

Development and Implementation of NetMap Tools in the Deadman and Bonaparte River Watersheds

A technical document drafted for the Thompson-Shuswap Salmon Collaborative

Overview

To support the development of the Thompson-Shuswap Salmon Ecosystem Action Plan, TerrainWorks was contracted to develop virtual watersheds of the Deadman and of the Bonaparte Rivers, using geospatial information in the NetMap application for ArcGIS Pro (versions 3.3 and 3.4). These virtual watershed models enable spatial analysis and data visualization at the watershed-scale. NetMap also includes a suite of analytical tools related to fluvial processes, aquatic habitats, riparian areas, erosion, roads, and wildfire/climate change impacts. These tools can help identify candidate areas for different restoration activities and highlight potential restoration opportunities at particular sites of interest. The NetMap virtual watershed models and associated outputs supported the development of the Thompson-Shuswap Ecosystem Action Plan (the 'Plan') by helping identify and recommend locations that could benefit from restoration actions. For more information on specific NetMap tools, refer to the online [Technical Help Guide](#) provided by TerrainWorks.

Virtual Watershed Development

To create the virtual watersheds, TerrainWorks developed synthetic hydrography using digital elevation model (DEM) and Light Detection and Ranging (LiDAR) data provided by the TSSC. For the Bonaparte watershed, both DEMs and LiDAR data were used because LiDAR coverage was not available across the entire watershed. LiDAR data came from the Fraser Basin Council (collected by TerraRemote Sensing).

For the Deadman watershed, LiDAR data of the entire watershed was collected by IGI Consulting on behalf of Skeetchestn Natural Resources in 2022. The synthetic hydrography and headwater channel initiation developed by TerrainWorks was intentionally conservative (resulting in a potentially denser headwater network channel) to minimize the risk of missing channels. These datasets were reviewed by technical experts familiar with the Bonaparte and Deadman watersheds.

TerrainWorks incorporates the following spatial data to run its multiple tools and analyses in NetMap: DEM/LiDAR, vegetation, 4-band orthoimagery, wetland and lake polygon, climate variables (polygon or raster), streamflow and channel morphology regression, road, recent fire scar, predicted fire probability and severity, lithology, and fish habitat models.

Sources for available data that DFO provided to TerrainWorks are listed below:

- DEMs/LiDAR (used for synthetic hydrography):
 - Bonaparte – used a mix of DEMs (2017-2021 LiDAR BC DEM and pre-2011 Canadian Digital Elevation Model (CDEM)) and LiDAR as described above
 - Deadman – used LiDAR for entire watershed as described above

- Vegetation (NetMap required tree height, diameter, stand density, and basal area)
 - [Vegetation Resources Inventory](#) (VRI) dataset provided stand height and basal area (Forest Analysis and Inventory Branch 2022)
- Wetlands and Lakes
 - [Freshwater Atlas Wetlands](#) (GeoBC Branch 2023a) and [Freshwater Atlas Lakes](#) (GeoBC Branch 2023b) polygon layers from the BC Data Catalogue
- Climate change
 - Raster layers from [ClimateBC](#) (Wang et al. 2016)
- Soil (used for READI model soil infiltration rates)
 - [Soil Survey Spatial View](#) (Knowledge Management 2023) from the BC Data Catalogue
- Predicted fire probability and severity for years 2015-2023
 - [Fire Burn Severity - Historical](#) (Forest Analysis and Inventory Branch 2023) and [Fire Burn Severity - Same Year](#) (Forest Analysis and Inventory Branch 2023) and [BC Wildfire Fire Perimeters - Historical](#) (BC Wildfire Service 2023) and [BC Wildfire Fire Perimeters - Current](#) (BC Wildfire Service 2023) layers from BC Data Catalogue
- Lithology
 - [Surficial geology index map](#) (Natural Resources Canada 2022)

When data specific to B.C. or the Deadman or Bonaparte River watersheds are not available, TerrainWorks uses default input settings to run NetMap tools. These defaults are primarily derived from datasets collected in Washington, Oregon, and California.

Model Outputs

The suite of tools available in NetMap can be used to identify specific stream reaches within a watershed that may benefit from restoration actions. For the Deadman and Bonaparte watersheds, analyses focused on identifying channels that could be reconnected and areas suitable for riparian restoration. In the Deadman River watershed, recent LiDAR data for roads were used in the READI model to identify locations of high sediment delivery from unpaved roads. In addition, given ongoing research in the area, the Beaver Habitat tool was used to identify specific areas that may be suitable for beaver re-introduction.

Model Implementation

Floodplain Mapping: Delineating Off-channel Habitat

The Delineating Off-channel Habitat tool identifies potential off-channel habitat by analyzing elevations relative to the surrounding terrain (local relief) and the elevation of the floodplain. Topographic depressions are calculated as a deviation from the mean elevation, and a defined threshold is used to highlight these areas as potential off-channel habitat. The off-channel habitat layers for the Deadman and Bonaparte watersheds have been clipped to the 5x bankfull depth floodplain output. Areas with values below a set threshold (-0.75 or -0.5 meters) represent potential or actual off-channel habitat. Stream reaches within this threshold may indicate opportunities for future restoration, particularly where wetlands and side-channels could be reconnected. Thresholds can be refined by

identifying a known flooded area within the watershed, measuring its elevation relative to the channel, and adjusting the threshold accordingly.

In some cases, additional side-channel access may be created through minor excavation. Because current outputs of this tool identify both potential and existing off-channel habitat, further analysis using a DEM could help identify areas that would connect under low to moderate flood conditions. Larger disconnected areas may represent opportunities for channel reconnection, particularly where suitable rearing or overwintering habitat exists. An important first step is to determine the cause of disconnection (e.g. roads, other infrastructure, or stream incision). Where reconnection is feasible, complementary restoration projects, such as riparian planting, could also be implemented to further improve fish habitat.

Figure 1 and Figure 2 show snapshots of potential and existing off-channel habitat areas in the Deadman River and Bonaparte River watersheds, respectively, that could be reconnected through minor excavation. Areas were identified throughout the watersheds using the Delineating Off-channel Habitat tool.

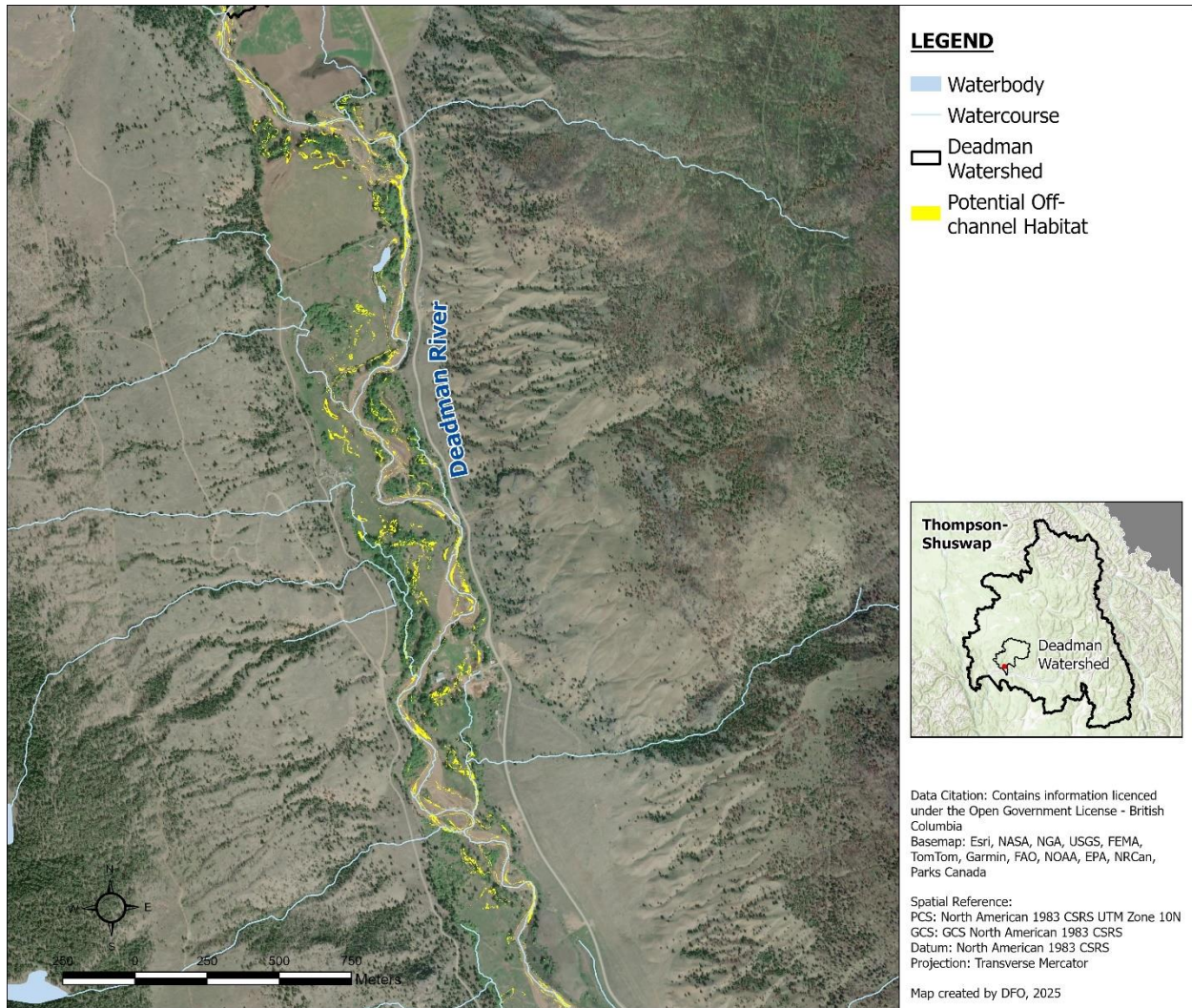


Figure 1. Potential or actual off-channel habitat in the Deadman River watershed. Using the Floodplain Mapping: Delineating Off-channel Habitat tool in NetMap, the local relief of the floodplain was calculated to identify areas of topographic depressions within a specific threshold (deviation from mean elevation between -0.75 and -0.5 meters) as potential off-channel habitat. Potential areas were highlighted throughout the lower Deadman River mainstem, as well as many upstream tributaries. These areas could be reconnected through restoration actions to open additional habitat for migrating salmon.

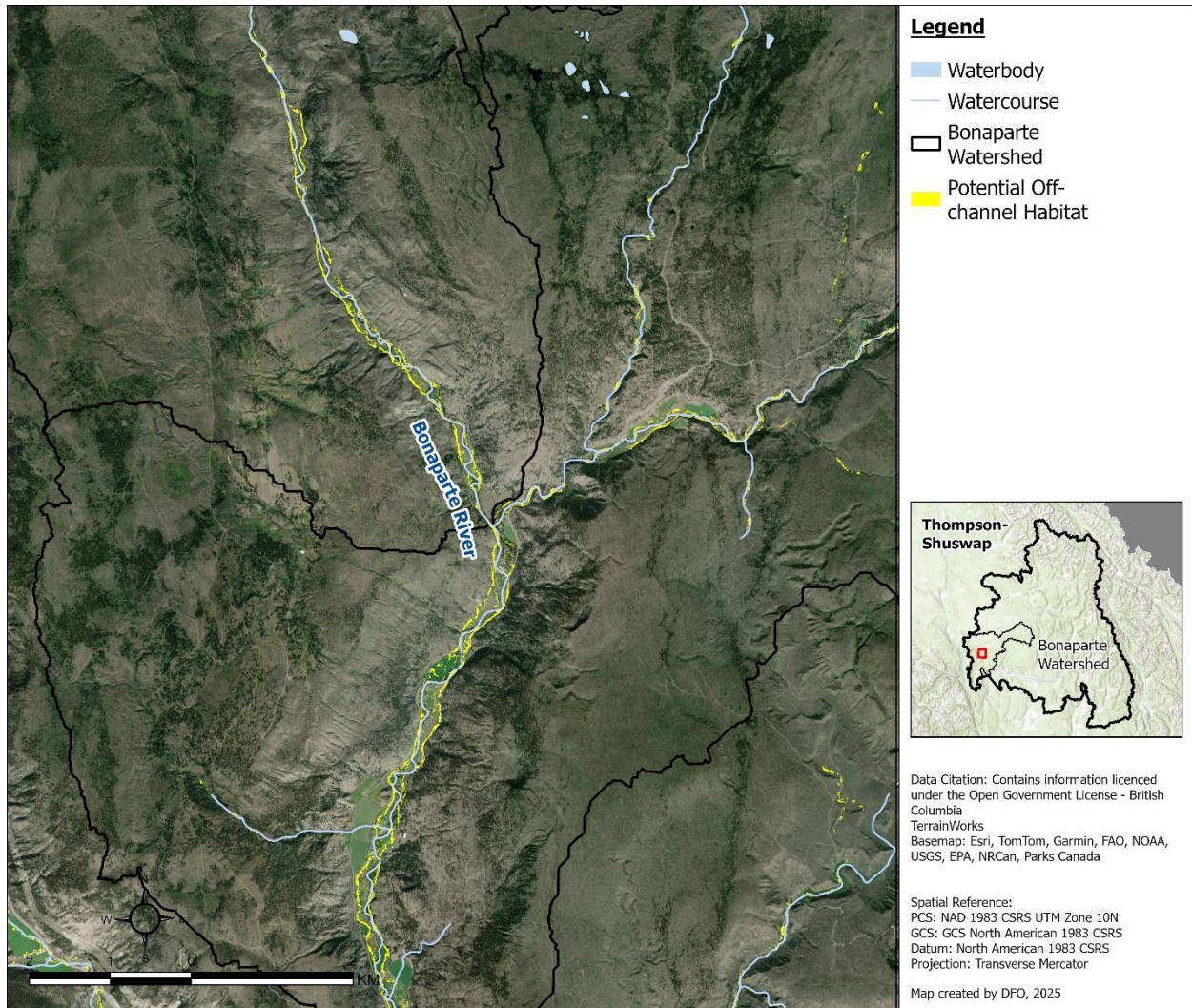


Figure 2. Potential or actual off-channel habitat in the lower Bonaparte River watershed. Using the Floodplain Mapping: Delineating Off-channel Habitat tool in NetMap, the local relief of the floodplain was calculated to identify areas of topographic depressions within a specific threshold (deviation from mean elevation between -0.75 and -0.5 meters) as potential off-channel habitat. These areas could be reconnected through restoration actions to open additional habitat for migrating salmon.

Shade-Thermal Loading (Current Shade-Maximum Shade)

The Shade-Thermal Loading tool in NetMap calculates the difference between current shade and maximum shade using thermal loading calculations, where “shade” is defined as the inverse of solar radiation. The difference between these two values identifies where increasing shade would have the greatest effect on stream thermal conditions. These areas may benefit most from riparian planting to increase stream shading. NetMap predicts that riparian restoration is generally more effective along narrow stream reaches than along wider mainstem sections. An important step in applying these results is confirming why riparian vegetation may be limited in these areas to identify long-term strategies for increasing stream shading.

Figure 3 identifies areas in the Deadman River watershed that may benefit from riparian planting using the Thermal Energy Difference tool.

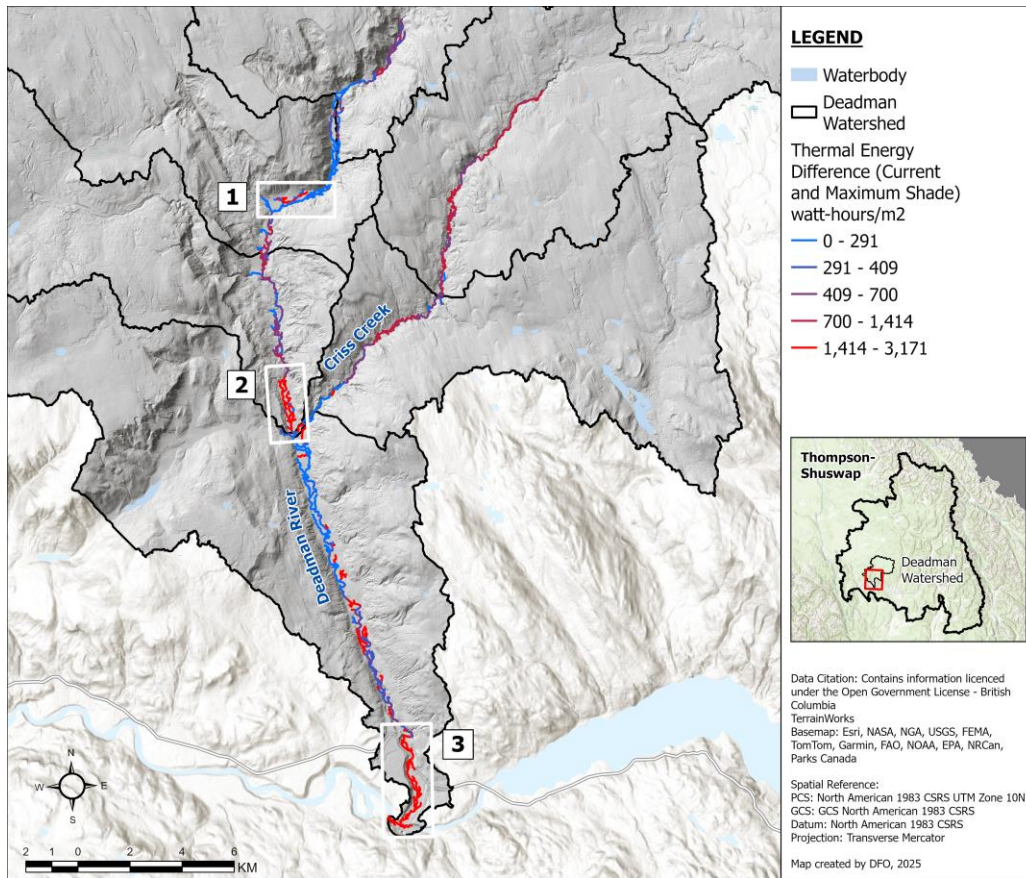


Figure 3. The Thermal Energy Difference in fish-bearing stream segments of the Deadman River watershed. This output is calculated as the difference between Current Shade and Maximum Shade using thermal loading tools in NetMap and highlights areas that may benefit the most from riparian planting and subsequent increased stream shading.

Location 1: Upstream Deadman River (area roughly between 50.9612380°N, 120.9762679°W and 50.9632450°N, 120.9606829°W)

- Approximately 1.4 km of potential riparian planting area, with multiple (4) stream segments, each ranging from 200-600 m in length, identified as potential locations for restoration action

Location 2: Deadman River, immediately upstream of Criss Creek confluence (area roughly between 50.8815941°N, 120.9724666°W and 50.8986282°N, 120.9755912°W)

- Approximately 2 km of stream length total, with stream reaches located in the mainstem available for potential restoration actions

Location 3: Downstream Deadman River, upstream of Thompson River confluence (area roughly between 50.7439790°N, 120.9135875°W and 50.7744320°N, 120.9125198°W)

- Approximately 4 km of stream length total, with stream reaches located in the mainstem available for potential restoration actions

Figure 4 identifies areas in the Bonaparte River watershed that may benefit from riparian planting using the Thermal Energy Difference tool.

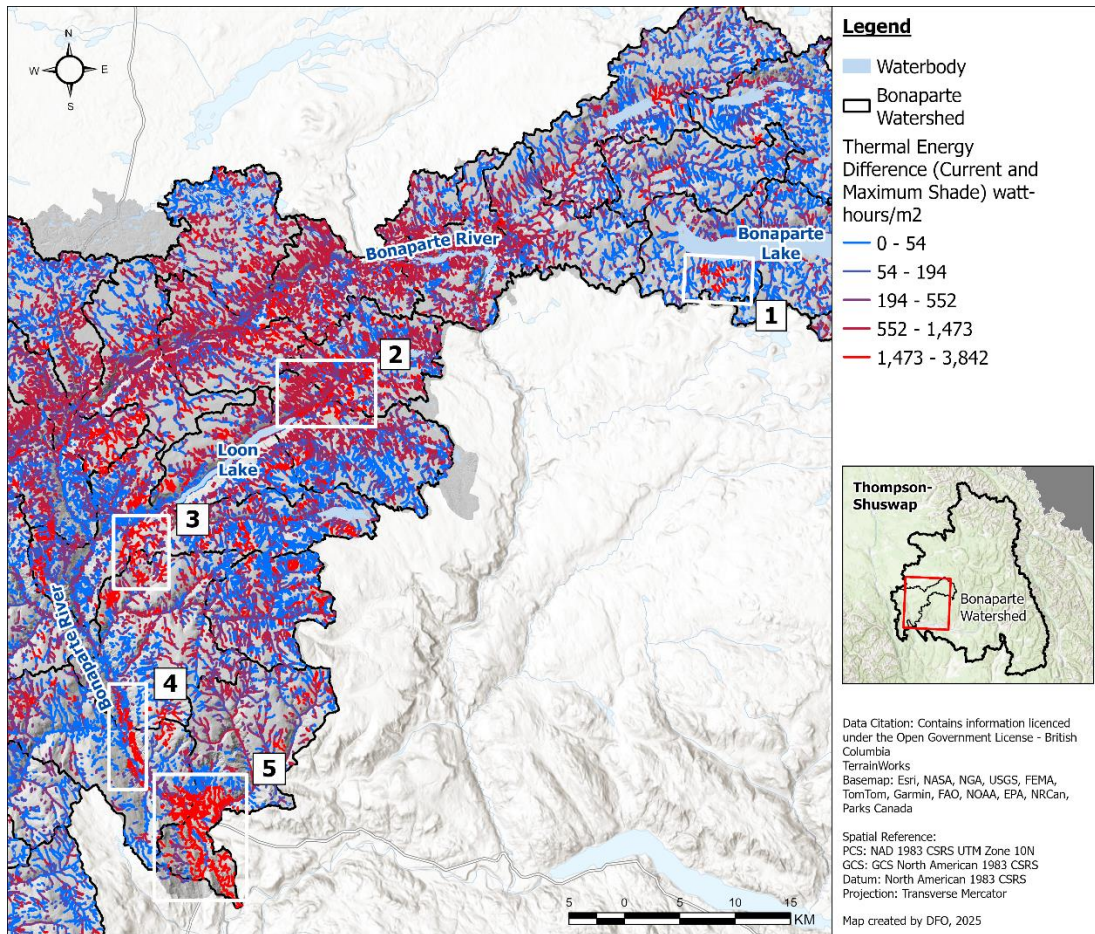


Figure 4. The Thermal Energy Difference in fish-bearing stream segments of the upper Bonaparte River watershed. This output is calculated as the difference between Current Shade and Maximum Shade using thermal loading tools in NetMap and highlights areas that may benefit the most from riparian planting and subsequent increased stream shading.

Location 1: Bonaparte Lake area (area roughly between 51.2244040°N, 120.6243758°W and 51.2478326°N, 120.6416257°W)

- Approximately 5 km of tributary lengths identified for potential riparian planting, located about 1 km from western Bonaparte Lake.

Location 2: Upstream Loon Lake area (area roughly between 51.1336264°N, 121.1747757°W and 51.1547145°N, 121.1255888°W)

- Approximately 4.5 km of Loon Creek identified just upstream of Loon Lake, with many additional tributaries (10+) of approximately 200m lengths.

Location 3: Downstream Loon Lake area (area roughly between 51.0470557°N, 121.3883231°W and 50.9988885°N, 121.3821510°W)

- Approximately 6.5 km of tributary lengths identified for potential riparian planting downstream of Loon Lake.

Location 4: Downstream Bonaparte River (area roughly between 50.8586427°N, 121.3898805°W and 50.8810038°N, 121.3963281°W)

- Approximately 2.5 km of tributary length off the Bonaparte mainstem and additional smaller tributary segments (200-500 m lengths) identified for potential riparian planting, located in the downstream Bonaparte River, about 15.5 km upstream from Thompson River confluence.

Location 5: Bonaparte River confluence with Thompson River (area roughly between 50.7403455°N, 121.2594184°W and 50.8296963°N, 121.3560968°W)

- Approximately 12 km of mainstem length, as well as nearby tributary lengths, identified for potential riparian planting, located in the Lower Bonaparte, at and immediately upstream of the confluence with the Thompson River.

READI Road Surface Erosion Model (Deadman only)

The Road Erosion and Delivery Index (READI) model predicts runoff and sediment delivery to streams based on storm duration and intensity. Using LiDAR in the Deadman River watershed, TerrainWorks created a road segment layer for analysis in the Road Surface Erosion tool. The analysis focused on unpaved roads, with known paved roads removed from the dataset, to identify natural drainage points and areas with potential sediment delivery to streams.

The READI model requires several parameter inputs, including storm parameters (intensity, duration, soil infiltration rate, and runoff plume width) and road parameters (ditch infiltration rate, ditch width, outslope proportion, road width, and road surface erodibility). Storm parameters were derived from a historical (1965-2021) Intensity-Duration-Frequency (IDF) curve from the Kamloops weather station, which indicates that a 10-year, 1-hour storm has an intensity of 13.2 mm/hour (Shephard et al. 2014; Environment and Climate Change Canada). Soil infiltration rates were assigned using a soils texture layer (Knowledge Management 2023) for the Deadman River watershed, with infiltration values based on established relationships between soil texture and infiltration (Hillel 1982). Road width was calculated from LiDAR road data, while all other model parameters used the default values.

Areas identified with high sediment delivery potential may benefit from mitigation measures such as installing or remediating natural or topographic drainage features, or improving existing ditches, culverts, or water bars. For projects involving new road drains or diversions, field verification and hydrological assessments should be completed prior to implementation to ensure new runoff patterns do not create landslide, debris flow, or gully issues. Future improvements to the analysis may include refining the road datasets to remove features that are no longer driveable (old decommissioned roads or trails, etc.) based on field observations.

Methodology:

From the READIoutSim_DrainPoints_Deadman layer, points were selected where sediment delivery was high (greater than or equal to 57, given the value range of 57-494 identified as being high by TerrainWorks) and within 150 m of a fish-bearing stream. Added optimization points were selected from

the READIout_DrainsToAdd_Deadman layer that were located within 100m of the high sediment delivery points identified in the last step. This provided a set of potential location options for adding drainage points to reduce sediment delivery to streams. A total of 22 high sediment delivery points were located within 150 m of fish-bearing stream (Figure 5), and 87 Added optimization drainage points were within 100 m of the 22 high sediment delivery points (Figure 6).

Data layers used for this analysis:

- READIoutSim_Opt_Deadman (Sed_Deliv)
- READIoutSim_Deadman (Sed_Deliv)
- READIoutSim_DrainPoints_Deadman (Sed_Deliv)
- READIout_DrainsToAdd_Deadman (Sed_Deliv)

Estimates for road data inputs:

- Road width: 5 m
- Ditch width: 1 m
- Ditch infiltration rate: 0.073 m/hr
- Outslope proportion: 0.25

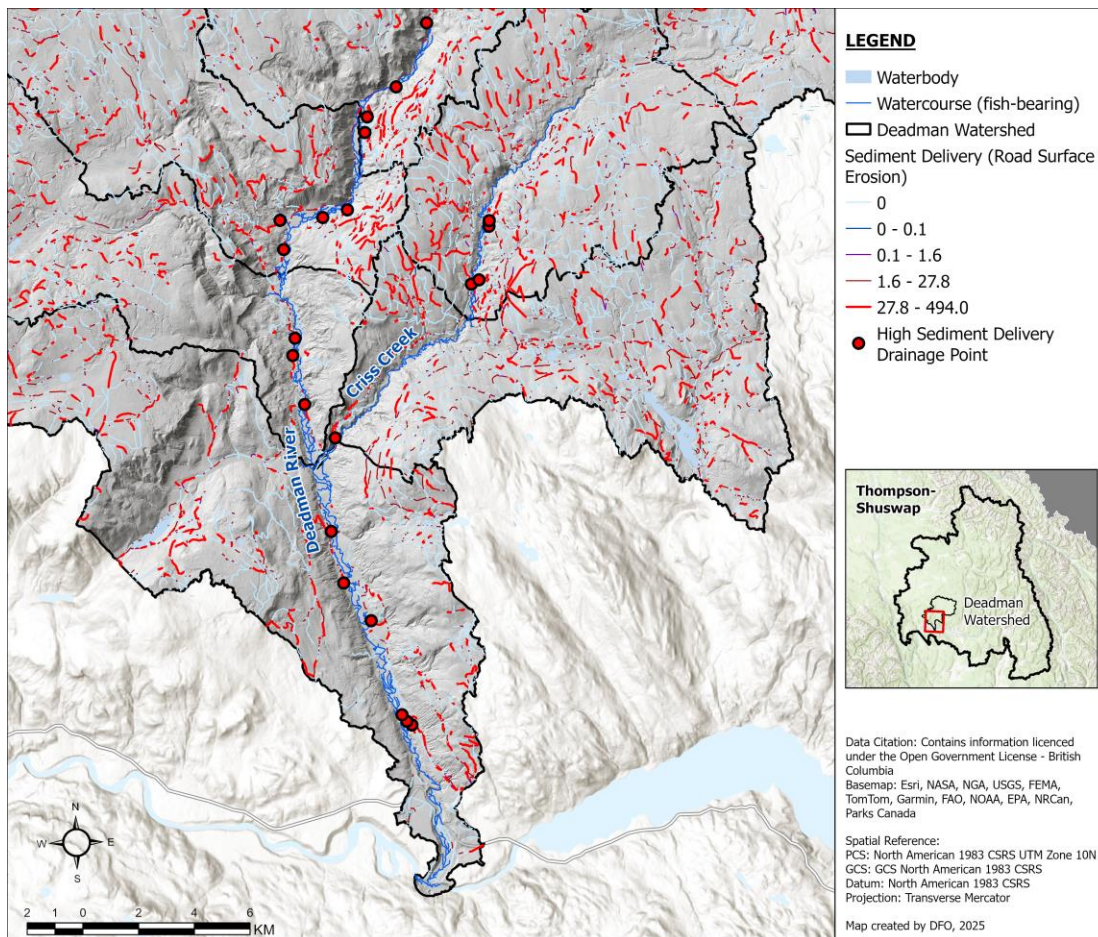


Figure 5. Road Erosion and Sediment Delivery Index (READI) model outputs from NetMap for the Deadman River watershed. Predicted sediment delivery to streams from road surfaces was calculated for road segments and drainage points. Drainage

points with high sediment delivery that are located within 150 m of fish-bearing segments of the Deadman River and Criss Creek are highlighted here.

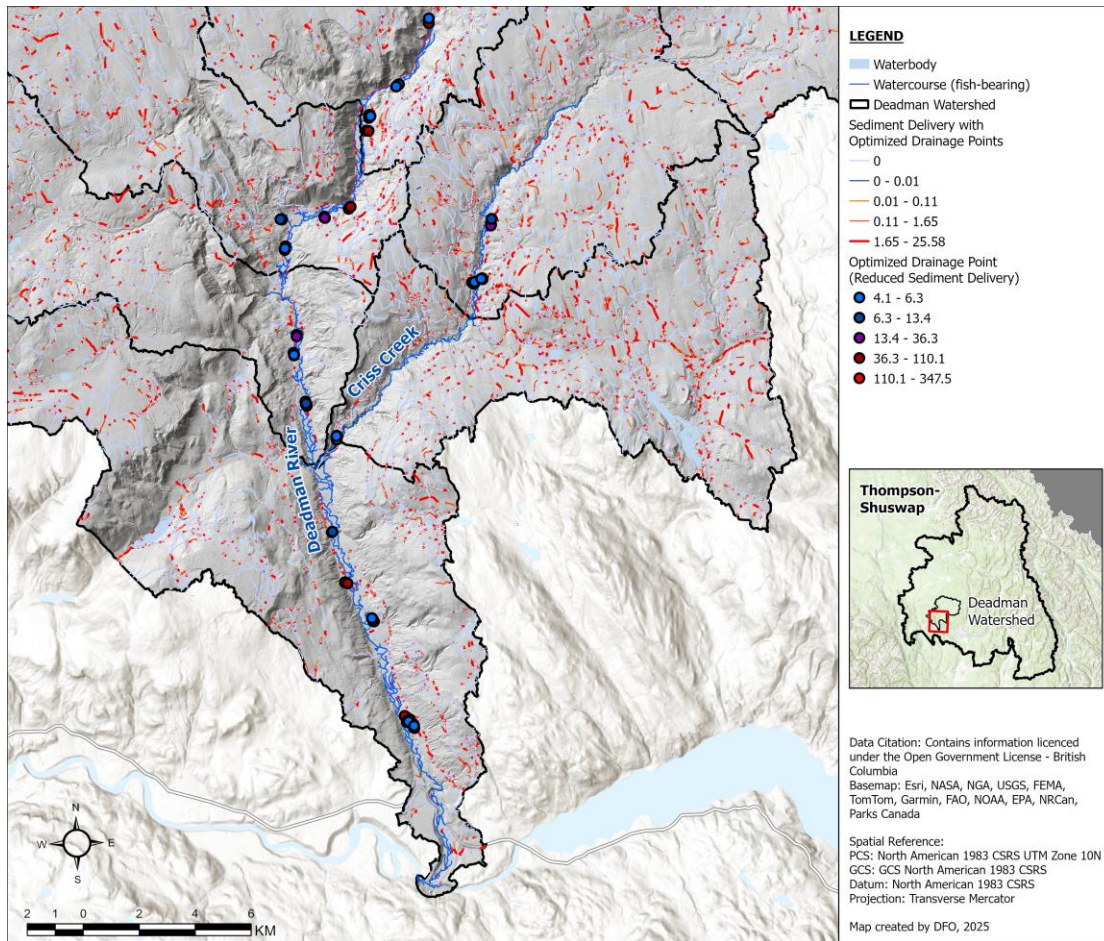


Figure 6. Road Erosion and Sediment Delivery Index (READI) model outputs from NetMap for the Deadman River watershed. Sediment delivery reductions to streams from road surfaces were estimated for road segments and additional drainage points placed at strategic topographic locations (optimized drainage point locations). Optimized drainage points located within 100 m of high sediment delivery drainage points (Figure 3) are highlighted here showing the reduction of sediment delivery between initial and final values. Drainage points are colour-coded and ranked by effectiveness, with blue points having the least reduction of sediment delivery to streams and red points having the greatest reduction.

Beaver Habitat (Deadman only)

The Beaver Habitat tool was used to identify potential areas of suitable beaver habitat in the Deadman River watershed to support ongoing beaver reintroduction efforts aimed at increasing wetland habitat and water storage. The tool identified a large extent of favourable beaver habitat (Figure 7), location-specific actions were not identified at this stage. The results are intended to guide further, site-specific analyses to determine optimal re-introduction sites. This tool is based on data from the Stilliguamish River basin in Washington (Pollock et al. 2004). Default values were used for slope-area threshold (0.3 km²) and stream power at bankfull discharge (2,000 Joules/s/m).

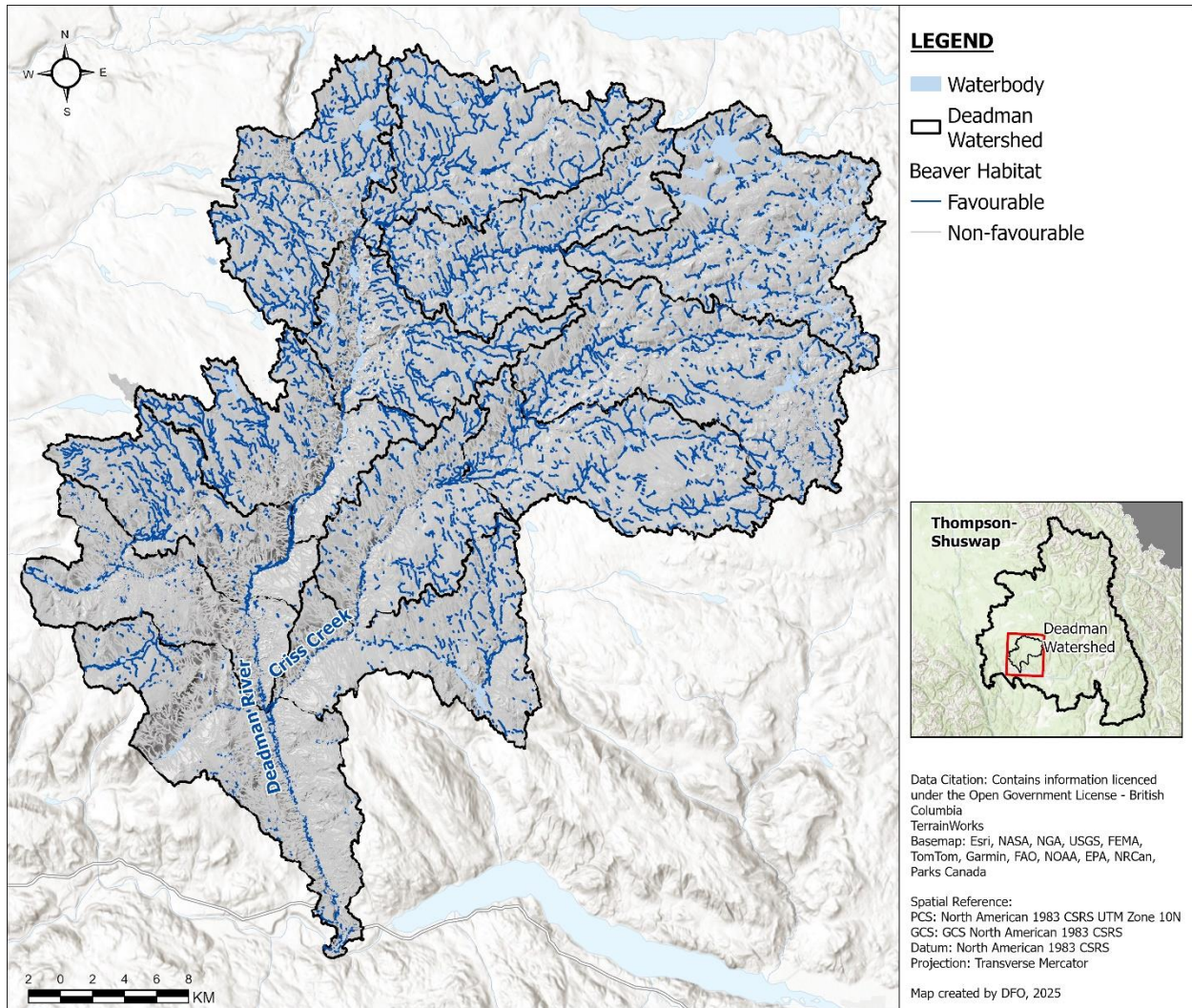


Figure 7. Favourable beaver habitat modeled for the Deadman River watershed using the Beaver Habitat Tool in NetMap. Favourable habitat areas could be potential candidate sites for beaver reintroduction projects occurring in the watershed.

Actions Identified using NetMap

The NetMap tools outlined above were used to identify location-specific salmon restoration actions in the Deadman and Bonaparte watersheds to help inform Chapter 4 of the Plan.

Deadman River watershed

1. Support and monitor Skeetchestn-led beaver translocation projects and identify upper-watershed sites for beaver dam analogues or beaver re-establishment to enhance water storage; NetMap habitat tools may assist in site identification.
2. Verify sites identified in NetMap as potential off-channel habitat and implement connectivity improvements where appropriate.
3. Verify sites identified in NetMap as having high thermal loading in the Deadman River and complete riparian planting at appropriate locations.

4. Verify sites identified by sediment sourcing research and modelling tools, including NetMap, as having high predicted sediment delivery to Deadman River and Criss Creek, and determine feasibility of drainage diversions and road remediation.

Bonaparte River watershed

1. Verify sites identified in NetMap as having high thermal loading in the Bonaparte River and complete riparian planting at appropriate locations.
2. Verify sites identified in NetMap as potential off-channel habitat and implement connectivity improvements where appropriate.

Limitations

Data availability:

Some NetMap tools could not be applied to the Deadman and Bonaparte watersheds due to data limitations. For example, the Wood Recruitment Tool, requires information on stem density of live and dead trees, as well as mortality rates and tree class data, which were not available in the VRI dataset provided to TerrainWorks. In other cases, where local datasets were unavailable for the Thompson-Shuswap region, default inputs derived from coastal Washington, Oregon, and California were used. Because of hydrological, topographical, and land disturbance (ex. Recent wildfires) differences between these regions and the Thompson-Shuswap, some model outputs may not fully represent local conditions and would benefit from improved regional data.

Accuracy:

Data quality may affect the accuracy of some tool outputs. For example, the Shade/Thermal Energy tools perform best when vegetation inputs come from remote sensing data like those provided by Landscape Ecology, Modeling, Mapping & Analysis ([LEMMMA](#)). These data use Gradient Nearest-Neighbor (GNN) modelling methods to calculate values for nearby pixels (Ohmann and Gregory 2002) and provide detailed outputs more representative of true ground cover (including riparian forest tree heights, diameters, and density). Because these data are available for the Pacific Northwest (Washington, Oregon, and California) and western United States, VRI data was used for watersheds in the Thompson-Shuswap. Because the VRI data used is static for the year 2022, it may also be less representative of current watershed conditions in the Deadman and Bonaparte as it does not account for recent wildfire-affected areas.

For synthetic hydrology development, the number and longitudinal extent of upstream headwaters may be overestimated. Determining accurate headwater locations is challenging due to the level of expertise required, the quality of imagery, and difficulty of ground-truthing in mountainous terrain. Additionally, there were inconsistencies between the BC provincial Lakes data layer and the DEM. Some polygons flagged as lakes in the BC Lakes data layer may be seasonal marshes. Finally, because the modelled outputs do not incorporate field-based measurements, on-the-ground verification will be necessary to confirm the results.

Future Directions and Transition Planning

NetMap models can be refined over time as B.C.-specific data inputs become available and LiDAR coverage increases. For example, recent LiDAR collection enhanced road datasets, enabling the READI model to assess erosion potential in the Deadman River watershed. This tool can be similarly applied in other watersheds where similar data exist. Improvements to vegetation datasets (e.g. LEMMA or similar) would increase the accuracy of the Shade/Thermal Energy tools and support outputs for the In-stream Wood Recruitment tool.

The NetMap models for Bonaparte and Deadman, along with user manuals and a recorded training session, have been shared with Bonaparte First Nation, Skeetchestn Indian Band (SNRC), Secwepemc Fisheries Commission (SFC), Canadian Wildlife Federation (CWF), and Fisheries and Oceans Canada (DFO). These organizations have access to the full suite of NetMap tools and the outputs generated by TerrainWorks for these watersheds.

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