 2—South Okanagan Streamflow Hazard Statistics and Maps

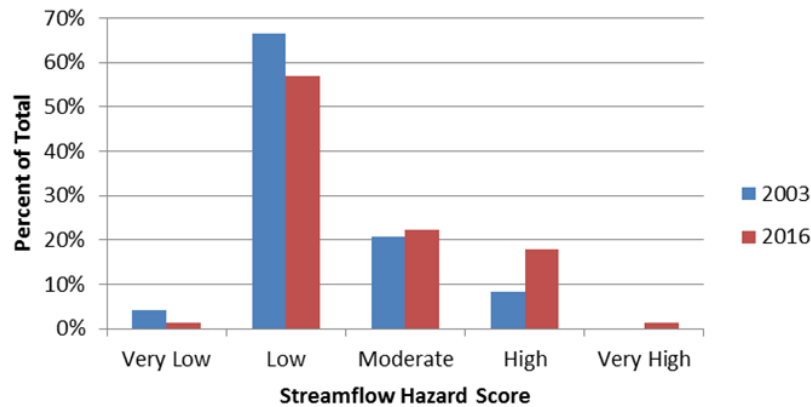
Streamflow Hazard- Sub-Basins



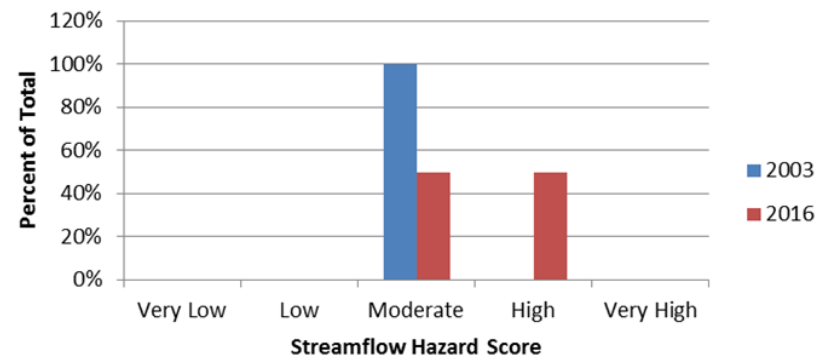
Streamflow Hazard- Basins

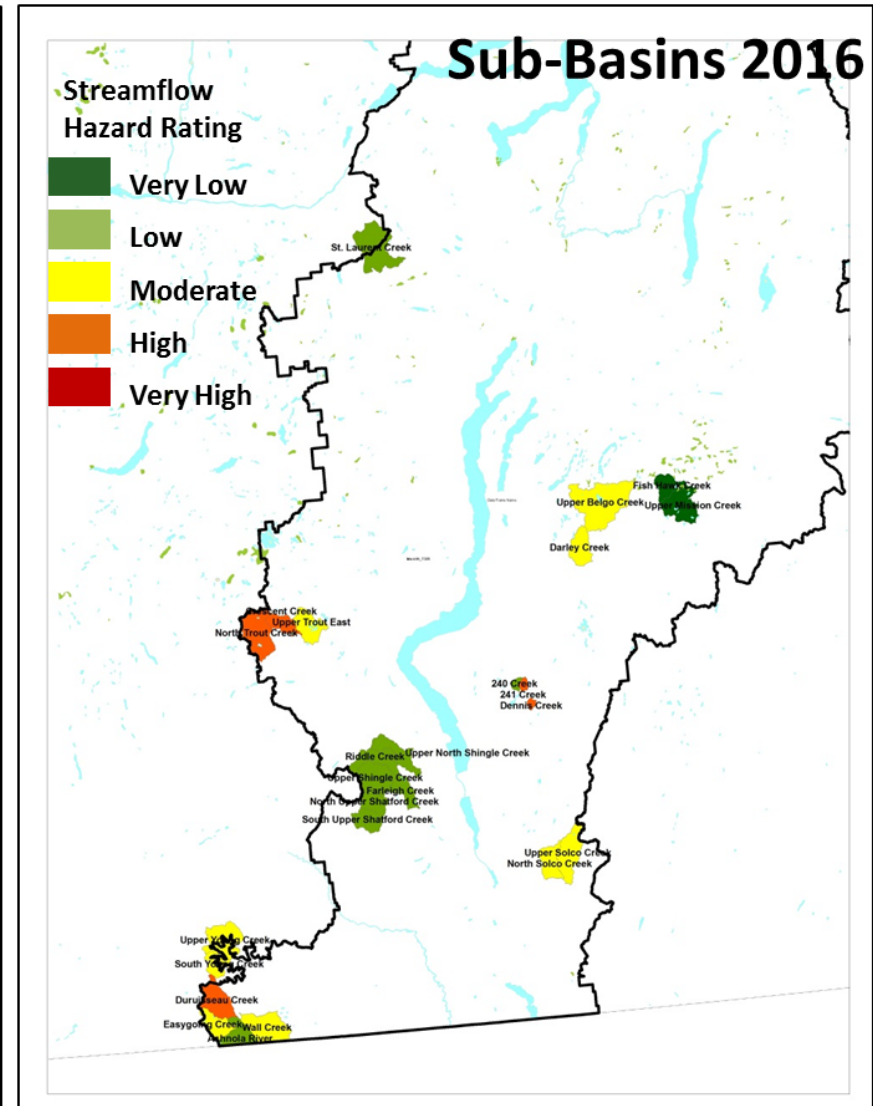
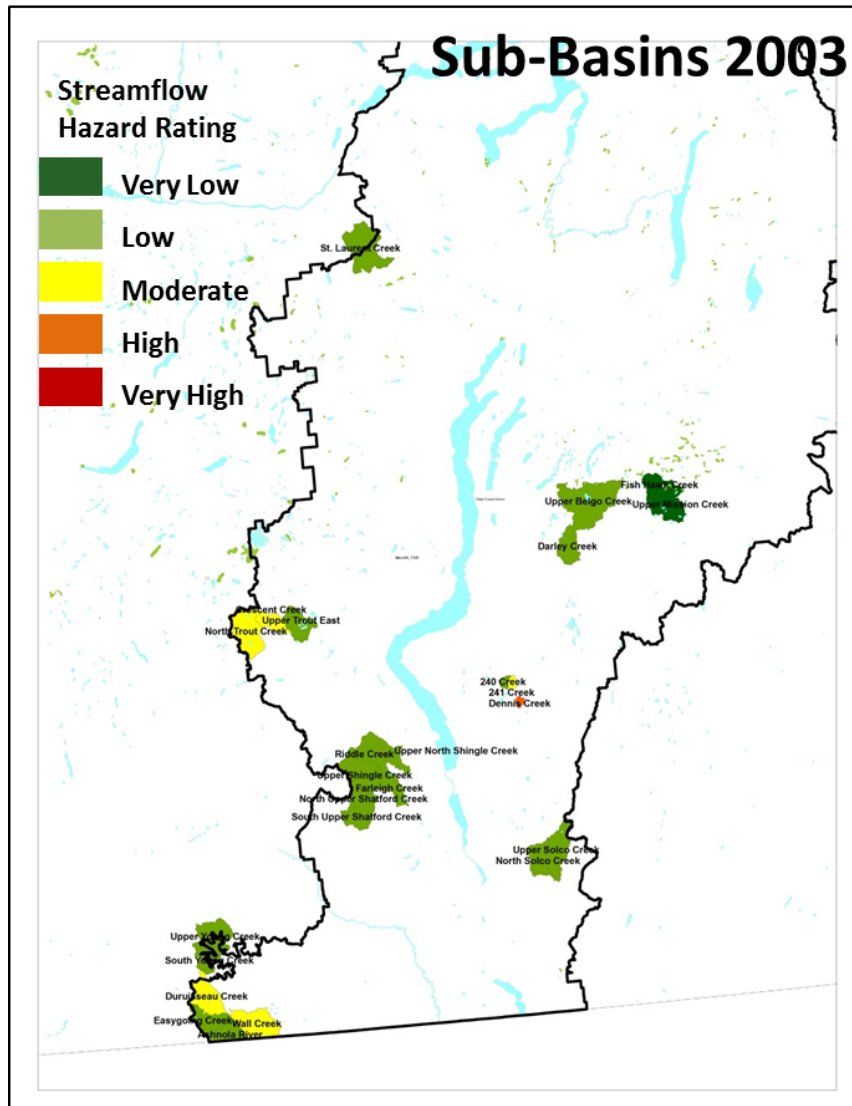


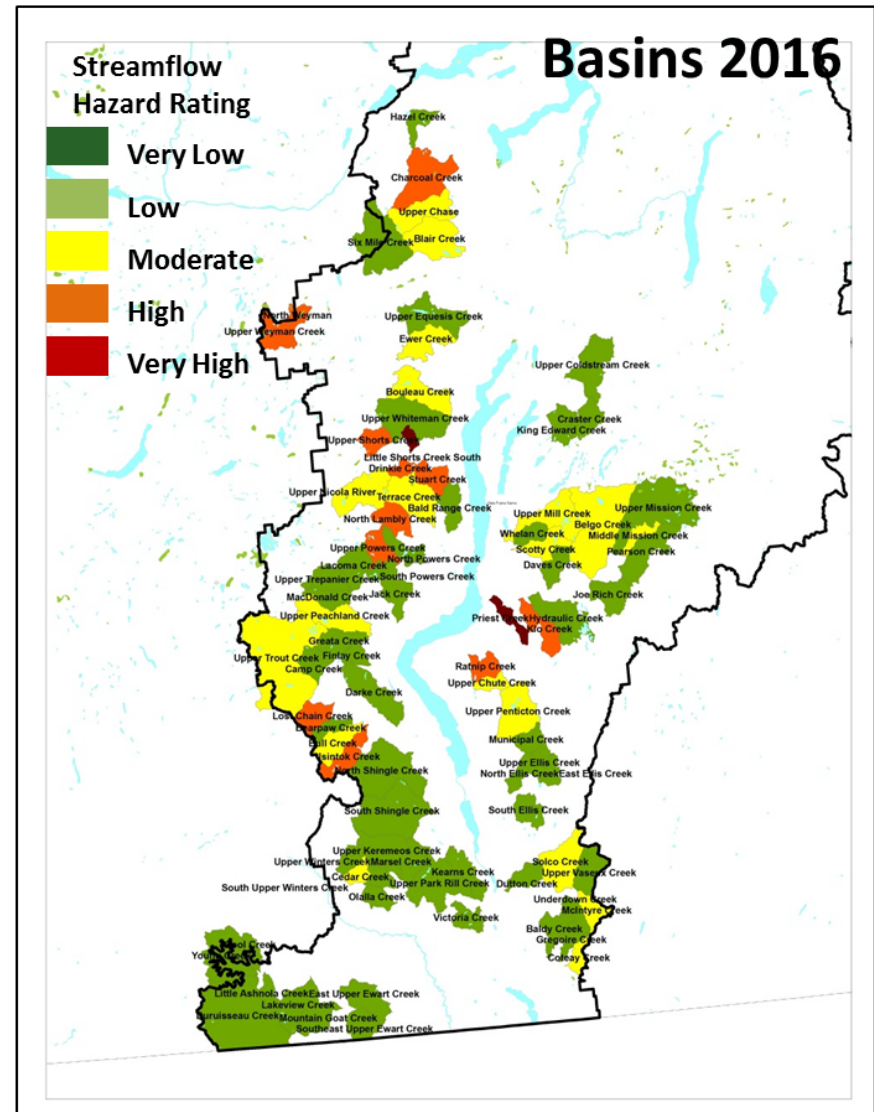
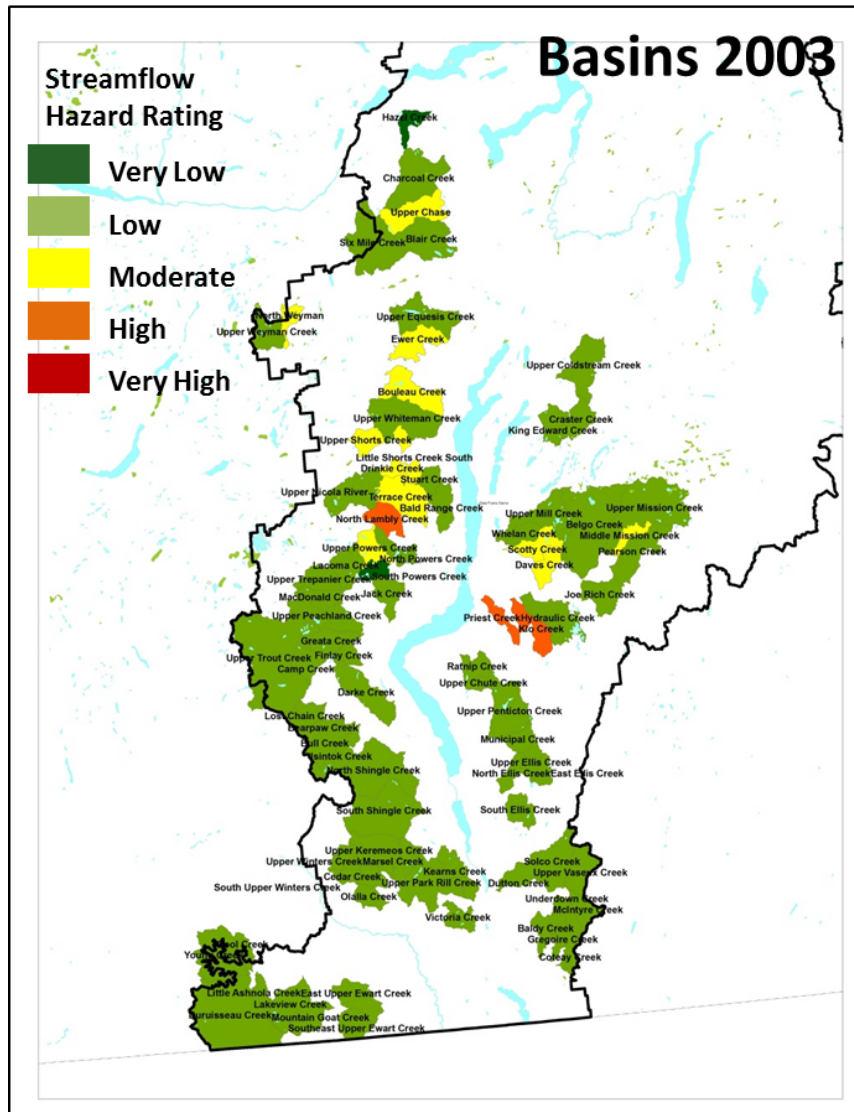
Streamflow Hazard- Watersheds

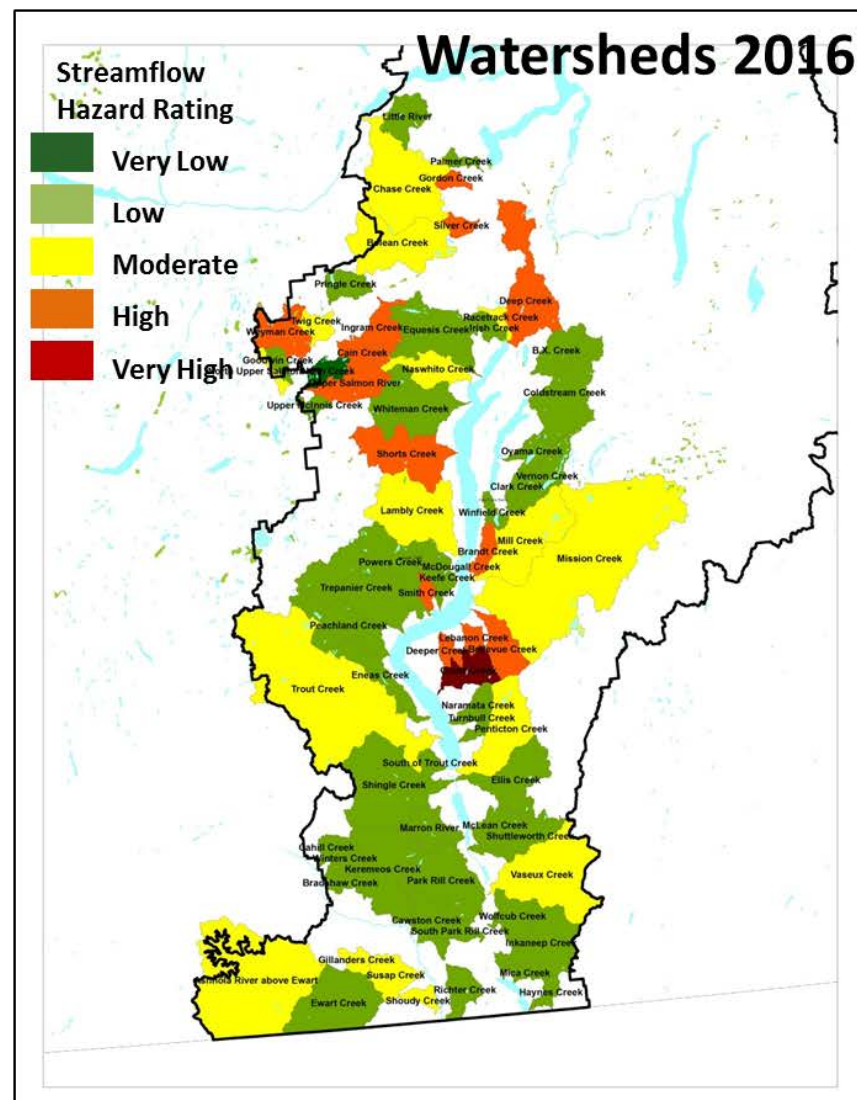
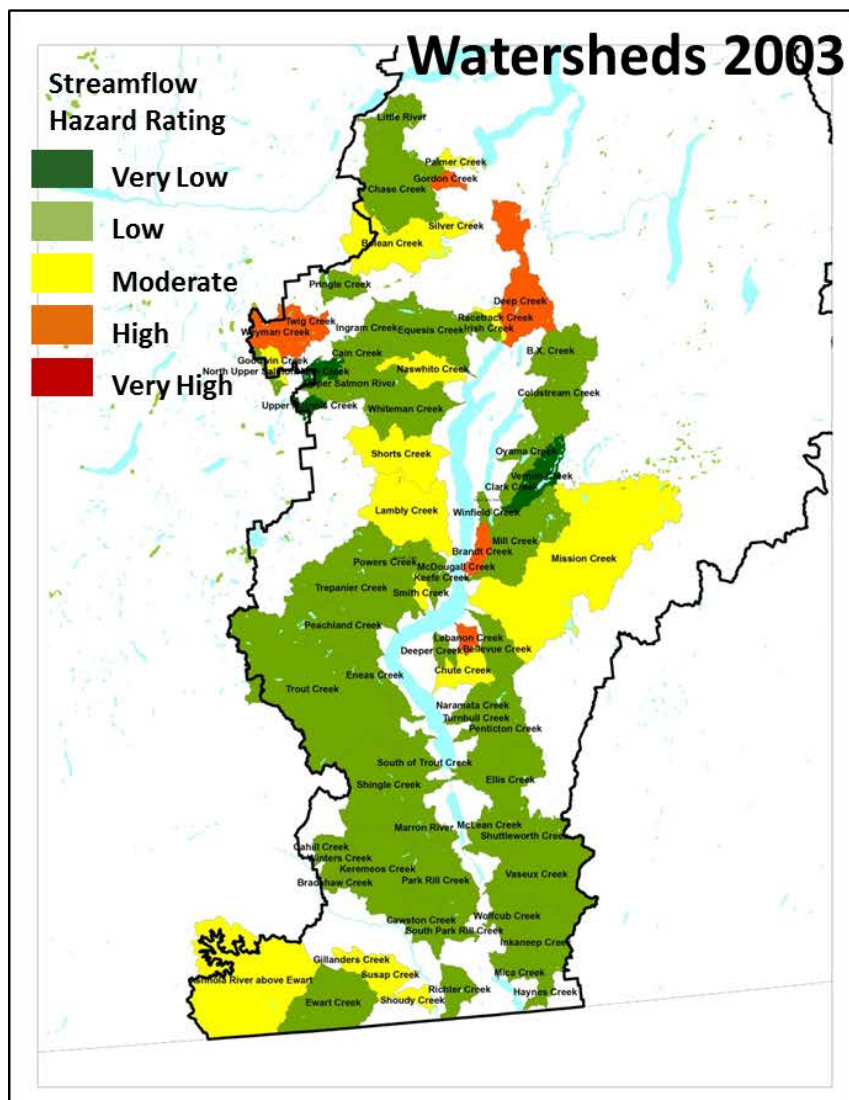


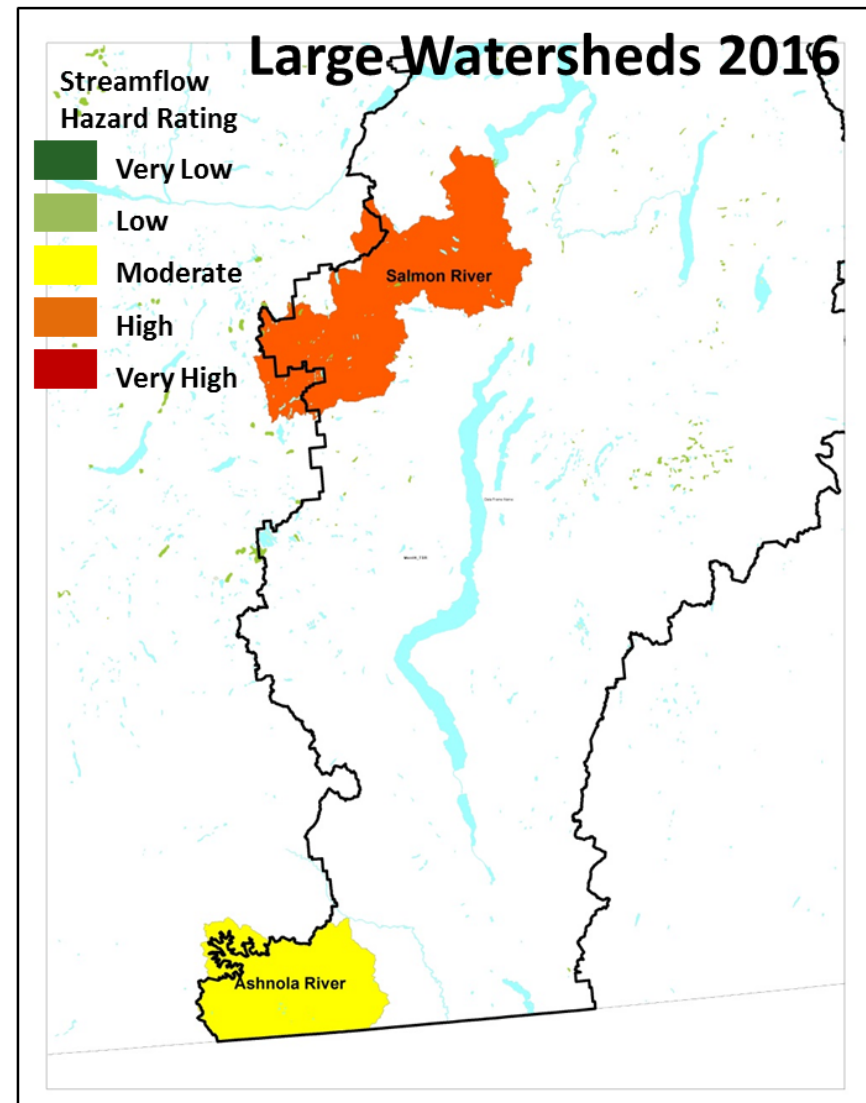
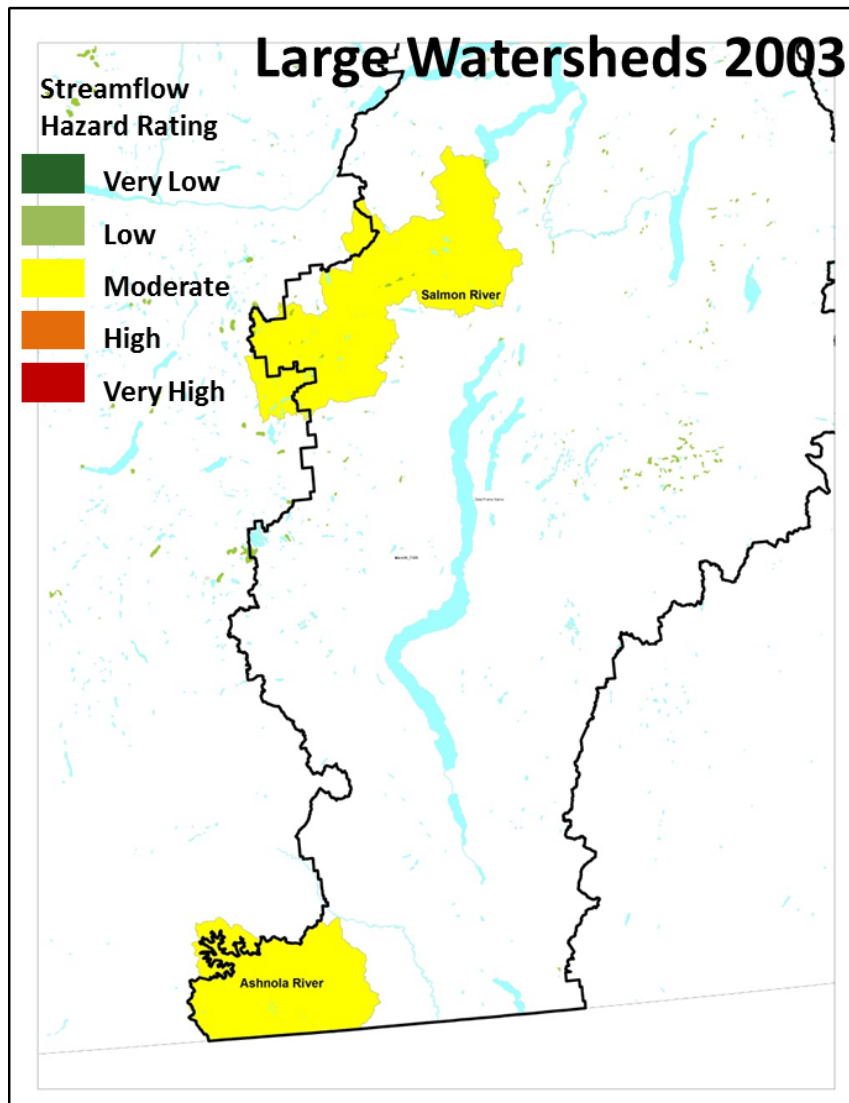
Streamflow Hazard- Large Watersheds



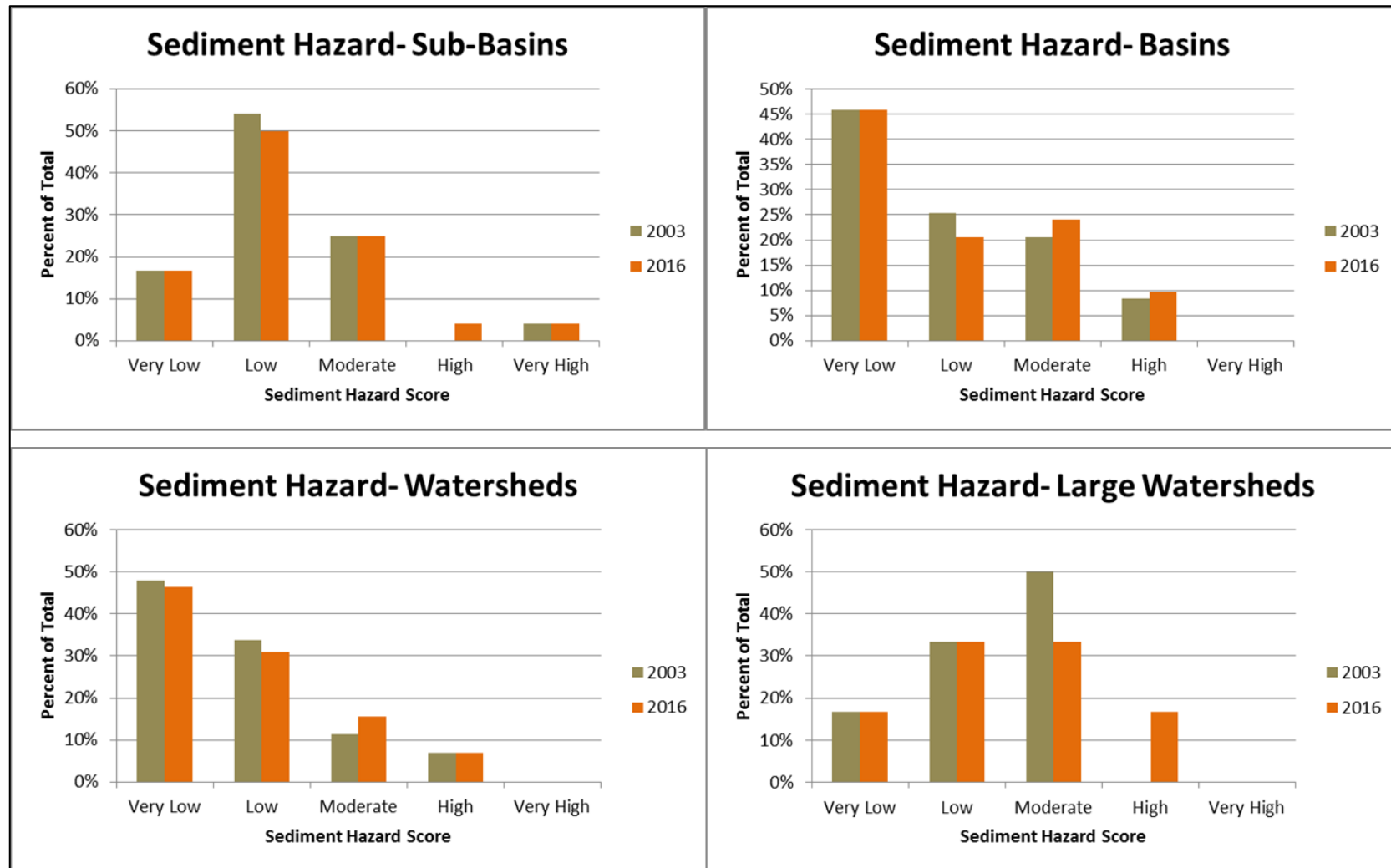


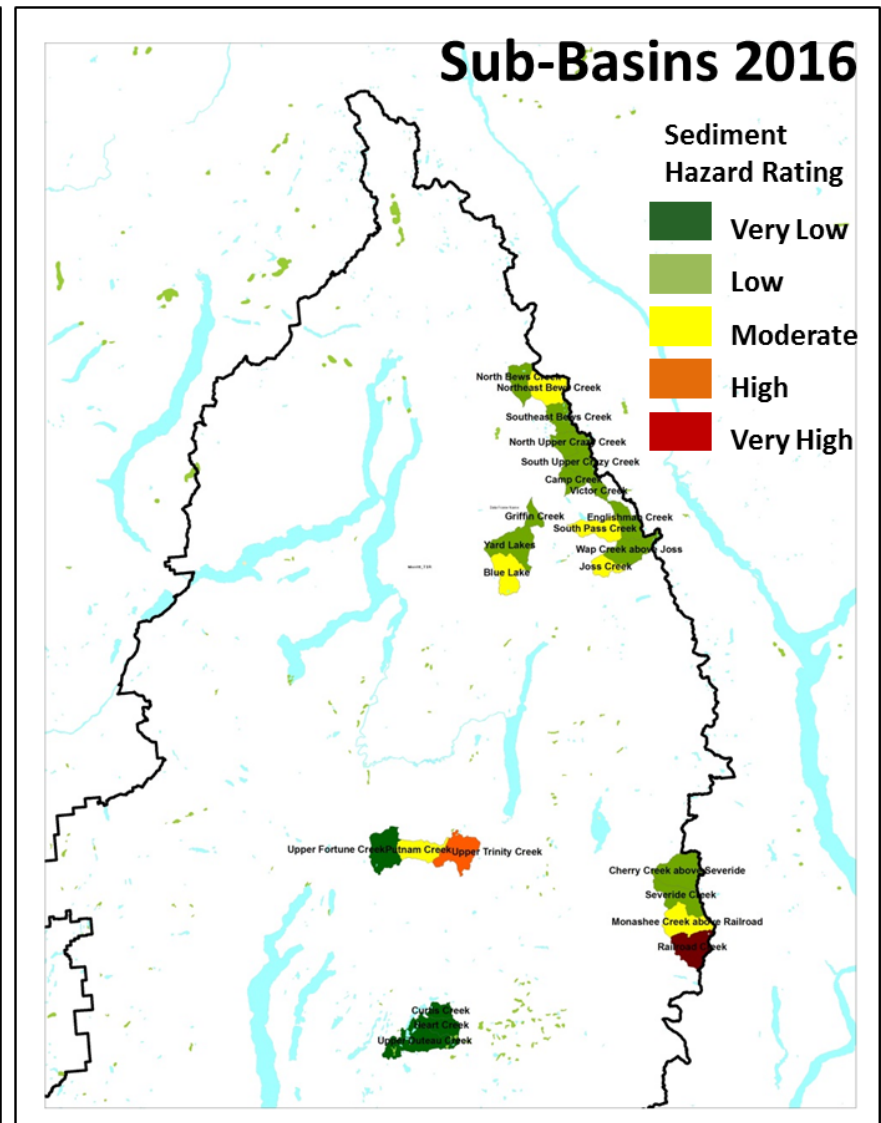
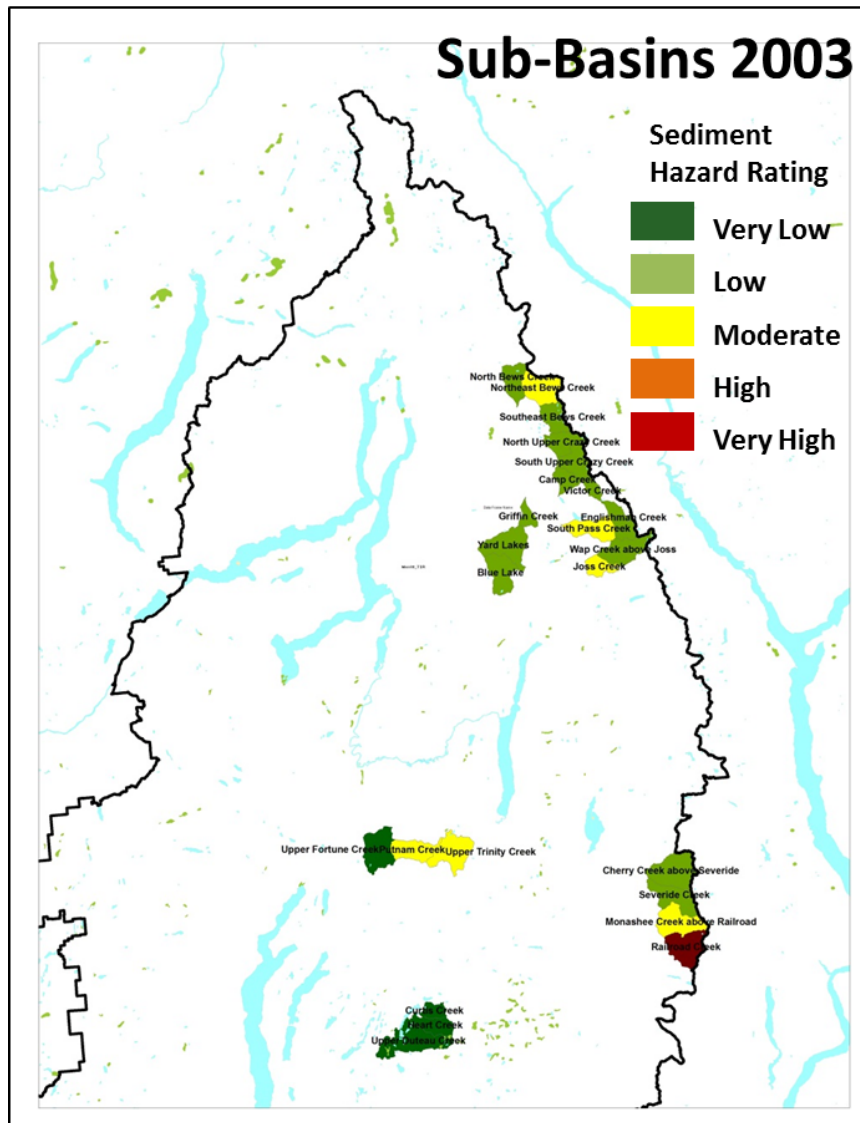


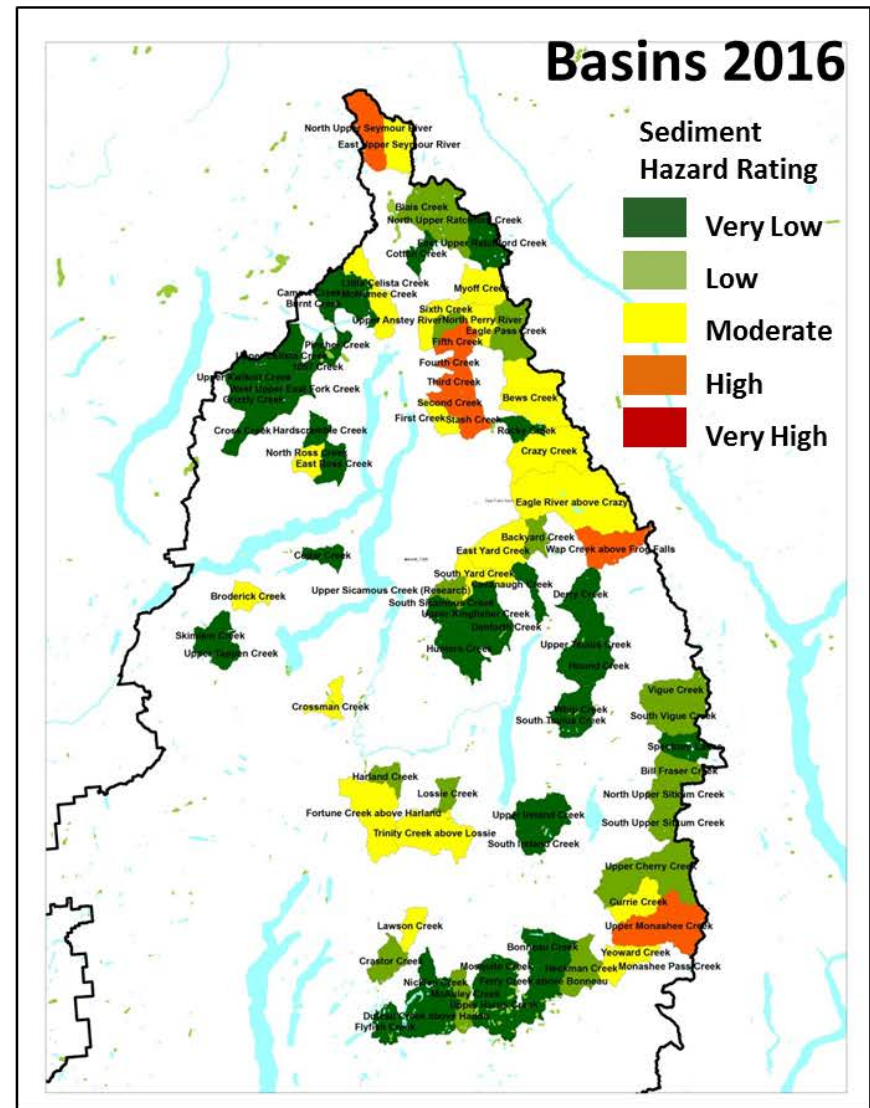
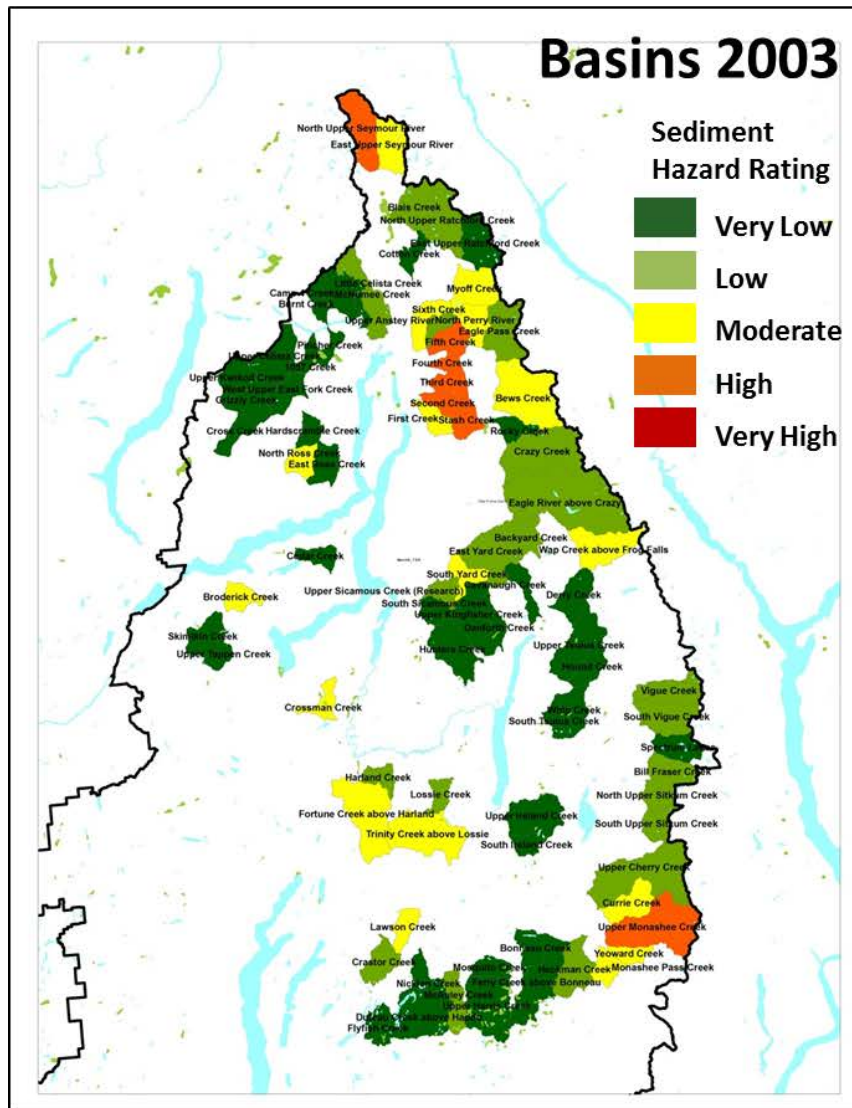


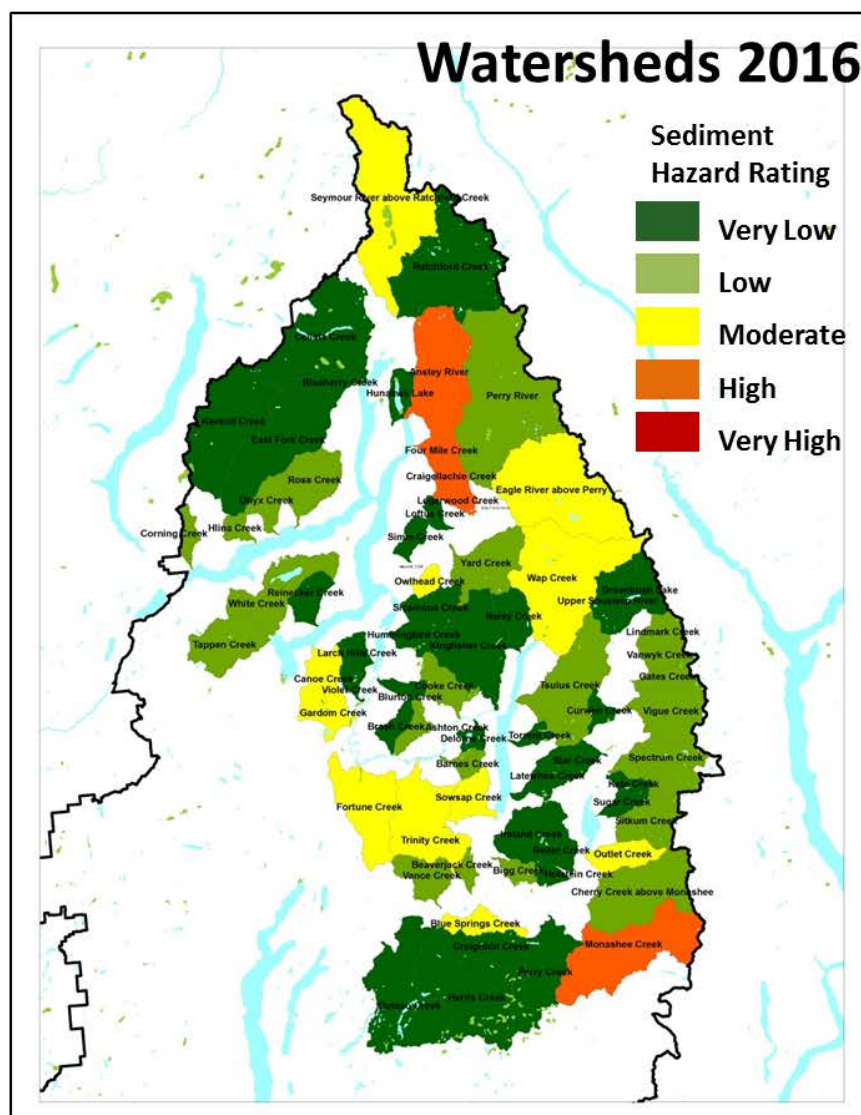
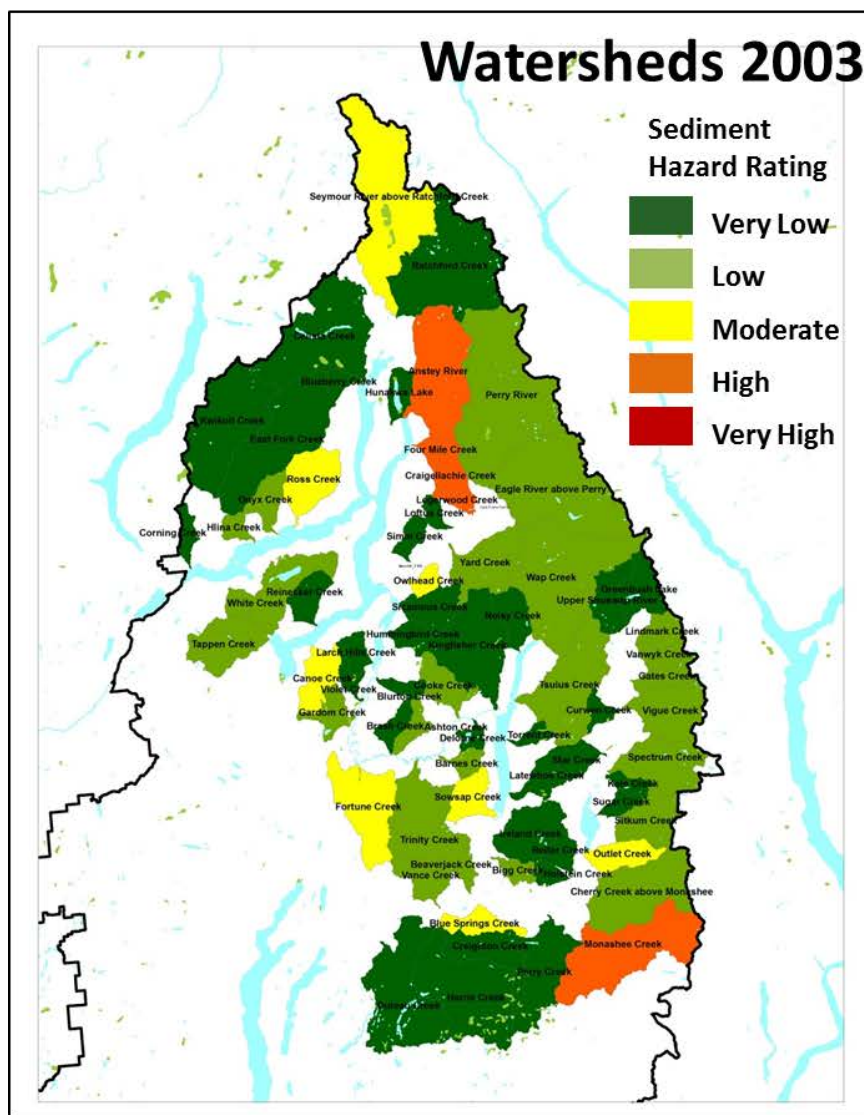


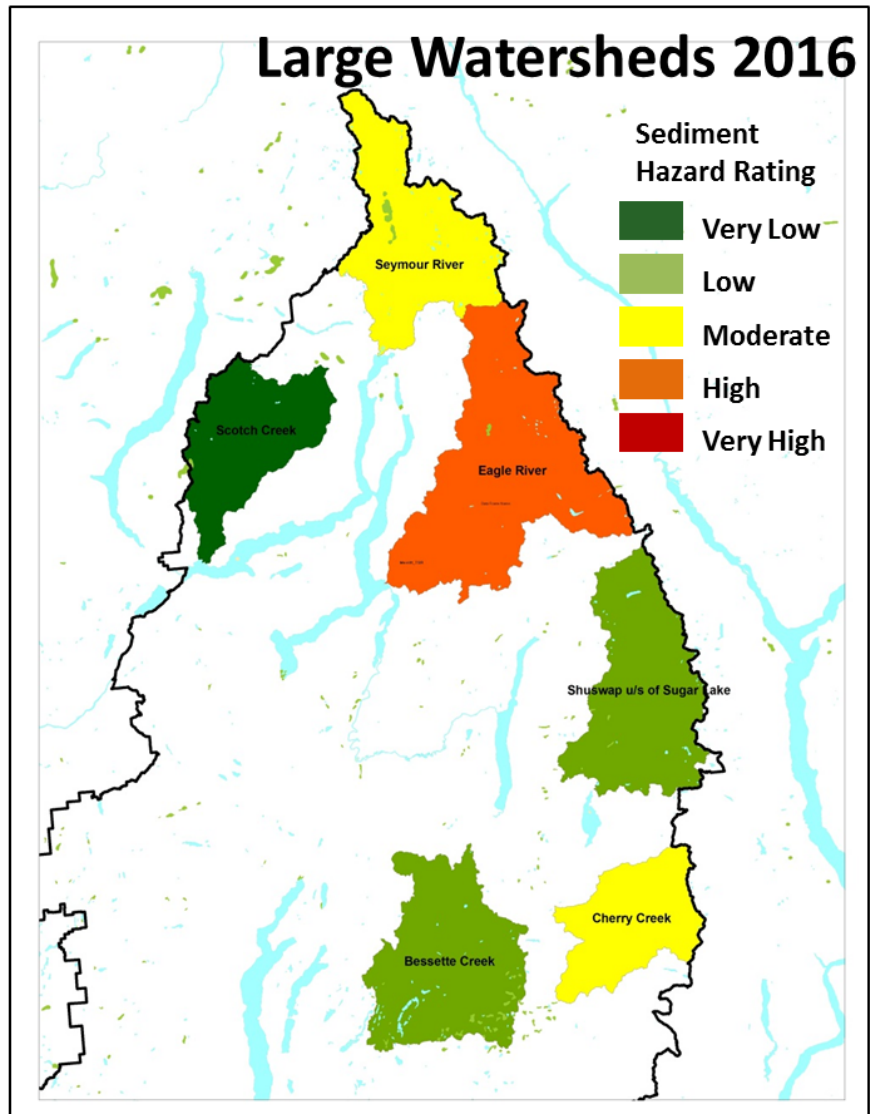
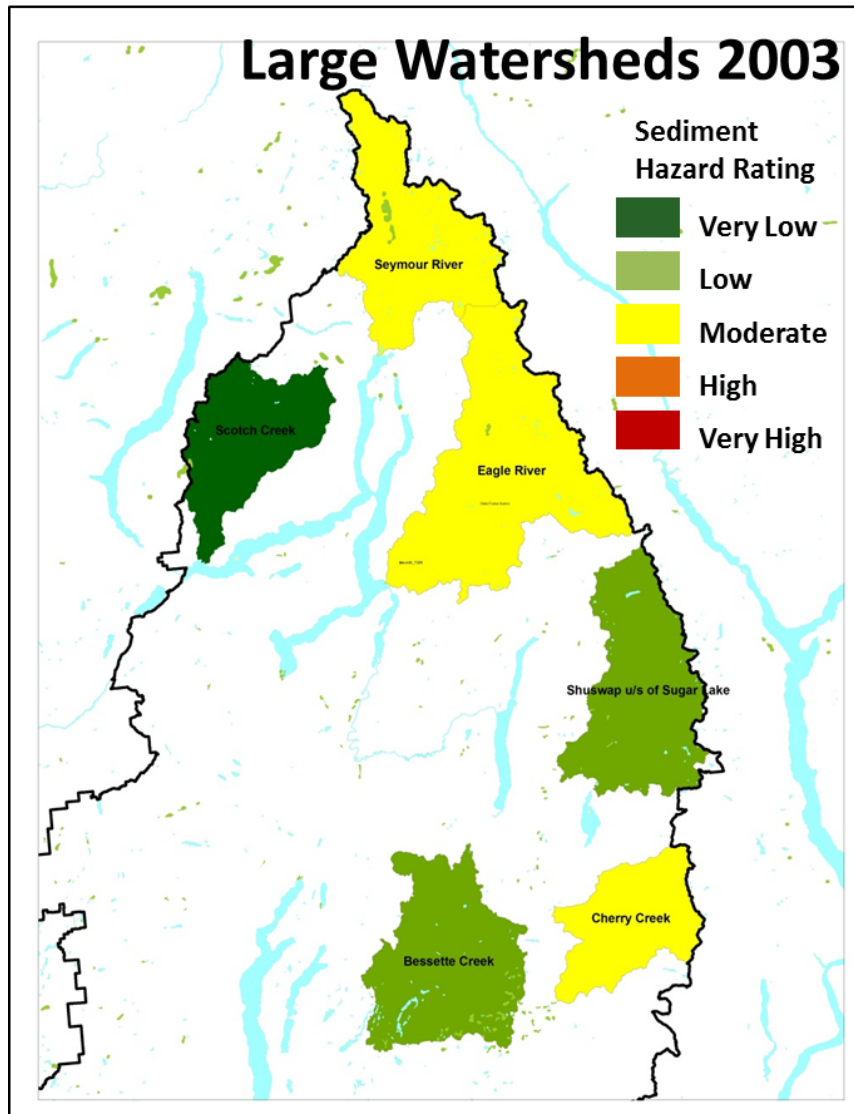
Appendix 3 – North Okanagan Sediment Hazard Statistics and Maps



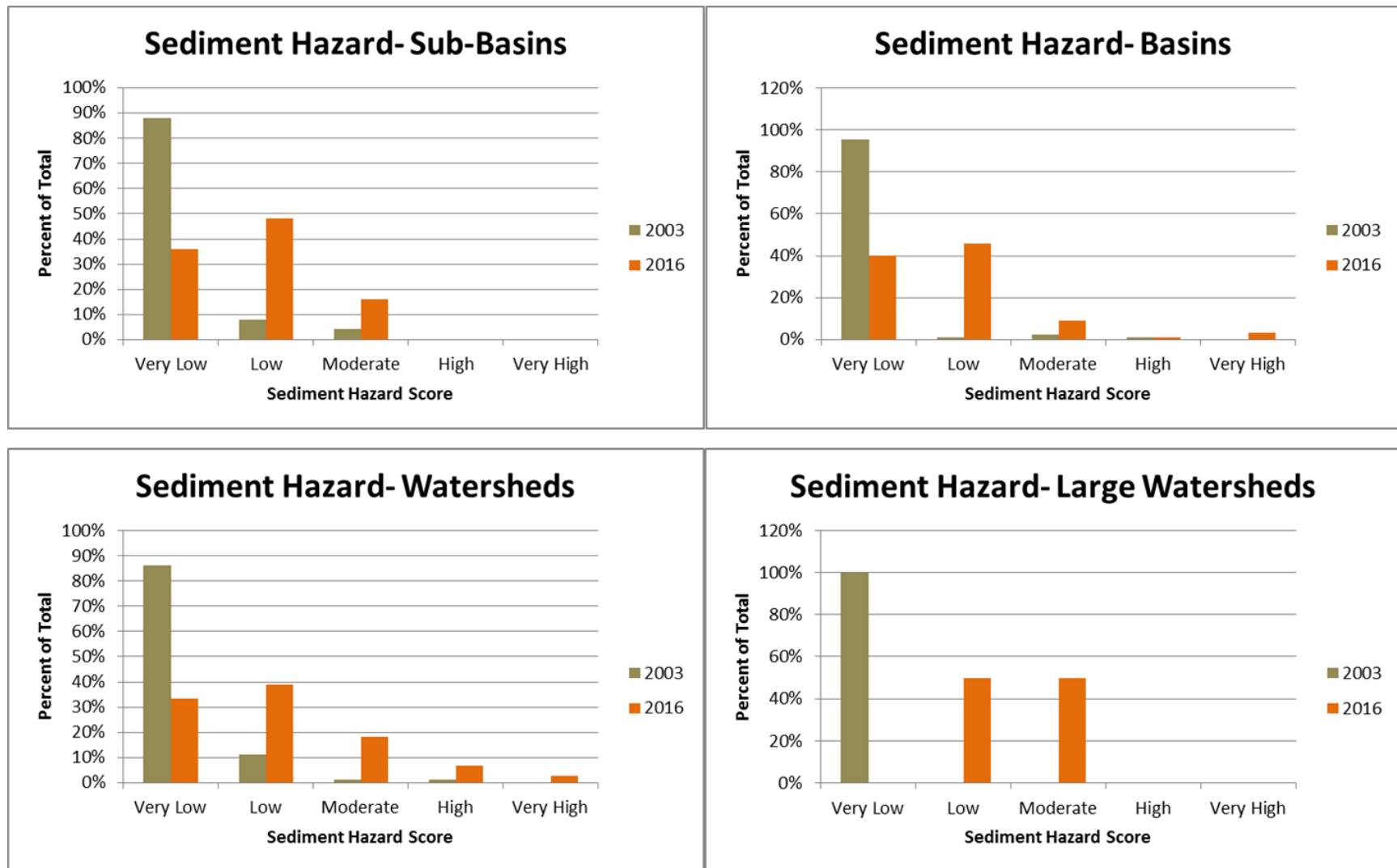


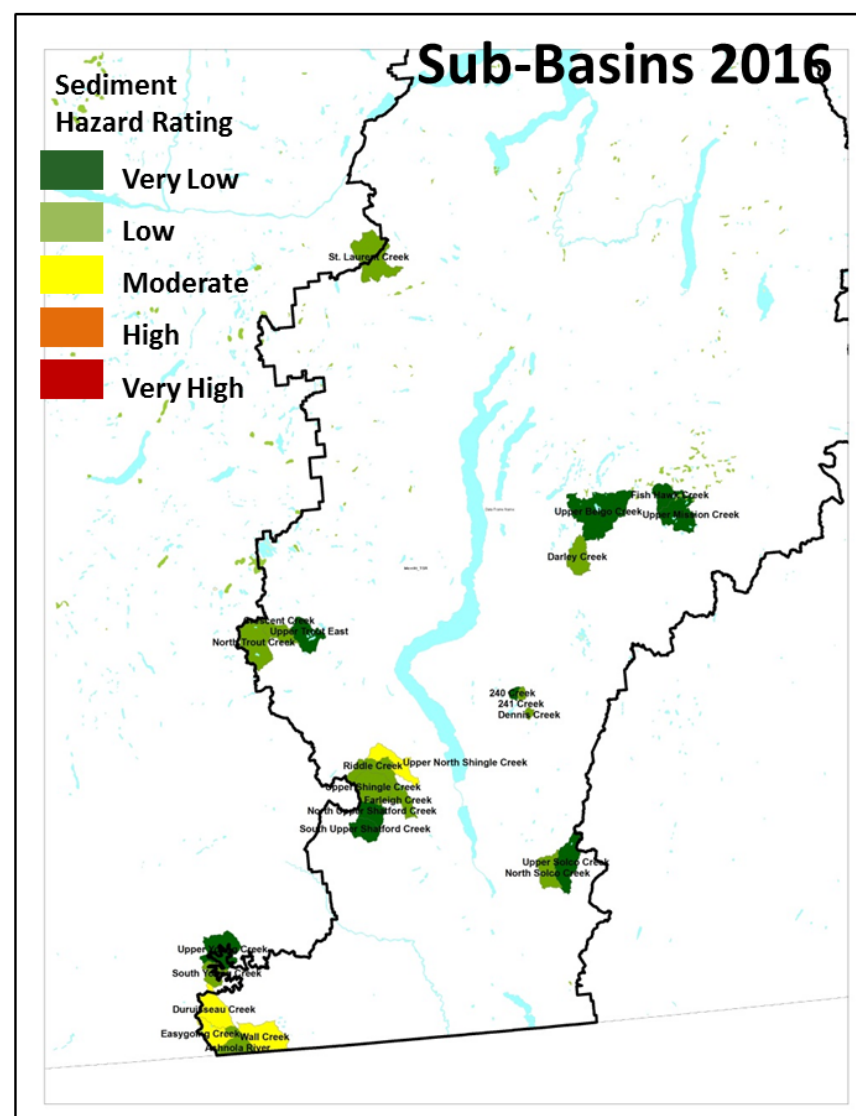
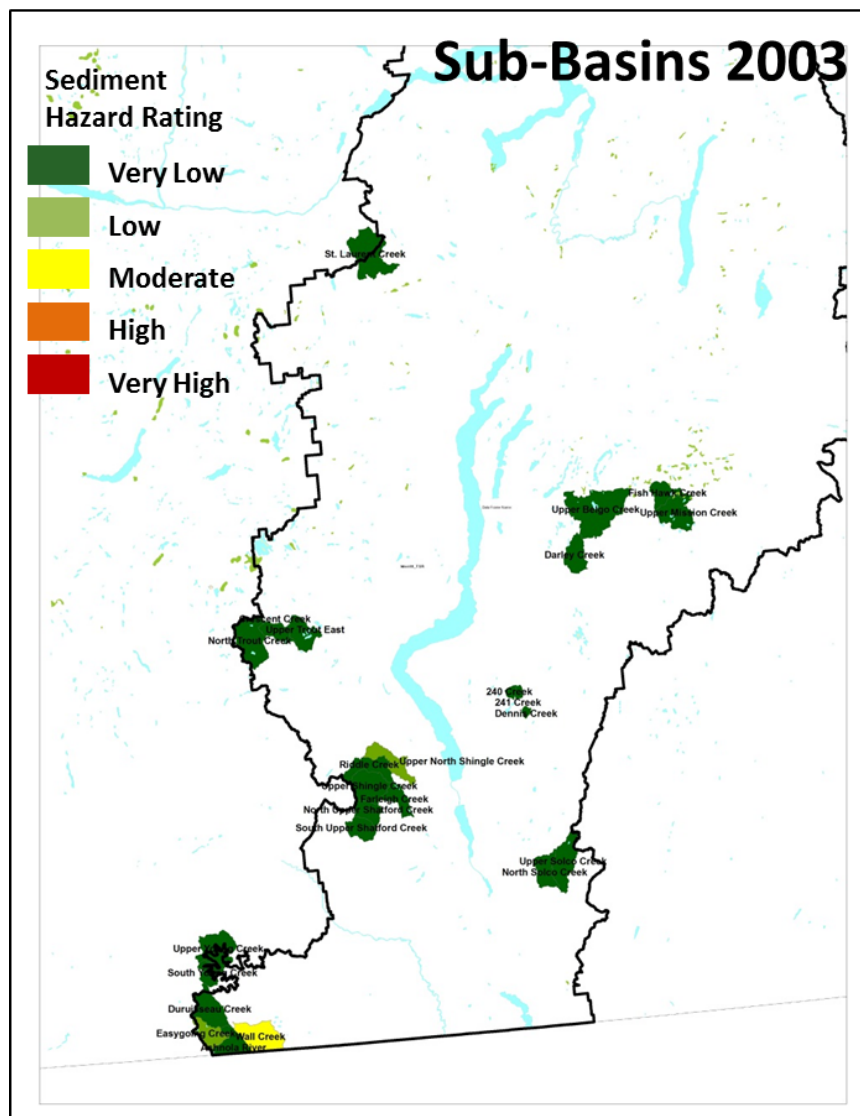


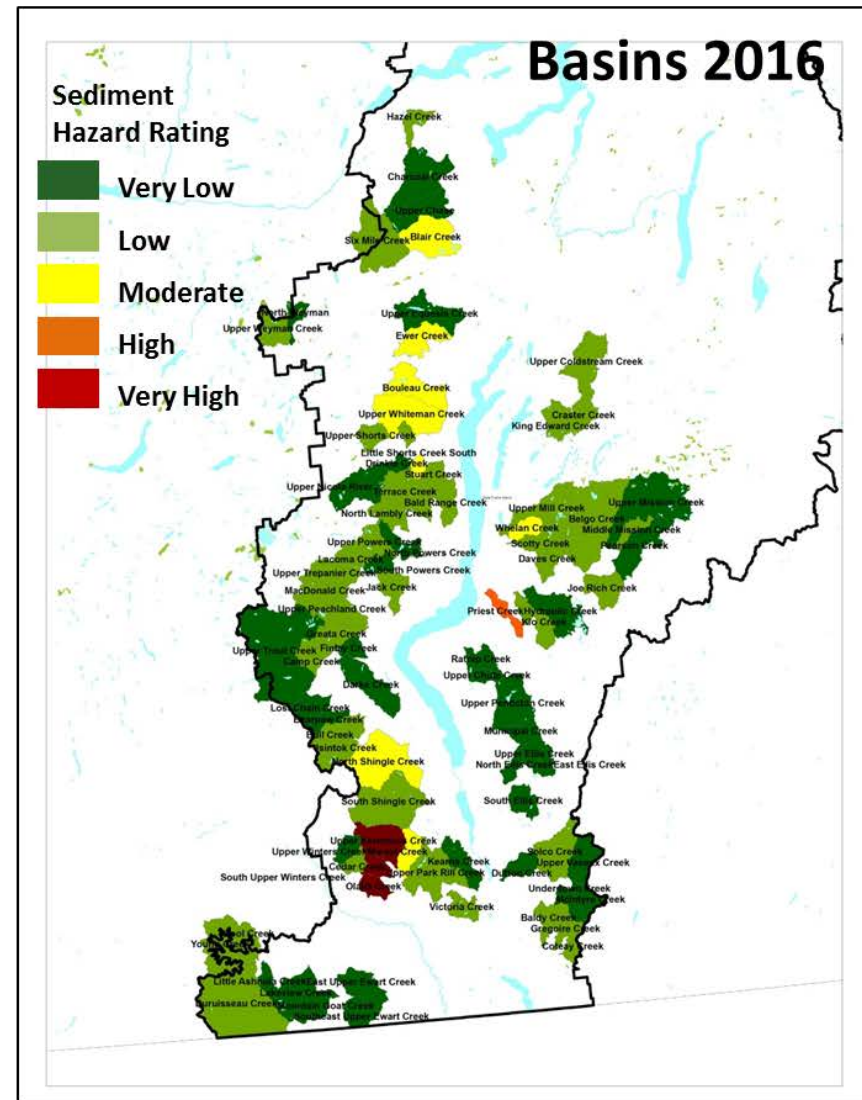
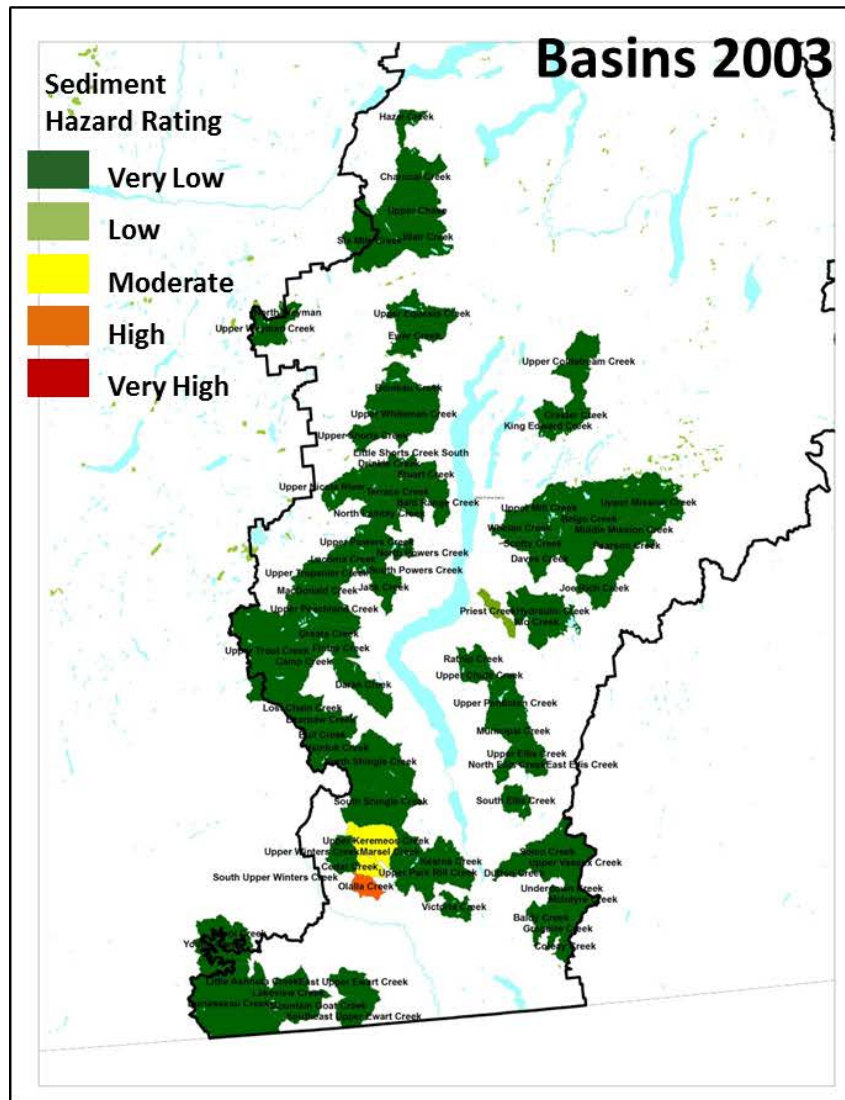


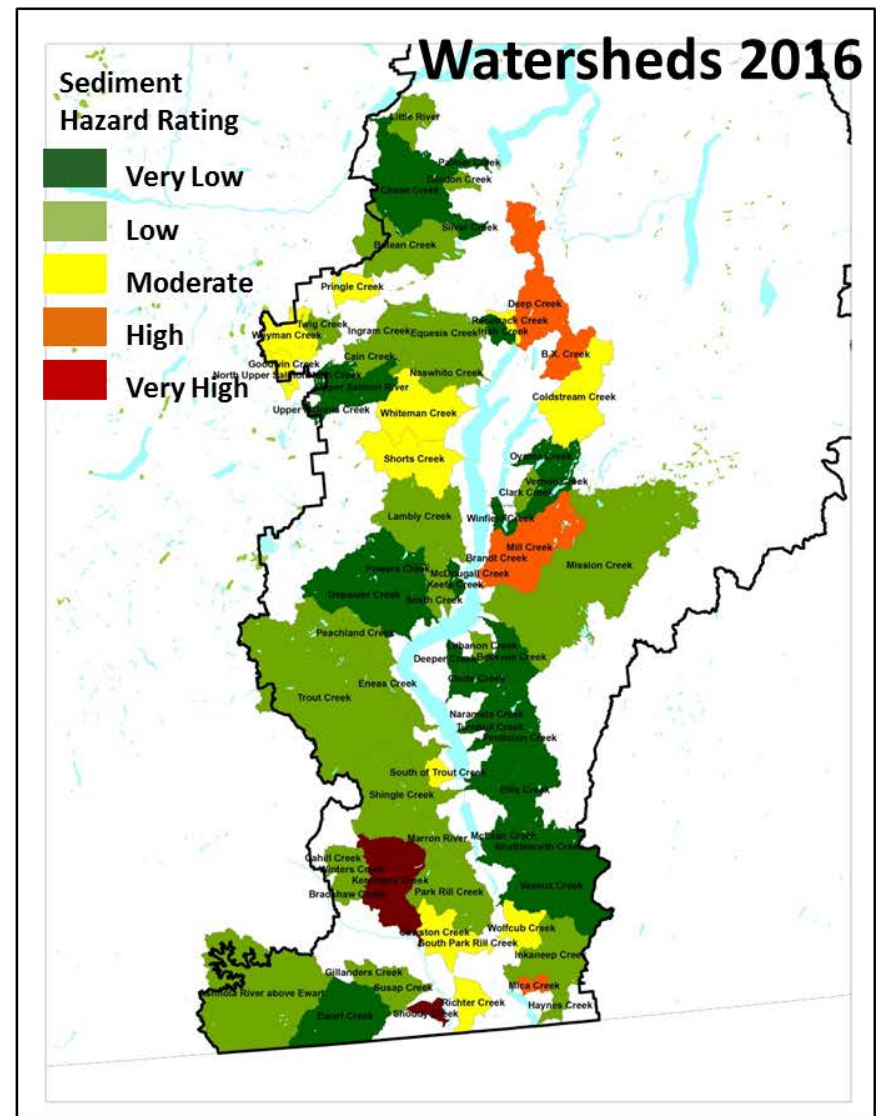
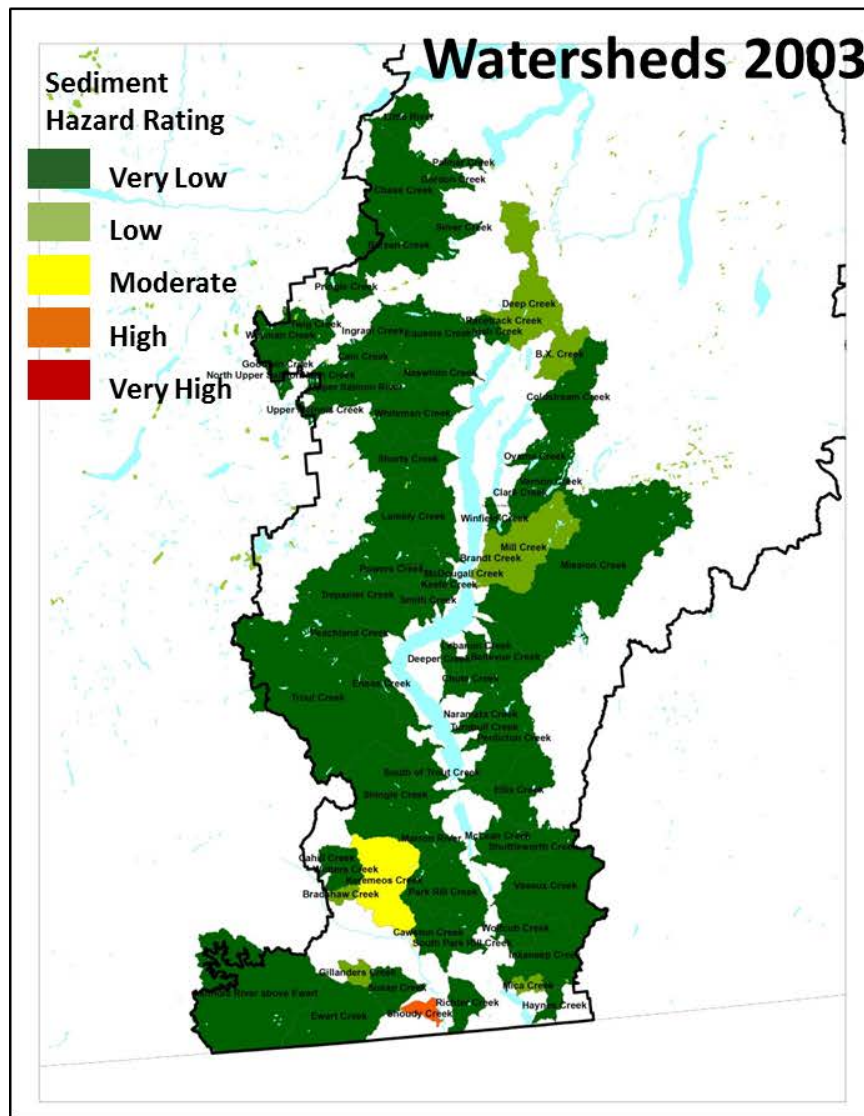


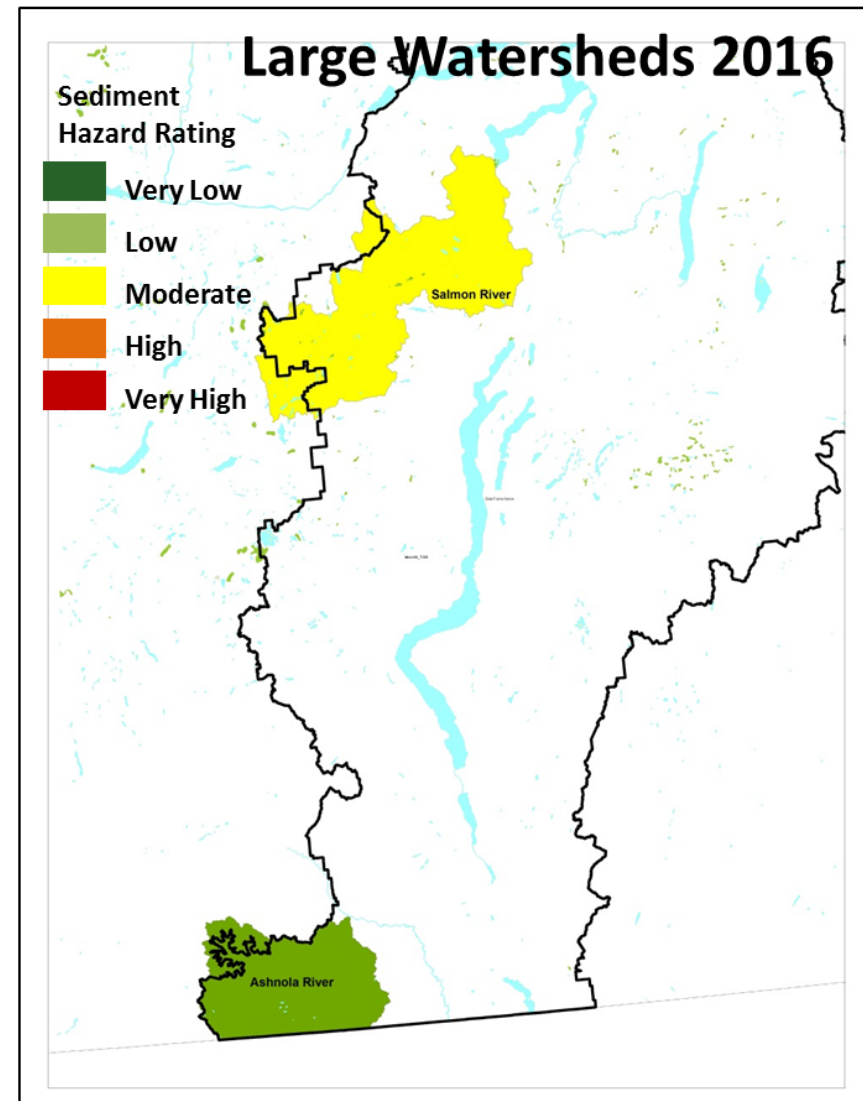
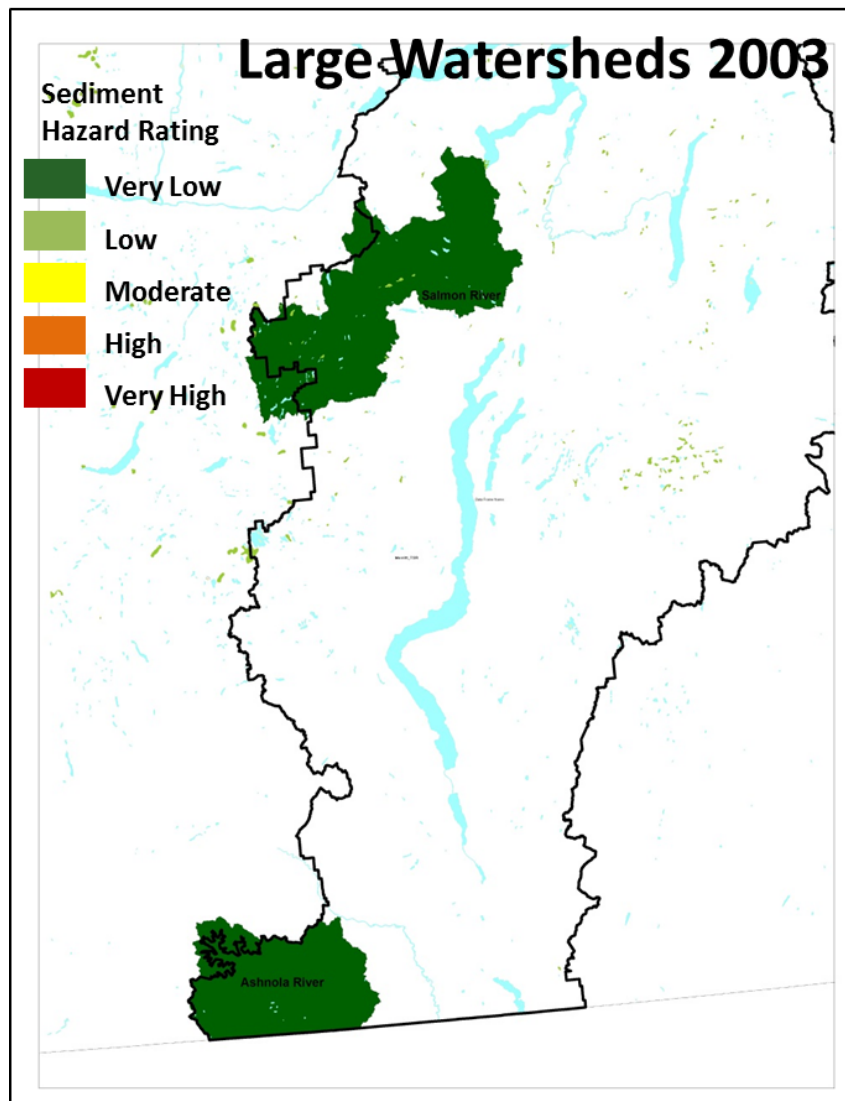
Appendix 4 – South Okanagan Sediment Hazard Statistics and Maps



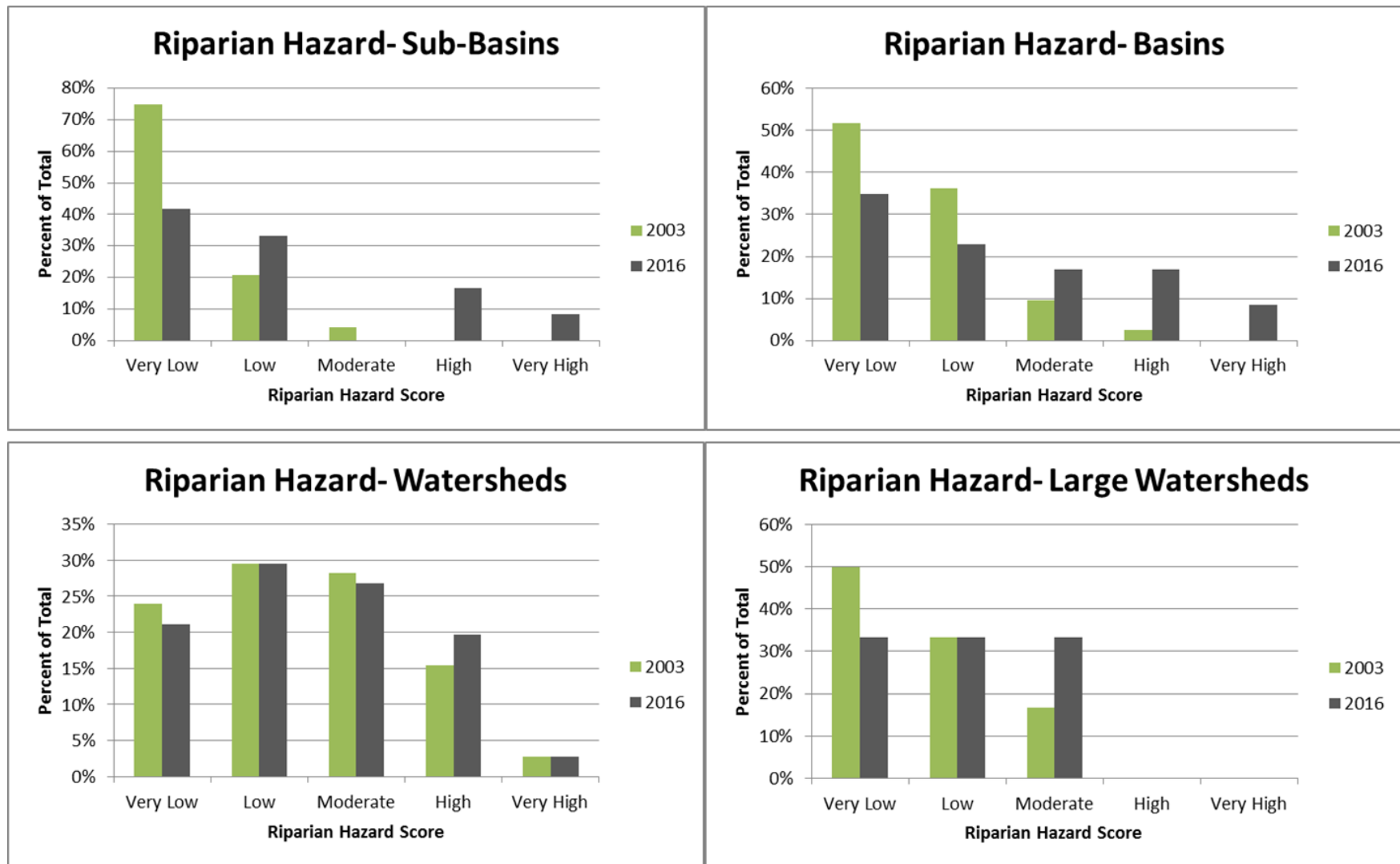


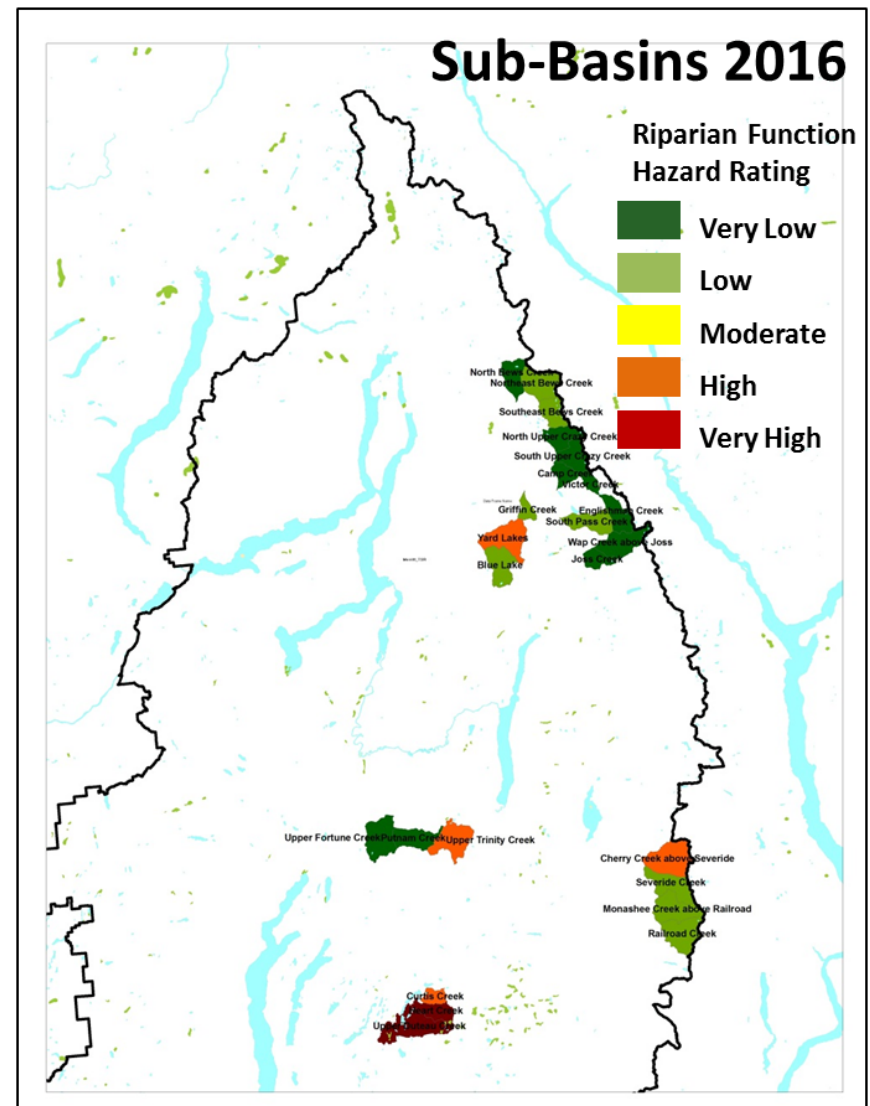
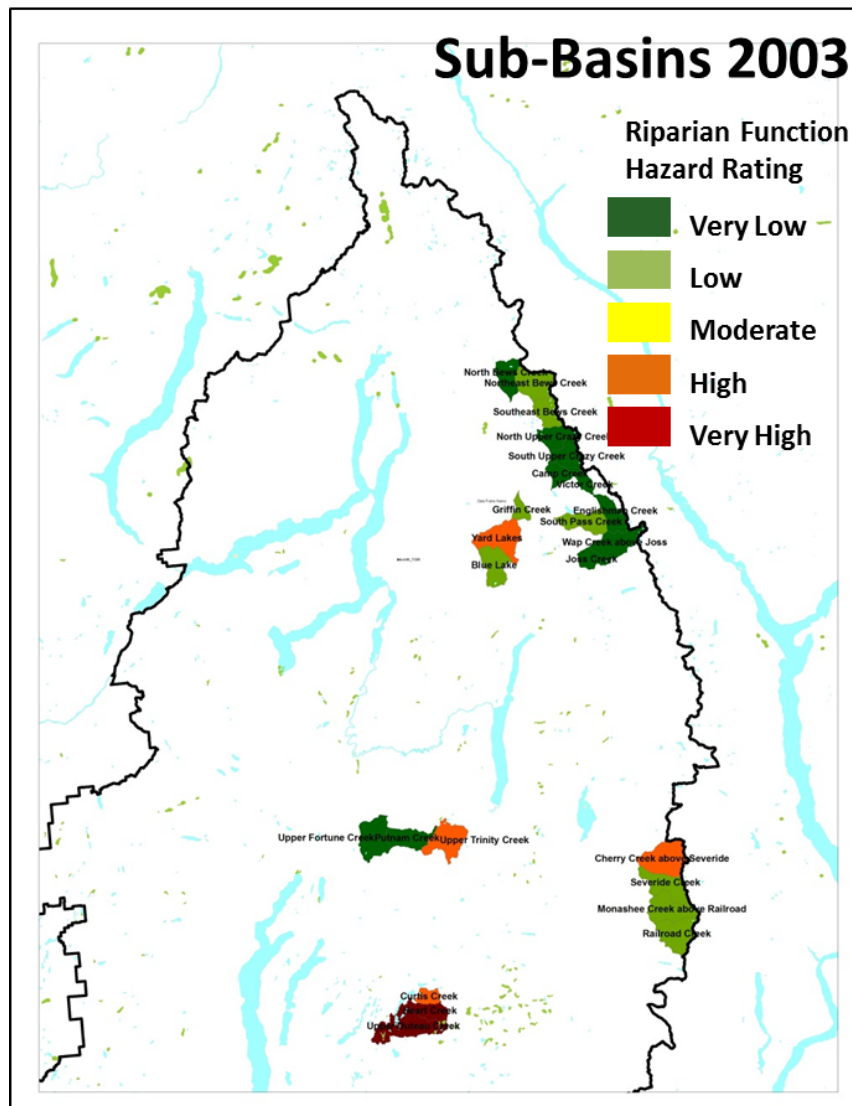


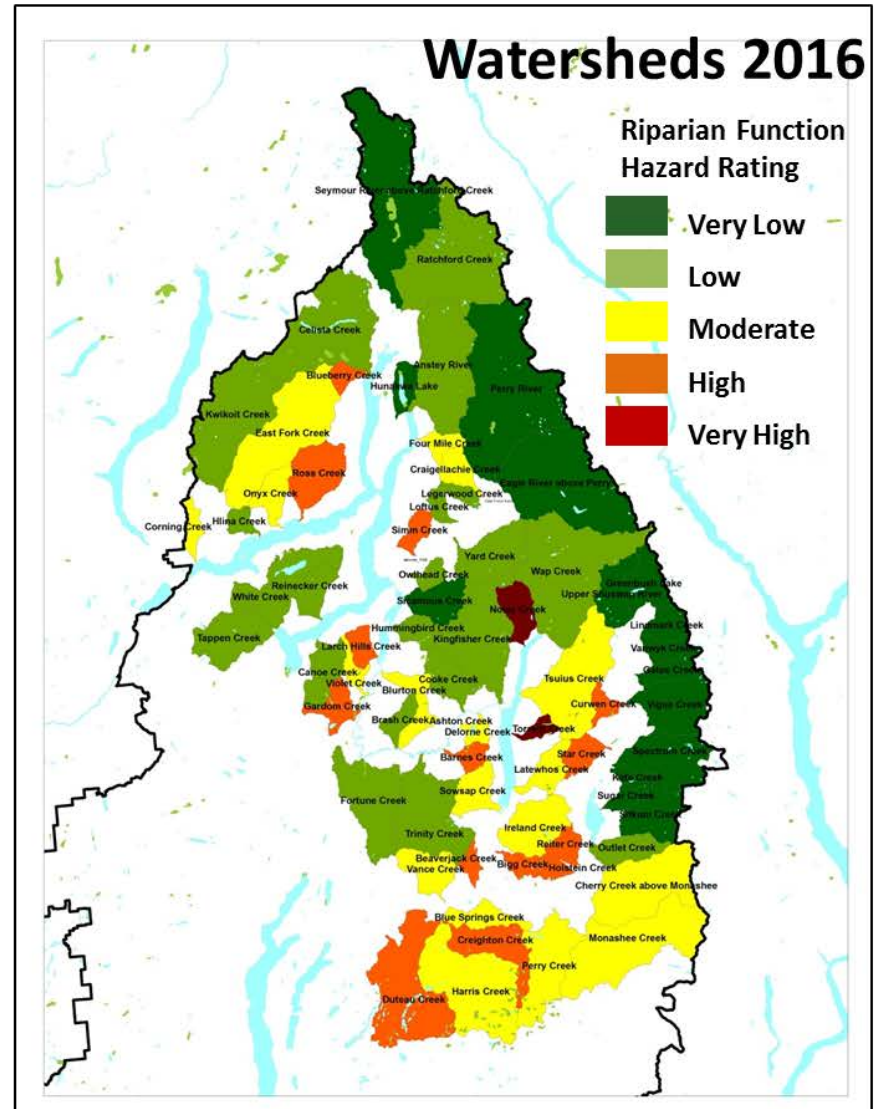
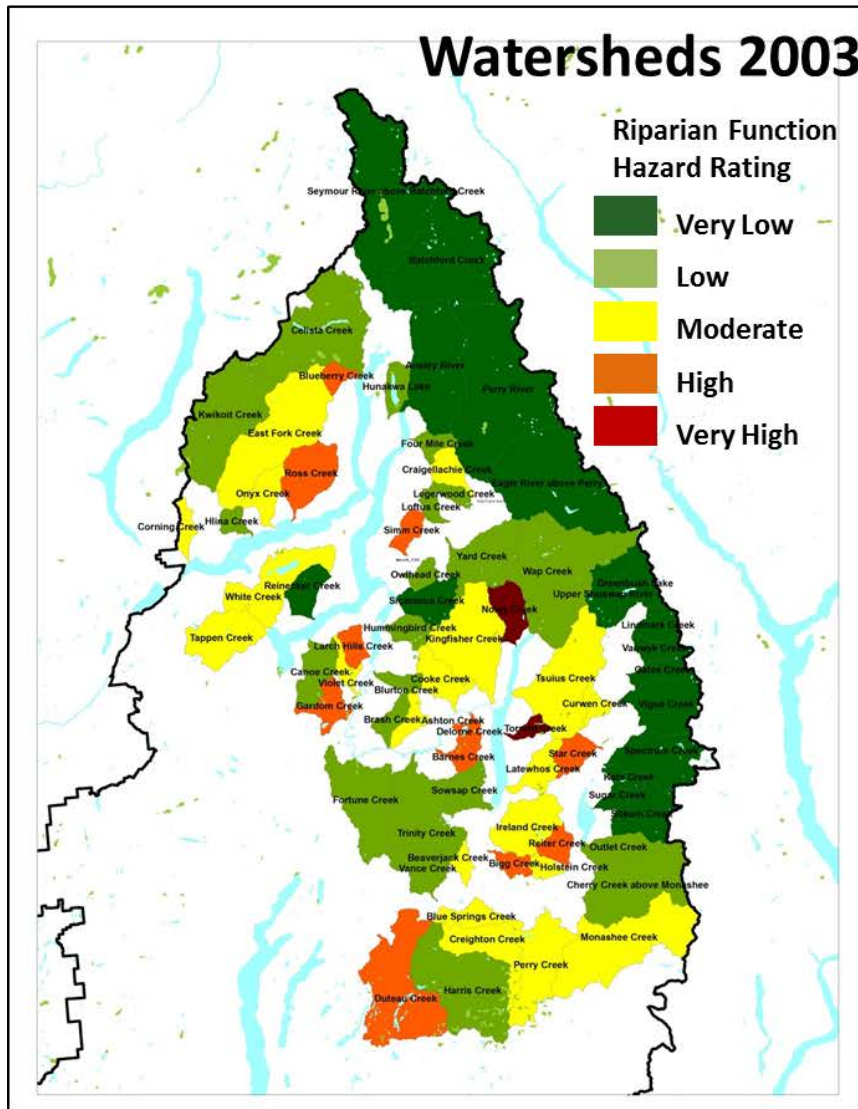


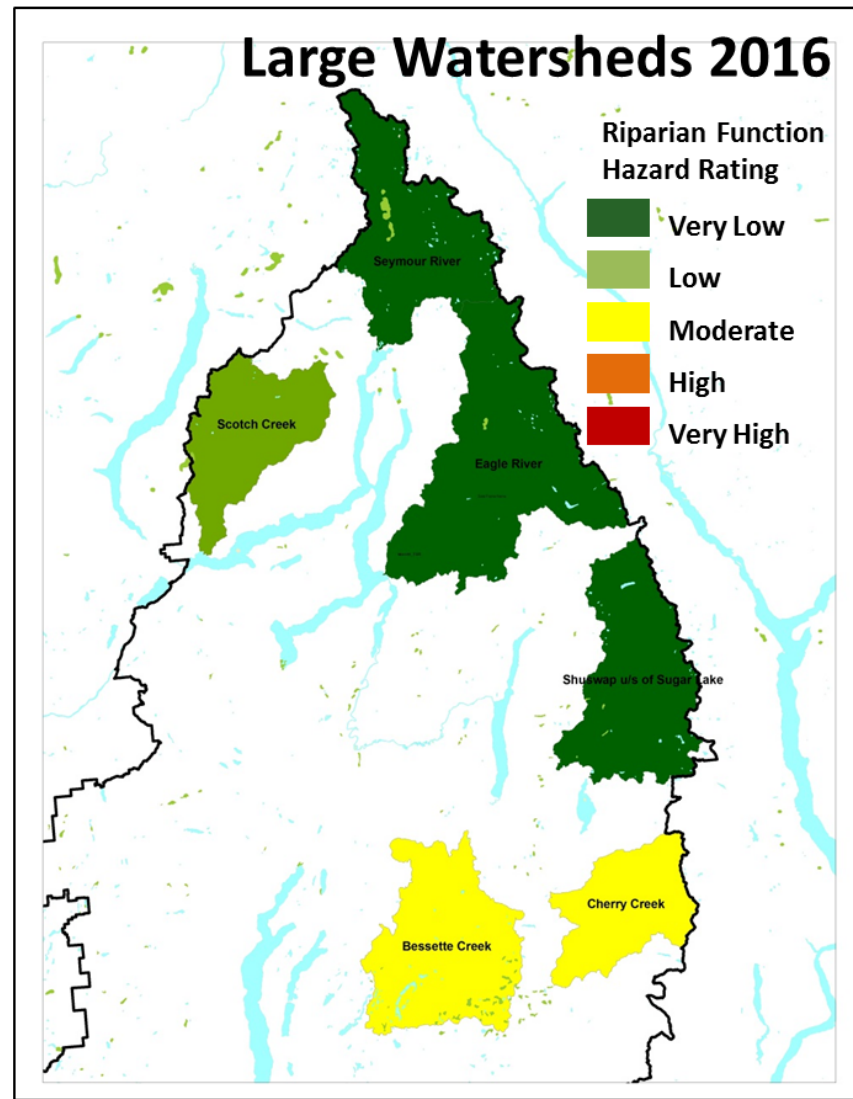
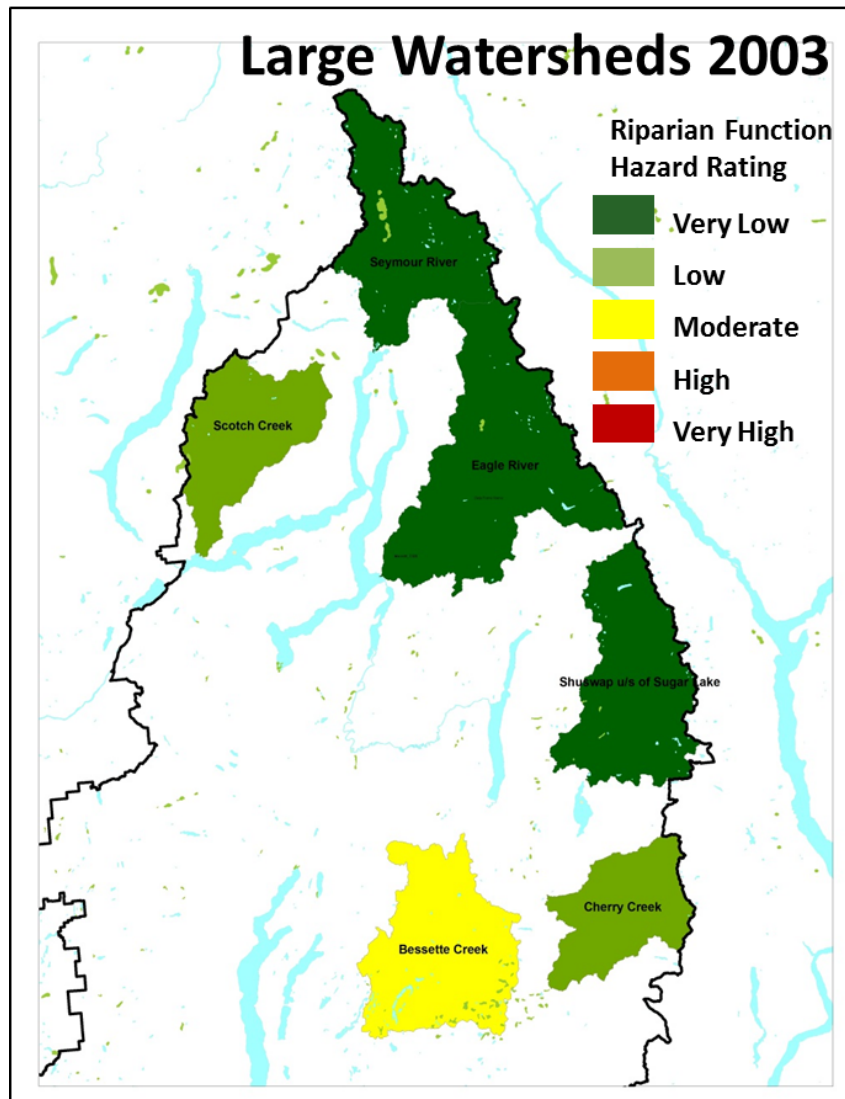


Appendix 5 – North Okanagan Riparian Hazard Statistics and Maps









Appendix 6 – South Okanagan Riparian Hazard Statistics and Maps

