Identification of Potential Habitats for Blocked Area Reintroduction

An Intrinsic Potential Analysis to Identify Tributary Habitats Available for Reintroduced Anadromous Spring Chinook and Summer/Fall Steelhead in the Upper Columbia River

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Abstract

An intrinsic potential stream habitat model was used to identify and quantify spawning and early rearing tributary habitats available to stream-type spring Chinook and steelhead within the United States portion of the blocked area of the upper Columbia River. The Spokane Tribe of Indians and co-managers of the blocked area reviewed an intrinsic potential model developed by the Northwest Fisheries Science Center and provided a comprehensive fish passage barrier data set to update the model. Habitat reach length and streambed area from the updated model iteration were summarized by subbasin. Excluding migratory corridors, the model identified 355.8 mi (1.8 mi^2) of spring Chinook and 1,161.6 mi (5.6 mi^2) of steelhead spawning and early rearing habitat rated as having low, moderate, or high potential. Additional anthropogenic barriers present within the region will, in the near-term, potentially limit the dispersal of reintroduced adults, constricting them to habitats immediately accessible from mainstem reservoirs. Considering these barriers, 136.0 mi (0.7 mi^2) of spring Chinook and 451.7 mi (1.3 mi^2) of steelhead tributary habitat are immediately accessible from Rufus Woods Lake and Lake Roosevelt.

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Introduction

The Identification of Potential Habitats for Blocked Area Reintroduction stems from a Northwest Power and Conservation Council (NPCC) request for a proposal addressing an emerging priority to, "investigate the habitat availability, suitability, and salmon survival potential in habitats above blocked areas in the Upper Columbia Basin within the United States," (NPCC 2015). To accomplish this, an existing intrinsic potential model was updated and refined; summarizing species specific stream reach lengths and streambed areas characteristic of spring Chinook and steelhead spawning and early rearing habitat.

Intrinsic potential is, "The estimated relative suitability of a habitat for spawning and rearing of anadromous salmon species under historical conditions" (NOAA 2017). As a concept and model, intrinsic potential was developed through the Coastal Landscape Analysis and Modeling Study (CLAMS) by Oregon State University's College of Forestry, the U.S. Forest Service's Pacific Northwest Research Station, and Oregon Department of Forestry in the early 2000's (Burnett et al. 2003, 2007). The goal of CLAMS was to develop a low-cost broad-scale technique for identifying streams geomorphically suited to support salmonid spawning and rearing habitats (Burnett et al. 2003). This tool has been used to identify historic habitats of anadromous species and develop conservation strategies; prioritizing rivers, reaches, and populations, when funding and empirical data are limited (e.g. Agrawal et al. 2005, Bjorkstedt et al. 2005, ICTRT 2006, Budy and Schaller 2007, Busch et al. 2013, Bidlack et al. 2014, Zweifel 2016). The model's ability to use widely-available geographic information systems (GIS) data and its low cost led to it being contributory to numerous Pacific coast salmon and steelhead recovery plans (e.g. NMFS 2009, ODFW and NMFS 2011, NMFS 2012, NMFS 2013, NMFS 2014, NMFS 2016a, NMFS 2016b, NMFS 2017a, NMFS 2017b). The model does not rely on empirical habitat data nor account for anthropogenic changes to the environment and thus is not considered an assessment of current stream conditions. Results represent a reach's potential given the characteristics of the surrounding landscape.

The National Oceanic and Atmospheric Administration's (NOAA) Technical Recovery Teams used intrinsic potential in many river systems to aid in the development of recovery criteria for species listed under the Endangered Species Act (ESA). In the mid-2000's the Northwest Fisheries Science Center (NWFSC) constructed this intrinsic potential model used for recovery planning by various salmon recovery domains. The Interior Columbia Technical Recovery Team (ICTRT) presented an iteration of the model in a 2007 memo to the National Marine Fisheries Service NW Regional Office. The memo identified likely historic populations and quantified potential tributary habitats within various blocked areas of the Interior Columbia (ICTRT 2007). However, the component for the blocked area of the upper Columbia did not receive local review or input. The NWFSC intrinsic potential model and the ICTRT's 2007 analysis are the foundation of the work presented here. For this 2016-2017 version of the model, the NWFSC provided extensive technical assistance by sharing their intrinsic potential model, updating it with feedback from regional managers, and providing multiple iterations and a finalized model output. The NWFSC is not using this information to recommend a specific action but views this exercise as an assessment of historic salmonid population structures.

Methods

The geographic area evaluated is the United States portion of the blocked area of the upper Columbia River upstream of Chief Joseph Dam to the Canadian border, between river miles 545.1 and 745. Within the more than 8,000 square miles are three subbasins, as defined by the NPCC: the Sanpoil Subbasin, Spokane Subbasin, and Upper Columbia Subbasin (Figure 1). These subbasins largely coincide with historic populations and major population groups described by the ICTRT (2005). Waters evaluated are smaller tributaries, the model does not evaluate inundated reaches or larger mainstem habitats such as the Spokane River and free-flowing portions of the Columbia River.

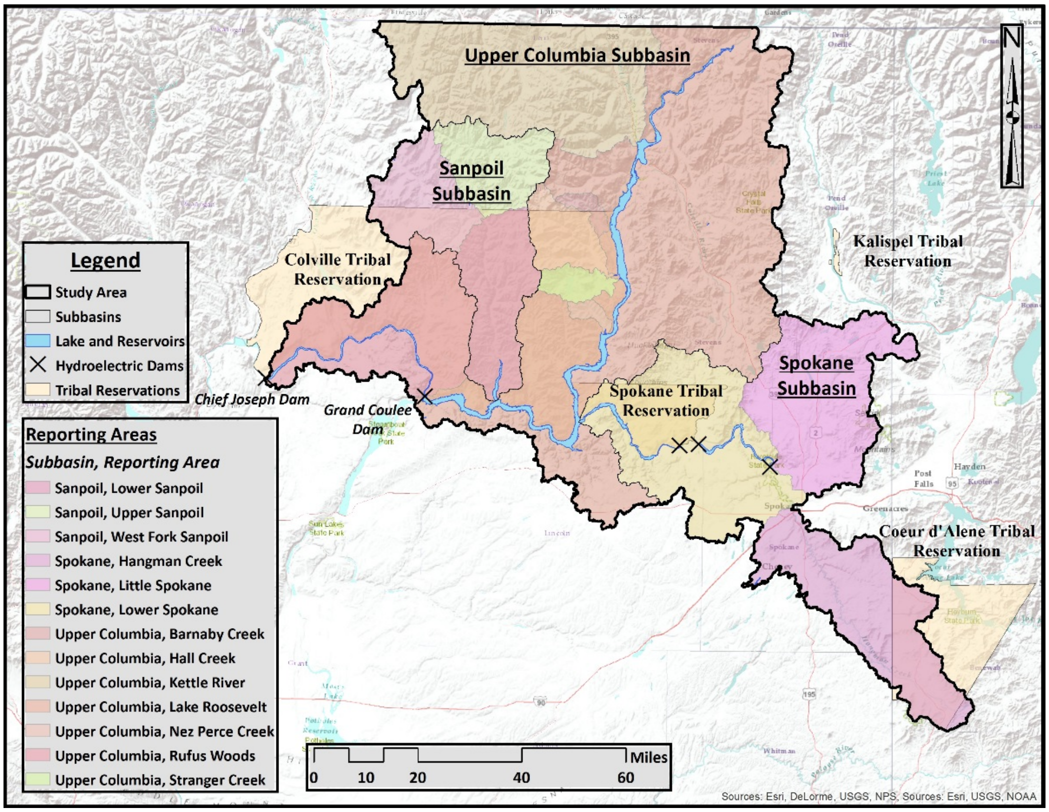

Figure 1. Map depicting the study area, associated subbasins, and reporting areas of interest for the Identification of Potential Habitats for Blocked Area Reintroduction.

The intrinsic potential model used in this project was developed and run by the NWFSC. It is specific to stream-type spring Chinook and summer/fall steelhead, identifying spawning and early rearing habitats. Various modeled parameters and associated data sources are presented in (Table 1). Methods describing development and implementation of the intrinsic potential model are more extensively addressed by the ICTRT (2006). In general, the NWFSC model parses the Pacific Northwest Hydrology Framework 1:100k dataset into 200m stream reaches. For each reach, parameters of gradient, bankfull width, wetted width, and valley confinement are estimated using digital elevation models and precipitation data from the National Climate Data Center. Potential upstream distribution of modeled species is constrained by natural barriers, stream width, and water temperature. Natural barriers are either a documented natural feature (e.g. falls, cascade, or sub-surface flow) or modeled features, where a 200m reach with ≥ 20% gradient represents a barrier. Criteria for stream width imposed barriers are informed by empirical data and ultimately defined as reaches with a modeled wetted width of < 3.6m for spring Chinook and reaches with a modeled bankfull width of < 3.8m for steelhead. Water temperature is considered a barrier for reaches with a likelihood of exceeding a weekly mean average water temperature (WMAT) of 22°C. Reach water temperatures are either empirical data or modeled estimates using mean July temperatures, percent forest cover, and elevation.

Table 1. Parameters and associated data sources used by the intrinsic potential model to rate habitat and apply habitat screens.

Model Parameter	Data Sources	Description of Data Sources
Base Stream Network	Pacific Northwest Hydrology Framework	1:100,000-scale networked reach model
Stream Gradient	Pacific Northwest Hydrology Framework	1:100,000-scale networked reach model
	USGS - Digital Elevation Model	10-meter horizontal resolution digital elevation model
Bankfull & Wetted Widths	NOAA - National Climate Data Center	4km grid of mean annual precipitation (1971-2000)
	USGS - Digital Elevation Model	10-meter horizontal resolution digital elevation model
Valley Confinement	Pacific Northwest Hydrology Framework	1:100,000-scale networked reach model
	USGS - Digital Elevation Model	10-meter horizontal resolution digital elevation model
Distribution - Natural Barriers	Various Empirical Data	see Table 4
	Pacific Northwest Hydrology Framework	1:100,000-scale networked reach model
	USGS – Digital Elevation Model	10-meter horizontal resolution digital elevation model
Distribution - Stream Width	NOAA - National Climate Data Center	4km grid of mean annual precipitation (1971-2000)
	USGS - Digital Elevation Model	10-meter horizontal resolution digital elevation model
Distribution - Water Temperature	Streamnet Temperature Dataset	repository of empirical water temperature data
	NOAA - National Climate Data Center	mean July temperatures (1971-2000)
	USGS - National Land Cover Dataset	percent forest cover
	USGS - Digital Elevation Model	10-meter horizontal resolution digital elevation model
Habitat Screen - Sedimentation	USDA - National Resource Conservation Service	STATSGO soil survey
	USGS - Digital Elevation Model	10-meter horizontal resolution digital elevation model
Habitat Screen - Stream Velocity	Pacific Northwest Hydrology Framework	1:100,000-scale networked reach model
	NHD Plus v2 Database	mean annual stream velocity attributes

Intrinsic potential aligns the modeled parameters with species specific habitat criteria to define the likely species distribution and assign a reach-level rating of habitat potential. The species specific habitat criteria were developed by the ICTRT, informed by adult spawner and juvenile distribution data collected within the Interior Columbia. Criteria considered by the model are thresholds for bankfull and wetted width, gradient, and valley confinement (Table 2 and Table 3). Stream reaches are rated as having none/negligible, low, moderate, or high potential dependent on the values of each parameter for a given reach. Additional habitat screens for sedimentation and water velocity are then applied to the reach network to identify habitats that, although fitting the criteria, may be unsuitable for spawning and rearing. Where violations of the habitat screens are found the model adjusts the habitat ratings accordingly.

Table 2. Species specific criteria of relative habitat potential for Interior Columbia basin spring Chinook salmon spawning and initial rearing as a function of stream reach physical characteristics. Adopted from Table C-1 in ICTRT 2006.

		Valley Width Ratio		
Bankfull Width (BF)	**Gradient (%)**	**Confined (≤ 4m x BF Width)**	**Moderate (4m to 20m x BF Width)**	**Wide (> 20m x BF Width)**
BF < 3.7m	≥ 0	None	None	None
BF 3.7m to 25m	0 - 0.5	***Medium***	***High***	***High***
	0.5 - 1.5	***Low***	***Medium***	***High***
	1.5 - 4.0	***Low***	***Low***	***Medium***
	4.0 - 7.0	Negligible	***Low***	***Low***
	> 7.0	None	None	None
BF 25m to 50 m	0 - 0.5	None	***Medium***	***Medium***
	0.5 - 10	None	None	None
	> 10	None	None	None
BF > 50m	≥ 0	None	None	None

Table 3. Species specific criteria of relative habitat potential for Interior Columbia basin steelhead spawning and initial rearing as a function of stream reach physical characteristics. Adopted from Table C-2 in ICTRT 2006.

		Valley Width Ratio		
Bankfull Width (BF)	**Gradient**	**Confined (≤ 4m x BF Width)**	**Moderate (4m to 20m x BF Width)**	**Wide (> 20m x BF Width)**
BF < 3.8m	≥ 0	None	None	None
BF 3.8m to 25m	0 - 0.5	None	***Medium***	***Medium***
	0.5 - 4.0	***Low***	***High***	***High***
	4.0 - 7.0	None	***Low***	***Low***
	> 7.0	None	None	None
BF 25m to 50 m	0 - 4.0	***Low***	***Medium***	***Medium***
	> 4.0	None	None	None
BF > 50m	≥ 0	None	***Low***	***Low***

The Northwest Fisheries Science Center provided the original intrinsic potential model output used in the ICTRT's 2007 analysis. This data set was reviewed by co-managers and biologists familiar with the study area. It was determined that natural barriers to fish passage were not adequately accounted for by the original model, over-estimating the amount of potential habitat available.

Fish passage barrier data were compiled from a multitude of sources (Table 4) and merged into one data set. The resulting data set was filtered to isolate natural features that pose a complete barrier to fish passage. Barriers that lacked supporting documentation were assumed to be complete barriers. The natural fish passage barrier data set was mapped using GIS and presented to regional co-managers and biologists who confirmed the presence, status, and location of each feature and provided additional information if available. The finalized natural fish passage barrier data set was sent to the NWFSC for inclusion into an updated intrinsic potential model run.

Table 4. Fish passage barrier data sets used to identify natural and anthropogenic features that may limit the potential distribution of reintroduced anadromous species within the blocked area of the upper Columbia River.

Data Source	**Survey**	**Date Accessed/Received**
Coeur d' Alene Tribe of Indians	Fisheries Program	November 17, 2016
Confederated Tribes of the Colville Reservation	Lake Roosevelt Rainbow Trout Habitat Improvement Project	January 4, 2017
Confederated Tribes of the Colville Reservation	Rufus Woods Habitat/Passage Improvement Project	May 10, 2017
Spokane County Conservation District	Hangman Creek Fish Passage Barrier Inventory	October 4, 2016
Spokane Tribe of Indians	Dams feature-class	January 11, 2017
U.S. Forest Service, Colville National Forest	Fish Barriers and Culverts data set	January 12, 2017
WA Dept. of Ecology	Dams Geodatabase	January 7, 2017
WA Dept. of Fish and Wildlife	Fish Passage and Diversion Screening Inventory	January 3, 2017
WA Dept. of Fish and Wildlife	Interior Redband Trout Project: Multi-Agency Database	October 4, 2016
WA Dept. of Fish and Wildlife	Joint Stock Assessment Project	January 3, 2017
WA Dept. of Fish and Wildlife	Redband Rainbow Trout Geodatabase	June 22, 2016

The NWFSC incorporated the natural and complete barriers to fish passage into their intrinsic potential model and, where possible, reviewed and updated additional model inputs such as stream temperature. The updated model output was provided to STI and incorporated into a GIS geodatabase. All feature classes were projected to the datum of the model output (NAD_27) to ensure accurate alignment and clipped to the study area. The model output included stream reaches that extended through existing lakes and reservoirs accounted for in the National Hydrography Dataset. These inundated reaches were subsequently erased to omit them from further analysis. The resulting reach network depicted all potential habitats available to spring Chinook and steelhead within the entirety of the study area.

However, the presence of additional anthropogenic barriers upstream of Chief Joseph and Grand Coulee dams significantly constricts the potential distribution of reintroduced species. Multiple dams and road crossings within the blocked area reduce the amount of habitat accessible from Rufus Woods and Lake Roosevelt. Co-managers wanted to know how much habitat would be immediately accessible to reintroduced adults should they be translocated to mainstem reservoirs. To determine this, the compiled fish passage barrier data set was re-filtered to identify anthropogenic features that pose a complete blockage to fish passage. Barriers that lacked supporting documentation were assumed to be complete barriers. These features were projected onto the intrinsic potential stream network. Barriers found to intersect streams with positively rated habitats were selected to further refine the barrier data set to features that may pose an impediment to anadromous species. A polygon was drawn connecting the first anthropogenic barrier encountered on a stream with positively rated habitat, isolating those habitats immediately accessible from both Rufus Woods Reservoir and Lake Roosevelt.

Within the geodatabase a model was created that summarized habitat metrics by subbasin and reporting areas that are of interest to co-managers. Metrics include stream reach length and streambed area for positively rated habitats (low, moderate, or high intrinsic potential) and reach length for migratory corridors (i.e. reaches rated as having none or negligible potential located between or downstream of positively rated habitats). These metrics were reported at two scales, one covering all habitats within the study area, the other for habitats immediately accessible from Rufus Woods and Lake Roosevelt.

Results

The intrinsic potential model identified a total of 355.8 mi of spring Chinook and 1,161.6 mi of steelhead tributary habitat that were rated as having low, moderate, or high potential. Modeled streambed area of these habitats is 1.80 mi^2 and 5.62 mi^2 for spring Chinook and steelhead, respectively (Table 5 and Table 6; Figure B 1 and Figure B 3). An additional 355.0 miles of spring Chinook and 448.6 miles of steelhead migratory corridors leading to or between rated habitats were also identified (Table A 1 and Table A 2). Of all rated habitats in the region, 49% of the spring Chinook habitat, by streambed area, were rated as high and 36% of steelhead streambed area was rated as high.

Considering the constraints posed by additional anthropogenic barriers in the region, the amount of habitat immediately accessible from mainstem reservoirs is reduced to 136.0 mi (0.67 mi^2) for spring Chinook and 451.7 mi (1.28 mi^2) for steelhead (Table 5 and Table 6; Figure B 1 through Figure B 4). Migratory corridors leading to these immediately accessible habitats is 298.3 miles for spring Chinook and 363.0 miles for steelhead (Table A 5 and Table A 6). Of these immediately accessible habitats, 37% of the streambed area for spring Chinook were rated as high and 46% for steelhead were rated as high.

For both species, the Spokane Subbasin is the subbasin with the greatest amount of rated habitat in terms of reach length and streambed area, 60% of all spring Chinook habitat and 57% of all steelhead habitat (Table 5). Among all reporting areas Hangman Creek, a MPG defined by the ICTRT, was found to have the most intrinsic potential habitat for both species (spring Chinook: 0.56 mi^2; steelhead: 1.54 mi^2) with the Little Spokane River having the second most habitat for both species (spring Chinook: 0.49 mi^2; steelhead: 1.30 mi^2). When considering only habitats immediately accessible from Rufus Woods Reservoir and Lake Roosevelt, the Sanpoil Subbasin, also an MPG defined by the ICTRT, bears the most potential tributary habitat for both species (spring Chinook: 82.2 mi, 0.64 mi^2; steelhead: 176.0 mi, 0.48 mi^2; Table A 5 through Table A 8; Figure B 6 and Figure B 8).

Of the 186.0 miles of highly rated potential spring Chinook habitat, 138.1 miles are within the Spokane Subbasin, much of it within the Hangman Creek (72.9 miles) and Little Spokane River (47.3 miles) watersheds. Of the 347.3 miles of highly rated potential steelhead habitat, nearly half lies within the Spokane Subbasin (150.5 miles). Much of the remaining highly rated habitat is within the Hangman (66.1 miles) and Little Spokane (49.7 miles) watersheds.

More detailed tables and figures results can be found within *Appendix A* and *Appendix B* of this report. The tables of *Appendix A* summarize the stream reach lengths and streambed areas by subbasin, reporting area, and habitat rating. The figures of *Appendix B* are maps depicting the study area as a whole and individual subbasins, delineating stream reaches and their associated intrinsic potential rating.

Table 5. Summary of spring Chinook intrinsic potential habitat stream reach lengths and streambed areas, by subbasin, for the entirety of the study area and habitats immediately accessible from Rufus Woods Reservoir and Lake Roosevelt. Migratory corridors have not been included.

	All Rated Habitats		**Immediately Accessible Rated Habitats**	
	Reach Length (mi)	Streambed Area (mi^2)	Reach Length (mi)	Streambed Area (mi^2)
Sanpoil Subbasin	82.2	0.48	82.2	0.48
Spokane Subbasin	214.4	1.11	0.2	0.001
Upper Columbia Subbasin	59.2	0.20	53.6	0.19
Blocked Area Total	**355.8**	**1.80**	**136.05**	**0.67**

Table 6. Summary of steelhead intrinsic potential habitat stream reach lengths and streambed areas, by subbasin, for the entirety of the study area and habitats immediately accessible from Rufus Woods Reservoir and Lake Roosevelt. Migratory corridors have not been included.

	All Rated Habitats		**Immediately Accessible Rated Habitats**	
	Reach Length (mi)	Streambed Area (mi^2)	Reach Length (mi)	Streambed Area (mi^2)
Sanpoil Subbasin	187.7	1.13	176.0	0.64
Spokane Subbasin	662.0	3.18	19.5	0.02
Upper Columbia Subbasin	312.0	1.31	256.2	0.62
Blocked Area Total	**1,161.6**	**5.62**	**451.7**	**1.28**

Discussion

The U.S. portion of the blocked area of the upper Columbia River has 355.8 mi (1.797 mi^2) of potential spring Chinook habitat and 1,161.6 mi (5.621 mi^2) of potential steelhead habitat within regional tributaries. An additional 470.5 mi of spring Chinook and 692.3 mi steelhead migration corridors exists in reservoirs and tributaries leading to and between potential habitats. Many reaches of these tributaries are shared by both species. This is expected to be the case for reintroduced summer/fall Chinook and sockeye salmon as well.

Approximately 60% of the positively rated habitat within the study area is blocked by additional anthropogenic barriers, the majority of that blocked habitat being in the Spokane River system. The Spokane River is impounded by multiple hydroelectric projects lacking fish passage facilities. Salmon and steelhead migrating to the Little Spokane River would need to pass Little Falls and Long Lake dams. Fish destined for Hangman Creek would need to pass an additional hydroelectric project, Nine Mile Dam (Figure B 10 and Figure B 12). Other barriers within the region are primarily road crossings, potentially being resolved with much less effort than the Spokane hydroelectric facilities.

Additional spawning habitats, not considered in this report, are expected to be found within the free-flowing portion of the upper Columbia River, alluvial fans within Lake Roosevelt, and the main-stem Spokane River. Spawning habitats in the upper Columbia are being assessed by the CCT using methods similar to those employed by Hanrahan et al. (2004). It is also expected that reintroduced anadromous species will use the productive reservoir environment of Lake Roosevelt as rearing habitat, as has been found in the Willamette River system (Monzyk et al. 2015).

Intrinsic potential modeling similar to the present analysis has been performed in Canada on select tributaries to the Columbia River from Lower Arrow Lake to the U.S. Canada border. The Okanogan National Alliance estimate there to be 0.26 mi^2 chinook and 1.11 mi^2 steelhead tributary habitat, 0.22 mi^2 and 0.94 mi^2 being immediately accessible from the main stem Columbia (Bussanich et al. 2017). Combined with U.S. waters, tributaries of the blocked area have 2.05 mi^2 of spring Chinook and 6.74 mi^2 of steelhead of potential spawning and early rearing habitat; of which 2.02 mi^2 and 6.56 mi^2 would be immediately accessible to translocated adults.

Intrinsic potential is a broad-scale model most appropriate to smaller tributaries and does not sufficiently consider anthropogenic impacts to water quality and quantity. The model is a “best-case-scenario” that reflects the potential of the landscape and defines what spawning and rearing habitats are available, not the current condition of those habitats. The 2014 Columbia River Basin Fish and Wildlife Program’s phased approach to reintroduction also calls for an evaluation of habitat suitability (NPCC 2014). To evaluate habitat suitability, the region is using the Ecosystem Diagnosis and Treatment (EDT). EDT uses empirical stream habitat data, species specific life-history models, Beverton-Holt survival functions, and a stream reach network to estimate fish performance in each watershed. The CCT used EDT on several Colville Reservation tributaries to evaluate the current condition of those streams and their suitability to support reintroduced salmonids (ICF 2017). As a means to providing regional consistency with how habitat suitability is evaluated, the Spokane Tribe constructed an EDT model for stream reaches within the Spokane Subbasin and portions of the Upper Columbia Subbasin (Figure 2). The modeled stream reach network was informed by the intrinsic potential analysis, modeling all rated reaches and tributary migratory corridors. Tributary habitat data needed to create the modeling environment was sourced largely from regional partners who collected relevant data during previous projects independent of reintroduction feasibility assessments. For more information on EDT modeling in the blocked area see ICF 2017 & ICF 2018.

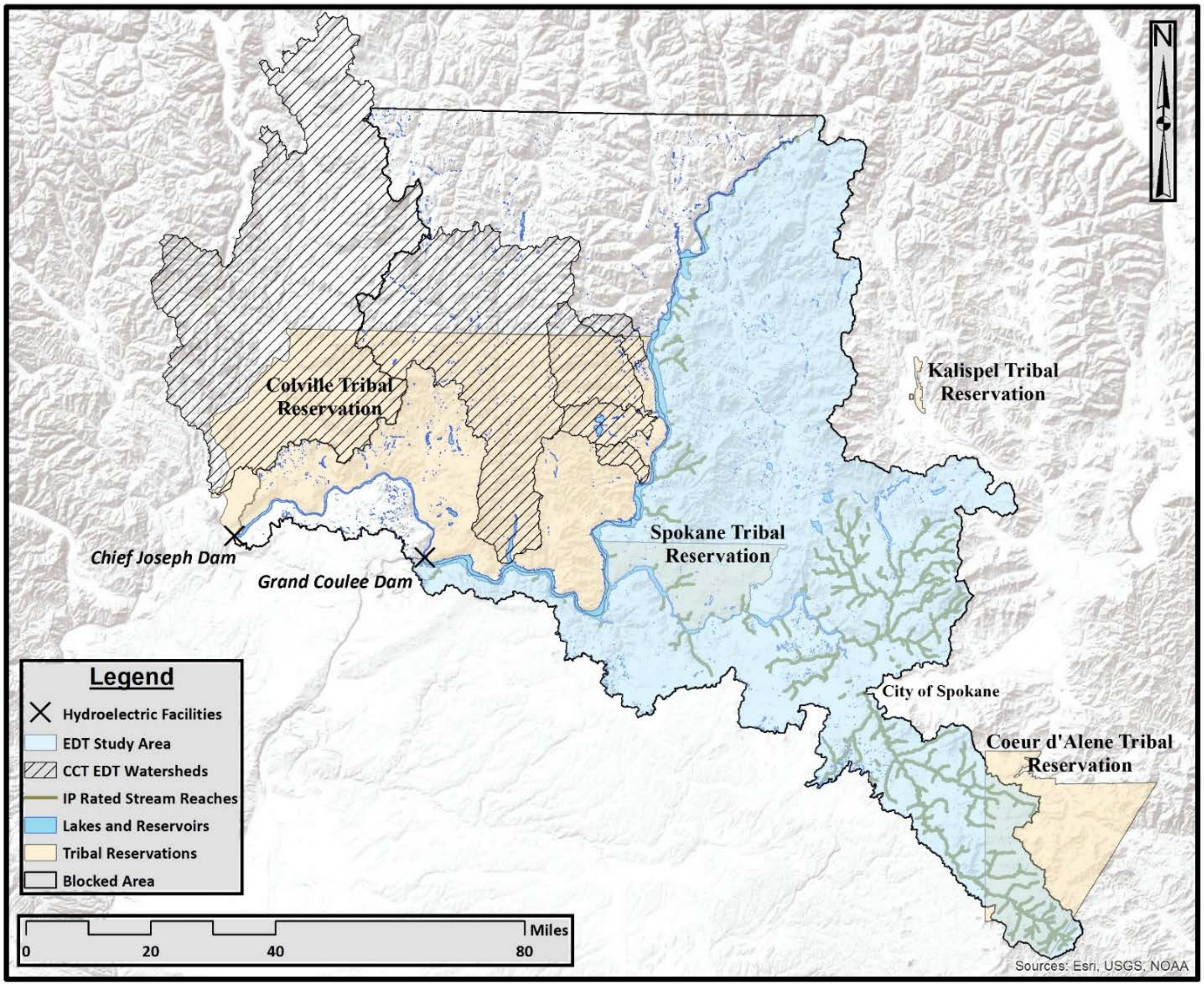

Figure 2. The study area and streams, identified by intrinsic potential, being modeled by Ecosystem Diagnosis and Treatment. Crosshatched watersheds denote where the Colville Tribe has already developed an EDT model.

This present analysis is one component that will contribute to the body of evidence needed to inform anadromous reintroduction feasibility. The remaining components and related projects will be assimilated by UCUT member tribes into a larger report to inform the feasibility of reintroducing salmon and steelhead to the blocked area of the upper Columbia River.

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Appendix A:
Detailed Intrinsic Potential Results Tables

Table A 1. Stream reach lengths (mi) of migratory corridors and intrinsic potential rated habitats for all spring Chinook tributaries modeled within the U.S. portion of the blocked area.

Subbasin	Reporting Area	Migratory Corridors	Intrinsic Potential Rating Low	Moderate	High	Total Rated Habitat
Sanpoil	Lower Sanpoil	13.8	7.6	10.1	13.3	31.0
	Upper Sanpoil	5.1	6.5	3.6	12.1	22.1
	West Fork Sanpoil	4.0	11.8	7.5	9.8	29.1
	Sanpoil Total	**22.9**	**25.9**	**21.1**	**35.1**	**82.2**
Spokane	Hangman	4.1	12.4	19.2	72.9	104.5
	Little Spokane	8.2	6.8	26.1	47.3	80.2
	Lower Spokane	73.8	5.2	6.6	17.9	29.7
	Spokane Total	**86.1**	**24.5**	**51.9**	**138.1**	**214.4**
Upper Columbia	Barnaby Creek	0.6	0.5	0.1	0.0	0.6
	Hall Creek	4.0	12.8	5.5	5.6	23.9
	Kettle River	35.2	10.3	2.2	2.5	15.0
	Lake Roosevelt	153.6	5.7	2.7	2.0	10.4
	Rufus Woods	51.5	0.1	0.2	0.1	0.5
	Stranger Creek	1.1	2.6	3.6	2.6	8.8
	Upper Columbia Total	**245.9**	**32.1**	**14.4**	**12.8**	**59.2**
Blocked Area Total		**355.0**	**82.5**	**87.4**	**186.0**	**355.8**

Table A 2. Stream reach lengths (mi) of migratory corridors and intrinsic potential rated habitats for all steelhead tributaries modeled within the U.S. portion of the blocked area rated as having between low and high intrinsic potential.

Subbasin	Reporting Area	Migratory Corridors	Intrinsic Potential Rating Low	Moderate	High	Total Rated Habitat
Sanpoil	Lower Sanpoil	20.4	35.1	4.6	31.9	71.6
	Upper Sanpoil	12.9	22.9	1.4	17.3	41.5
	West Fork Sanpoil	10.7	29.7	0.6	44.2	74.5
	Sanpoil Total	**44.0**	**87.7**	**6.6**	**93.4**	**187.7**
Spokane	Hangman	8.2	215.6	33.8	66.1	315.5
	Little Spokane	13.4	163.3	41.8	49.7	254.9
	Lower Spokane	77.4	49.4	7.5	34.7	91.6
	Spokane Total	**99.0**	**428.4**	**83.1**	**150.5**	**662.0**
Upper Columbia	Barnaby Creek	1.2	1.0	0.0	0.1	1.1
	Hall Creek	13.4	40.4	0.6	24.6	65.6
	Kettle River	46.5	53.7	0.0	15.7	69.4
	Lake Roosevelt	177.9	76.1	2.4	31.1	109.6
	Nez Perce Creek	0.6	3.7	0.0	4.6	8.3
	Rufus Woods	64.3	22.5	0.5	18.3	41.3
	Stranger Creek	1.6	7.2	0.5	9.0	16.7
	Upper Columbia Total	**305.6**	**204.6**	**4.0**	**103.4**	**312.0**
Blocked Area Total		**448.6**	**720.7**	**93.6**	**347.3**	**1,161.6**

Table A 3. Streambed area (mi²) and associated habitat ratings for all spring Chinook tributary habitats within the U.S. portion of the blocked area rated between low *and* high *intrinsic potential. Migratory corridors are not included.*

		Intrinsic Potential Rating			Total Rated
Subbasin	**Reporting Area**	**Low**	**Moderate**	**High**	**Habitat**
Sanpoil	Lower Sanpoil	0.07	0.09	0.12	0.28
	Upper Sanpoil	0.03	0.02	0.05	0.10
	West Fork Sanpoil	0.04	0.03	0.04	0.11
	Sanpoil Total	**0.14**	**0.14**	**0.21**	**0.48**
Spokane	Hangman	0.07	0.11	0.37	0.56
	Little Spokane	0.03	0.23	0.20	0.46
	Lower Spokane	0.02	0.02	0.06	0.09
	Spokane Total	**0.12**	**0.36**	**0.63**	**1.11**
Upper Columbia	Barnaby Creek	0.00	0.00	0.00	0.00
	Hall Creek	0.04	0.02	0.02	0.08
	Kettle River	0.03	0.01	0.01	0.04
	Lake Roosevelt	0.02	0.02	0.01	0.05
	Rufus Woods	0.00	0.00	0.00	0.00
	Stranger Creek	0.01	0.01	0.01	0.03
	Upper Columbia Total	**0.11**	**0.06**	**0.04**	**0.20**
Blocked Area Total		**0.36**	**0.55**	**0.88**	**1.80**

Table A 4. Streambed area (mi²) and associated habitat ratings for all steelhead tributary habitats within the U.S. portion of the blocked area rated between low *and* high *intrinsic potential. Migratory corridors are not included.*

		Intrinsic Potential Rating			Total Rated
Subbasin	**Reporting Area**	**Low**	**Moderate**	**High**	**Habitat**
Sanpoil	Lower Sanpoil	0.18	0.06	0.33	0.57
	Upper Sanpoil	0.12	0.01	0.10	0.23
	West Fork Sanpoil	0.11	0.00	0.22	0.33
	Sanpoil Total	**0.40**	**0.08**	**0.64**	**1.13**
Spokane	Hangman	0.74	0.31	0.49	1.54
	Little Spokane	0.52	0.48	0.31	1.30
	Lower Spokane	0.14	0.04	0.16	0.34
	Spokane Total	**1.40**	**0.82**	**0.96**	**3.18**
Upper Columbia	Barnaby Creek	0.00	0.00	0.00	0.00
	Hall Creek	0.14	0.00	0.13	0.28
	Kettle River	0.34	0.00	0.07	0.41
	Lake Roosevelt	0.27	0.03	0.11	0.40
	Nez Perce Creek	0.01	0.00	0.02	0.03
	Rufus Woods	0.06	0.00	0.06	0.12
	Stranger Creek	0.02	0.00	0.04	0.07
	Upper Columbia Total	**0.85**	**0.04**	**0.42**	**1.31**
Blocked Area Total		**2.66**	**0.94**	**2.02**	**5.62**

Table A 5. Stream reach lengths (mi) of migratory corridors and intrinsic potential rated habitats for spring Chinook immediately accessible from Rufus Woods Reservoir and Lake Roosevelt.

Subbasin	Reporting Area	Migratory Corridors	Intrinsic Potential Rating Low	Moderate	High	Total Rated Habitat
Sanpoil	Lower Sanpoil	13.8	7.6	10.1	13.3	31.0
	Upper Sanpoil	5.1	6.5	3.6	12.1	22.1
	West Fork Sanpoil	4.0	11.8	7.5	9.8	29.1
	Sanpoil Total	**22.9**	**25.9**	**21.1**	**35.1**	**82.2**
Spokane	Lower Spokane	29.4	0.1	0.1	0.0	0.2
	Spokane Total	**29.4**	**0.1**	**0.1**	**0.0**	**0.2**
Upper Columbia	Barnaby Creek	0.6	0.5	0.1	0.0	0.6
	Hall Creek	4.0	12.8	5.5	5.6	23.9
	Kettle River	35.2	5.0	2.0	2.5	9.4
	Lake Roosevelt	153.6	5.7	2.7	2.0	10.4
	Rufus Woods	51.5	0.1	0.2	0.1	0.5
	Stranger Creek	1.1	2.6	3.6	2.6	8.8
	Upper Columbia Total	**245.9**	**26.7**	**14.1**	**12.8**	**53.6**
Blocked Area Total		**298.3**	**52.7**	**35.4**	**47.9**	**136.0**

Table A 6. Stream reach lengths (mi) of migratory corridors and intrinsic potential rated habitats for steelhead immediately accessible from Rufus Woods Reservoir and Lake Roosevelt.

Subbasin	Reporting Area	Migratory Corridors	Intrinsic Potential Rating Low	Moderate	High	Total Rated Habitat
Sanpoil	Lower Sanpoil	17.0	29.6	4.6	31.2	65.4
	Upper Sanpoil	12.9	22.9	1.4	17.3	41.5
	West Fork Sanpoil	10.3	25.6	0.6	42.8	69.1
	Sanpoil Total	**40.2**	**78.1**	**6.6**	**91.3**	**176.0**
Spokane	Lower Spokane	31.8	13.6	0.1	5.8	19.5
	Spokane Total	**31.8**	**13.6**	**0.1**	**5.8**	**19.5**
Upper Columbia	Barnaby Creek	1.2	1.0	0.0	0.1	1.1
	Hall Creek	13.4	40.4	0.6	24.6	65.6
	Kettle River	35.3	26.6	0.0	9.7	36.3
	Lake Roosevelt	175.8	66.6	2.4	28.4	97.4
	Nez Perce Creek	0.6	3.7	0.0	4.6	8.3
	Rufus Woods	63.1	18.7	0.5	11.6	30.7
	Stranger Creek	1.6	7.2	0.5	9.0	16.7
	Upper Columbia Total	**291.0**	**164.2**	**4.0**	**88.0**	**256.2**
Blocked Area Total		**363.0**	**255.9**	**10.7**	**185.1**	**451.7**

Table A 7. Streambed area (mi^2) and associated habitat ratings for spring Chinook reaches immediately accessible from Rufus Woods Reservoir and Lake Roosevelt rated between low *and* high *intrinsic potential. Migratory corridors are not included.*

Subbasin	Reporting Area	Intrinsic Potential Rating Low	Moderate	High	Total Rated Habitat
Sanpoil	Lower Sanpoil	0.07	0.09	0.12	0.28
	Upper Sanpoil	0.03	0.02	0.05	0.10
	West Fork Sanpoil	0.04	0.03	0.04	0.11
	Sanpoil Total	**0.14**	**0.14**	**0.21**	**0.48**
Spokane	Lower Spokane	0.00	0.00	0.00	0.00
	Spokane Total	**0.00**	**0.00**	**0.00**	**<0.01**
Upper Columbia	Barnaby Creek	0.00	0.00	0.00	0.00
	Hall Creek	0.04	0.02	0.02	0.08
	Kettle River	0.01	0.01	0.01	0.03
	Lake Roosevelt	0.02	0.02	0.01	0.05
	Rufus Woods	0.00	0.00	0.00	0.00
	Stranger Creek	0.01	0.01	0.01	0.03
	Upper Columbia Total	**0.09**	**0.05**	**0.04**	**0.19**
Blocked Area Total		**0.23**	**0.19**	**0.25**	**0.67**

Table A 8. Streambed area (mi^2) and associated habitat ratings for steelhead reaches immediately accessible from Rufus Woods Reservoir and Lake Roosevelt rated between low *and* high *intrinsic potential. Migratory corridors are not included.*

Subbasin	Reporting Area	Intrinsic Potential Rating Low	Moderate	High	Total Rated Habitat
Sanpoil	Lower Sanpoil	0.10	0.04	0.20	0.34
	Upper Sanpoil	0.06	0.01	0.06	0.13
	West Fork Sanpoil	0.05	0.00	0.12	0.17
	Sanpoil Total	**0.21**	**0.05**	**0.38**	**0.64**
Spokane	Lower Spokane	0.02	0.00	0.01	0.02
	Spokane Total	**0.02**	**0.00**	**0.01**	**0.02**
Upper Columbia	Barnaby Creek	0.00	0.00	0.00	0.00
	Hall Creek	0.07	0.00	0.08	0.15
	Kettle River	0.16	0.00	0.02	0.18
	Lake Roosevelt	0.12	0.02	0.05	0.19
	Nez Perce Creek	0.01	0.00	0.01	0.01
	Rufus Woods	0.03	0.00	0.02	0.04
	Stranger Creek	0.01	0.00	0.02	0.04
	Upper Columbia Total	**0.40**	**0.02**	**0.20**	**0.62**
Blocked Area Total		**0.62**	**0.07**	**0.58**	**1.28**

Appendix B:
Detailed Intrinsic Potential Model Maps

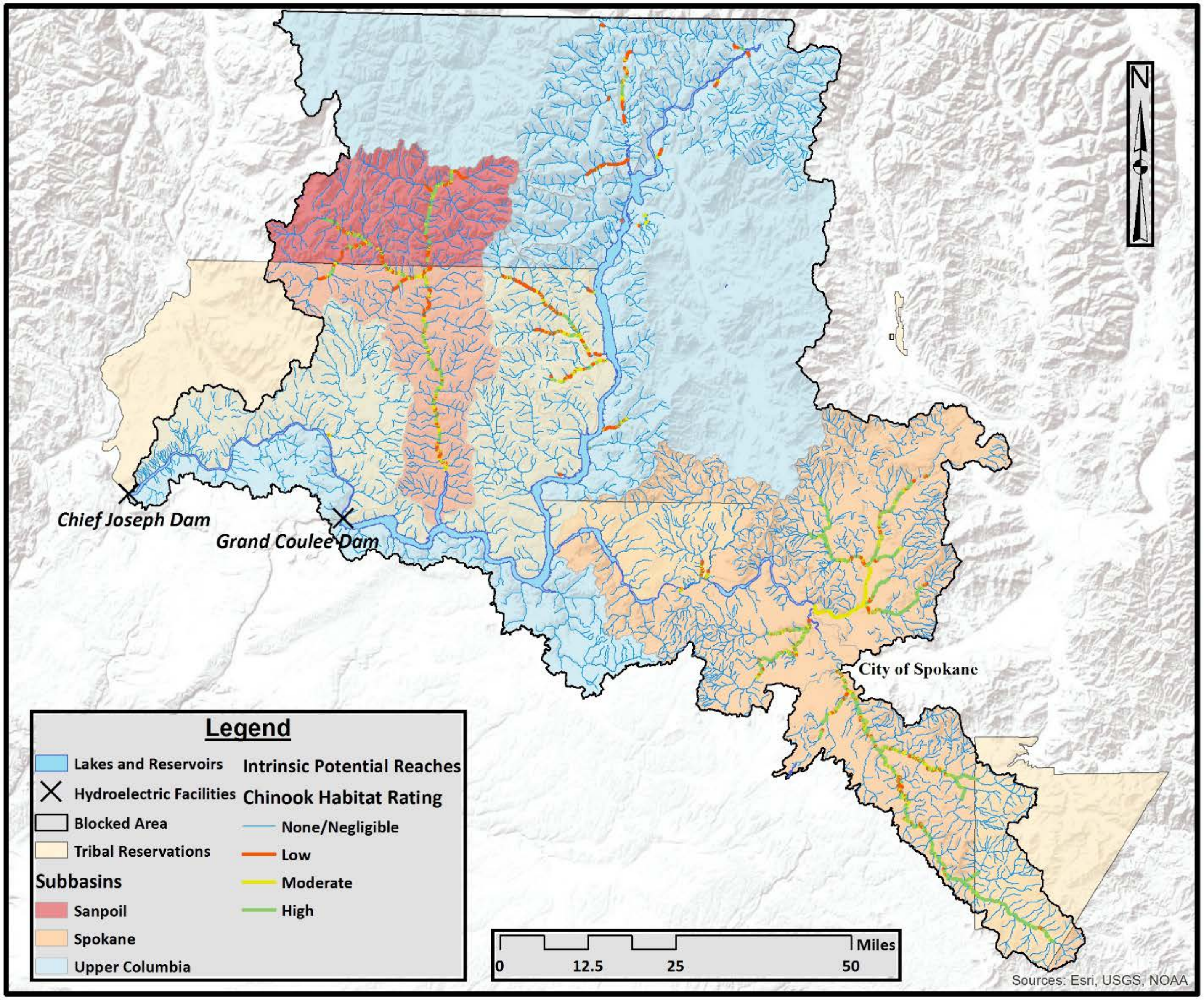

Figure B 1. All intrinsic potential stream reaches and habitat ratings for spring Chinook within the U.S. portion of the blocked area.

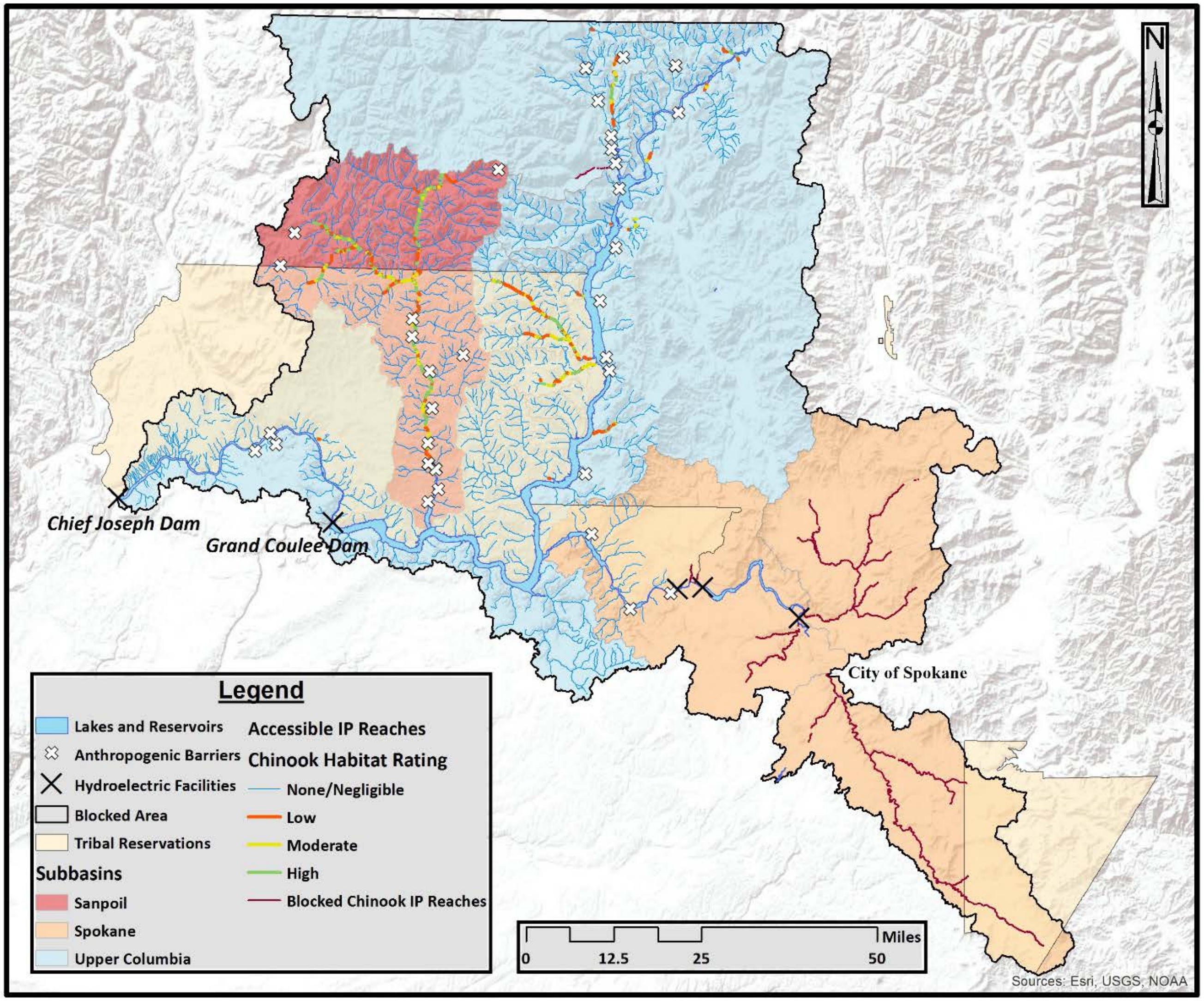

Figure B 2. Intrinsic potential stream reaches and habitat ratings for spring Chinook immediately accessible from Rufus Woods Reservoir and Lake Roosevelt. Blocked intrinsic potential (IP) habitats are those that scored higher than "low" production potential but are blocked by at least one anthropogenic barrier. Many barriers are located on smaller tributaries. The habitats they block are indicated by black stream reaches.

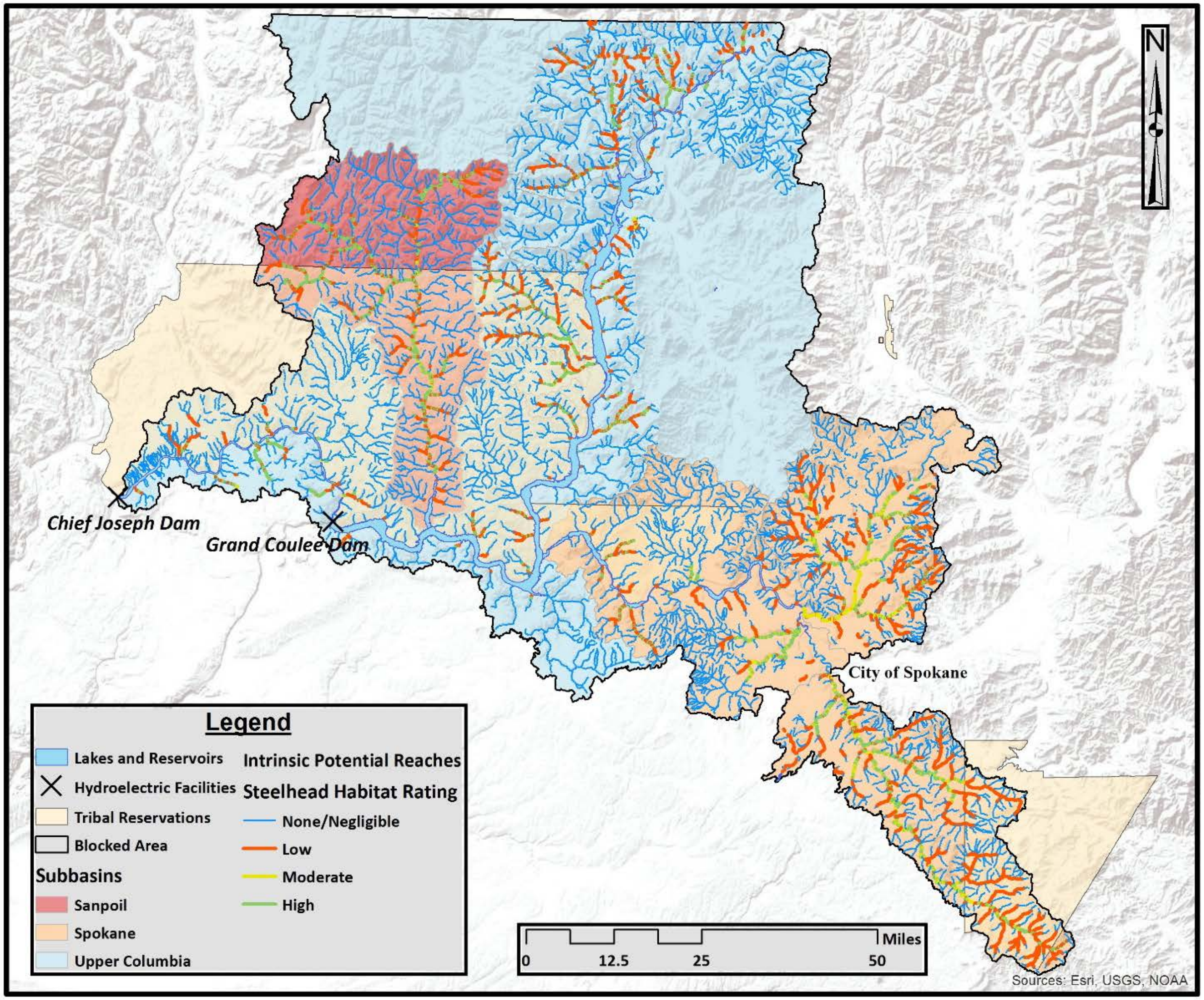

Figure B 3. All intrinsic potential stream reaches and habitat ratings for steelhead within the U.S. portion of the blocked area.

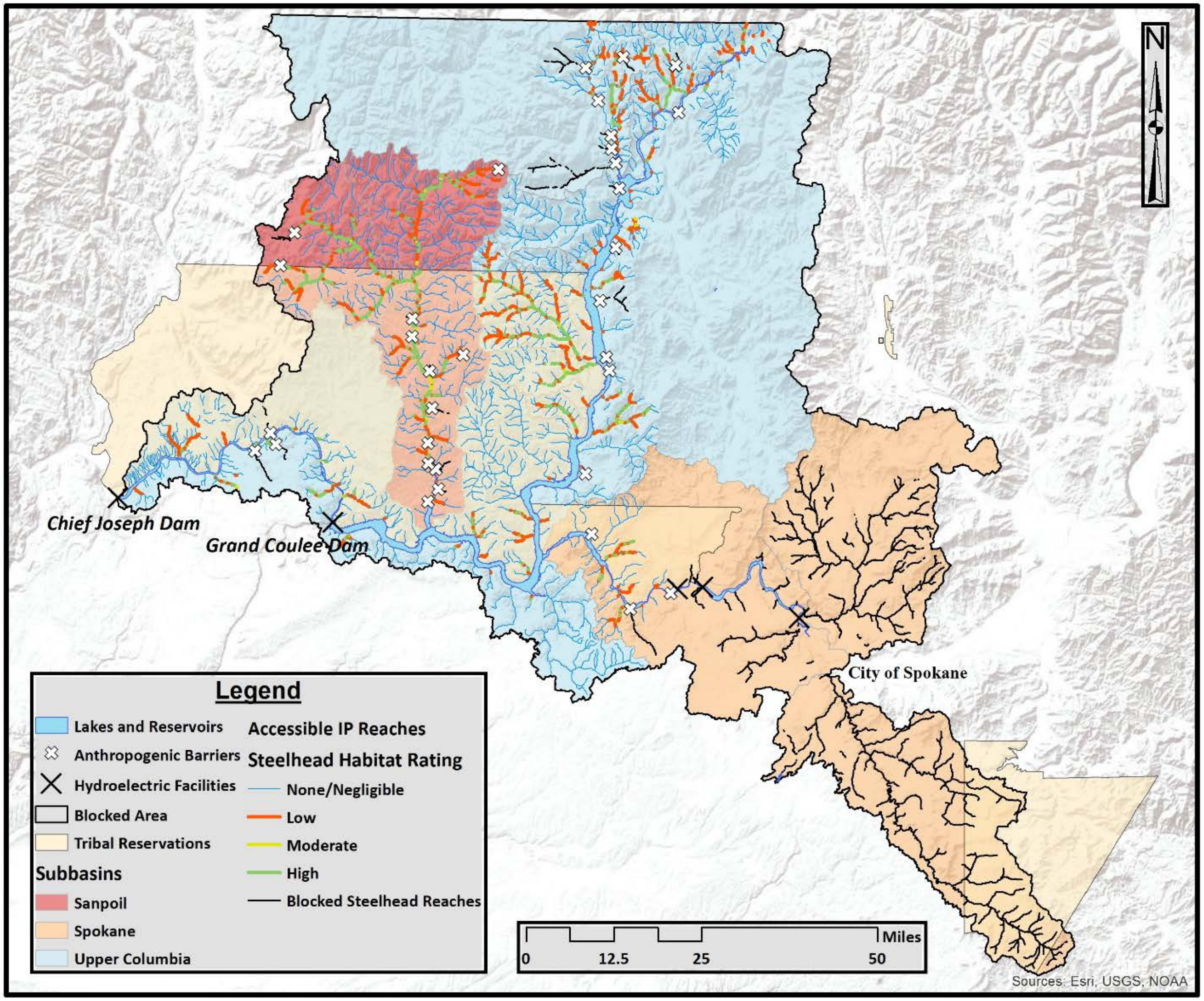

Figure B 4. Intrinsic potential stream reaches and habitat ratings for steelhead immediately accessible from Rufus Woods Reservoir and Lake Roosevelt. Blocked intrinsic potential (IP) habitats are those that scored higher than "low" production potential but are blocked by at least one anthropogenic barrier. Many barriers are located on smaller tributaries. The habitats they block are indicated by black stream reaches.

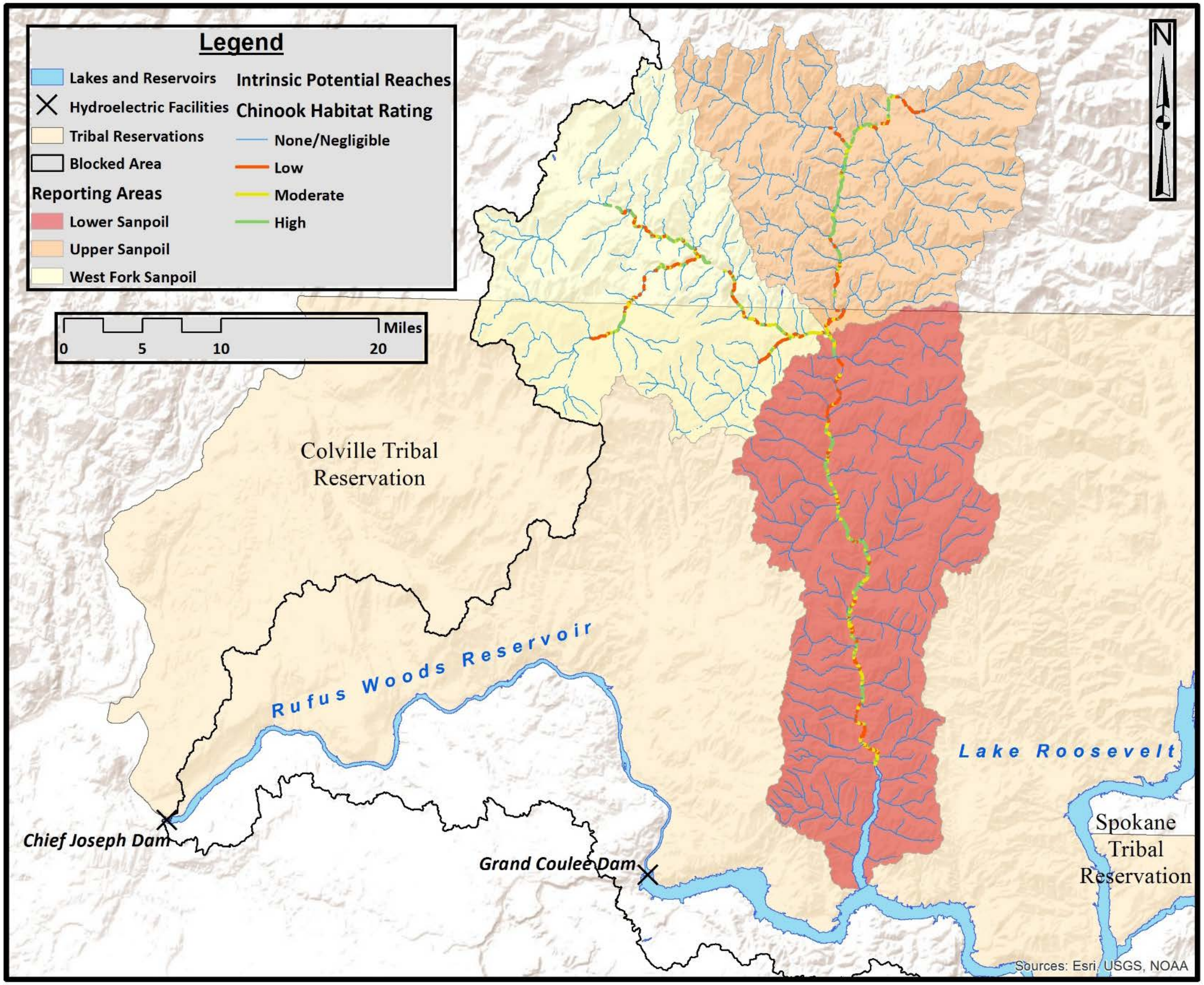

Figure B 5. All intrinsic potential stream reaches and habitat ratings for spring Chinook within the Sanpoil Subbasin.

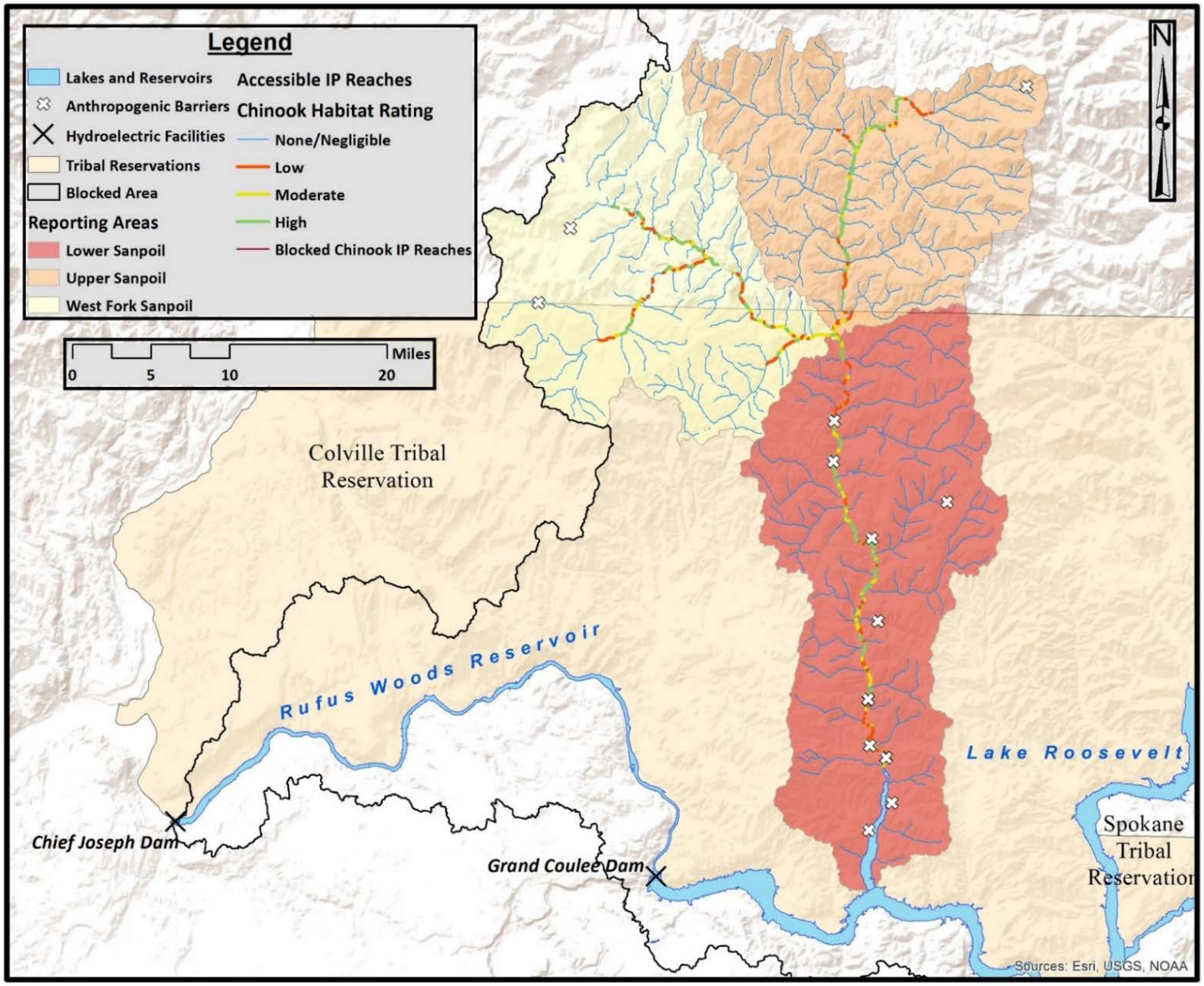

Figure B 6. Intrinsic potential stream reaches and habitat ratings for spring Chinook within the Sanpoil Subbasin immediately accessible from Lake Roosevelt. Blocked intrinsic potential (IP) habitats are those that scored higher than "low" production potential but are blocked by at least one anthropogenic barrier. Many barriers are located on smaller tributaries. The habitats they block are indicated by black stream reaches.

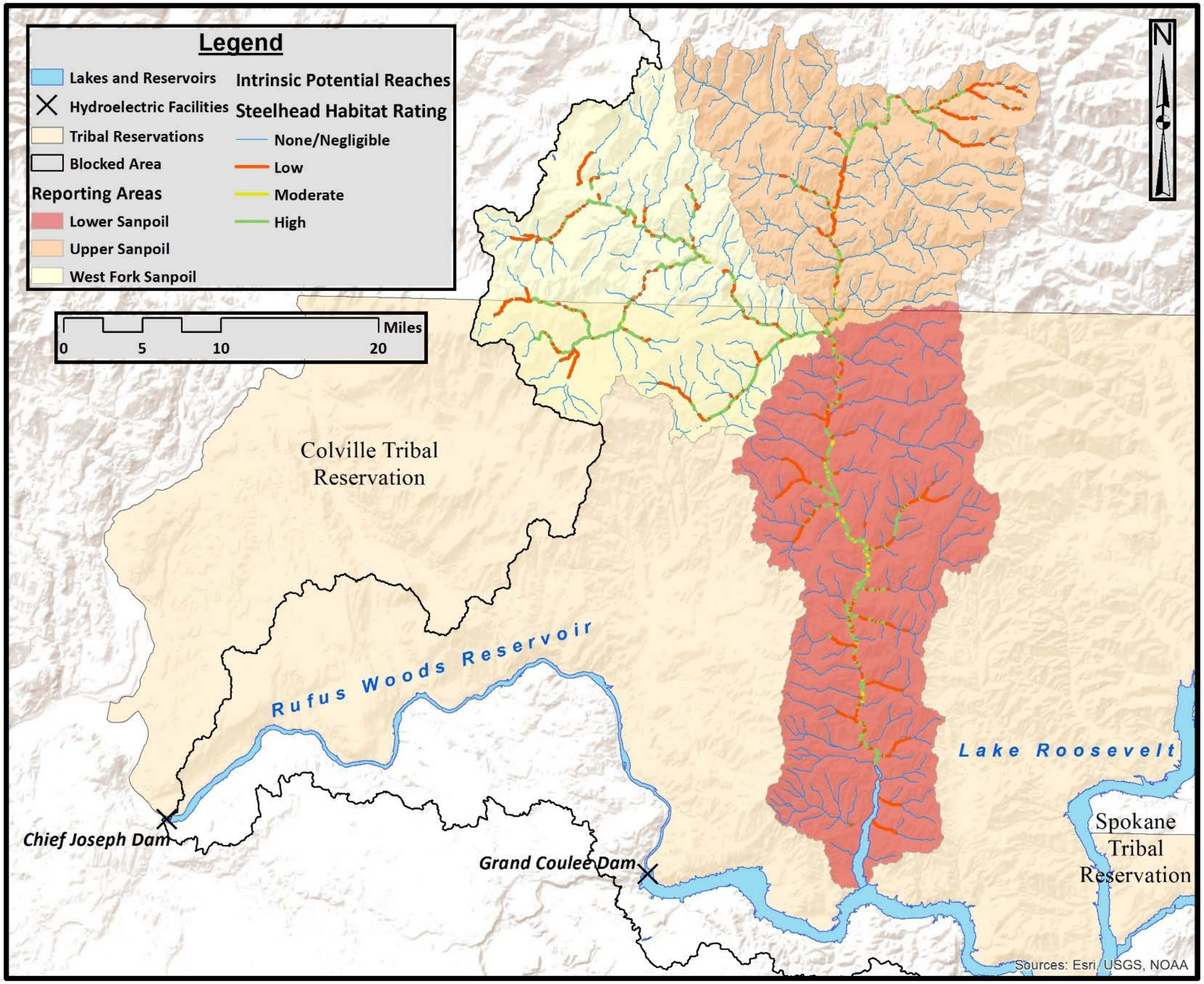

Figure B 7. All intrinsic potential stream reaches and habitat ratings for steelhead within the Sanpoil Subbasin.

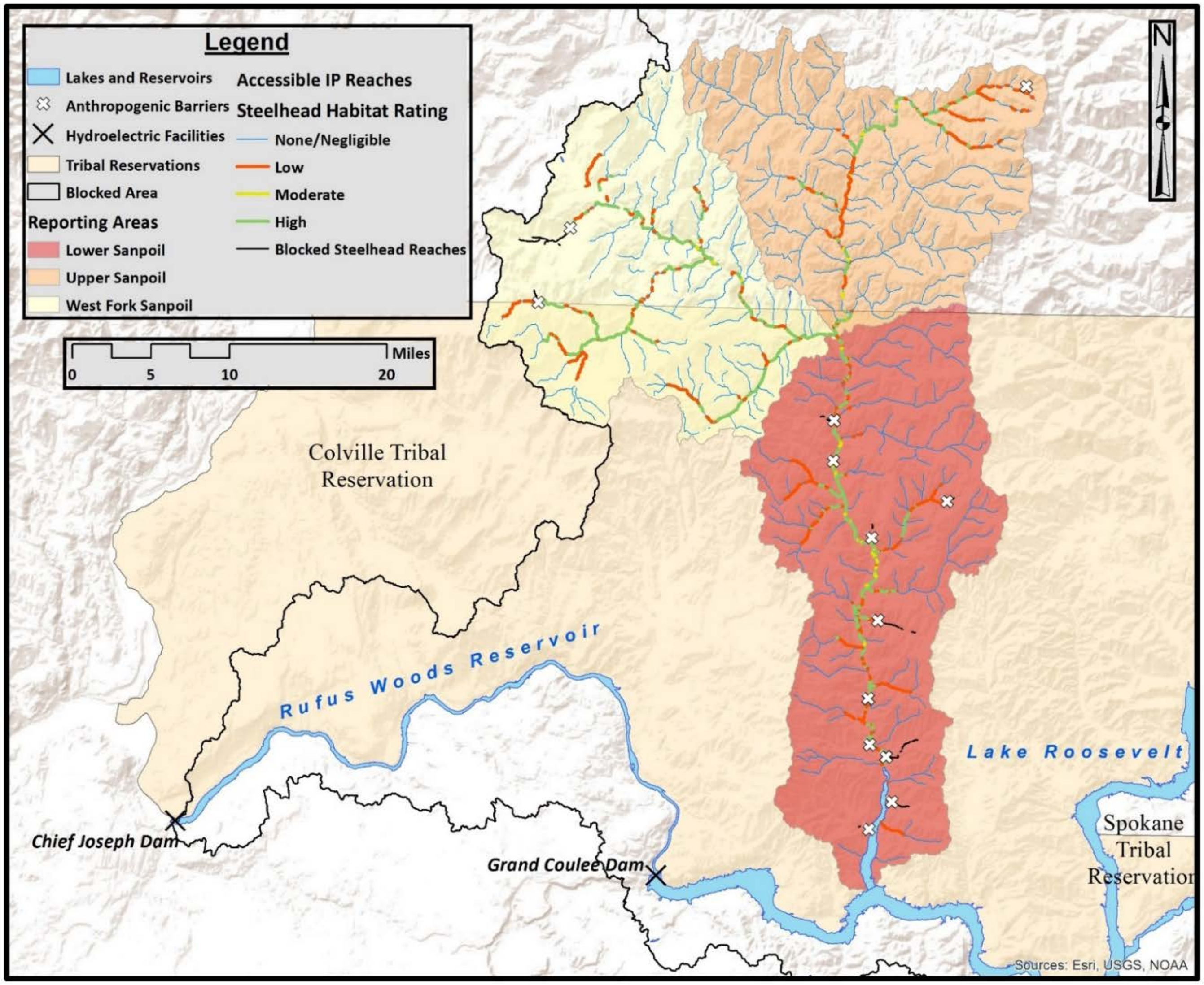

Figure B 8. Intrinsic potential stream reaches and habitat ratings for steelhead within the Sanpoil Subbasin immediately accessible from Lake Roosevelt. Blocked intrinsic potential (IP) habitats are those that scored higher than "low" production potential but are blocked by at least one anthropogenic barrier. Many barriers are located on smaller tributaries. The habitats they block are indicated by black stream reaches.

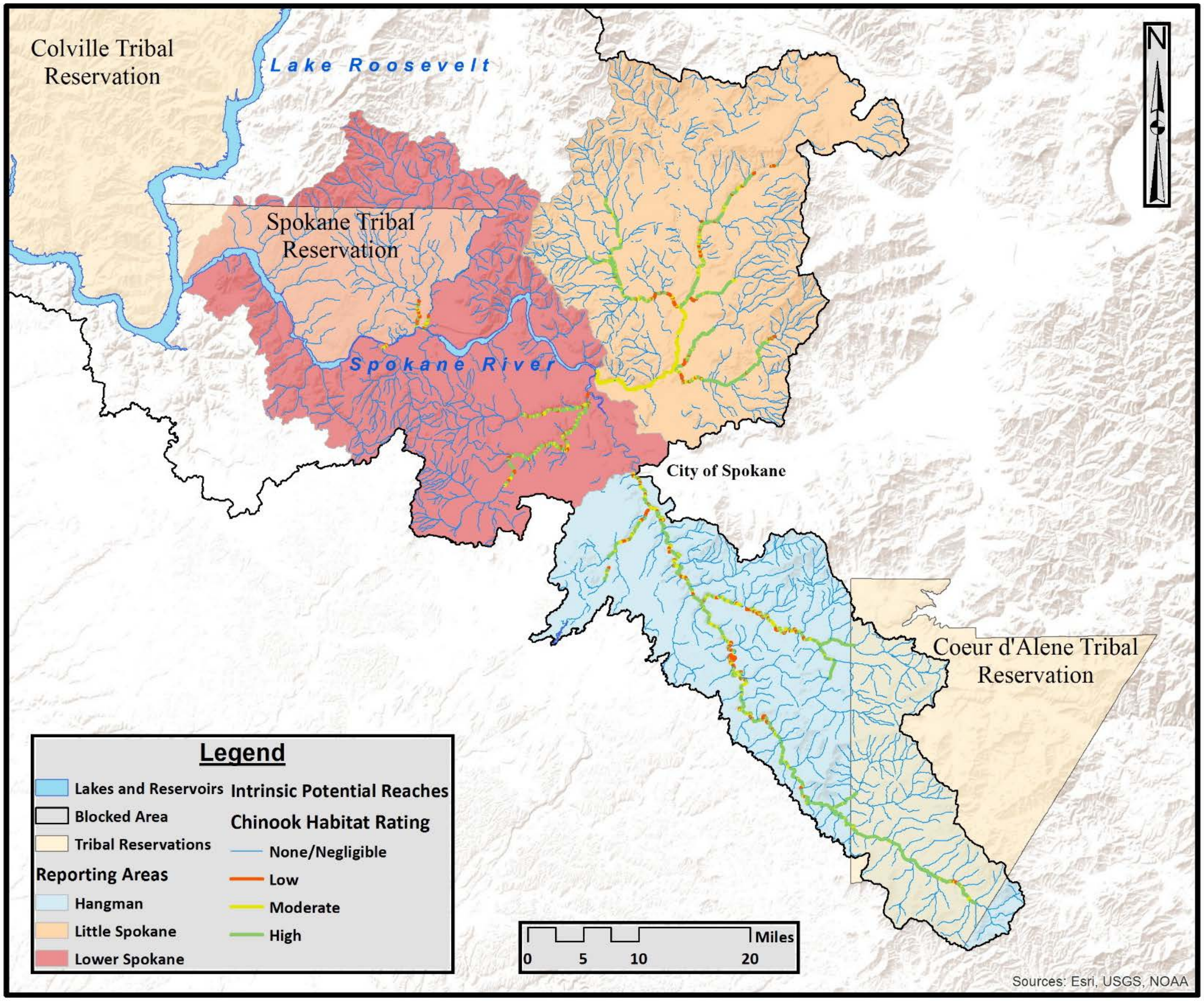

Figure B 9. All intrinsic potential stream reaches and habitat ratings for spring Chinook within the Spokane Subbasin.

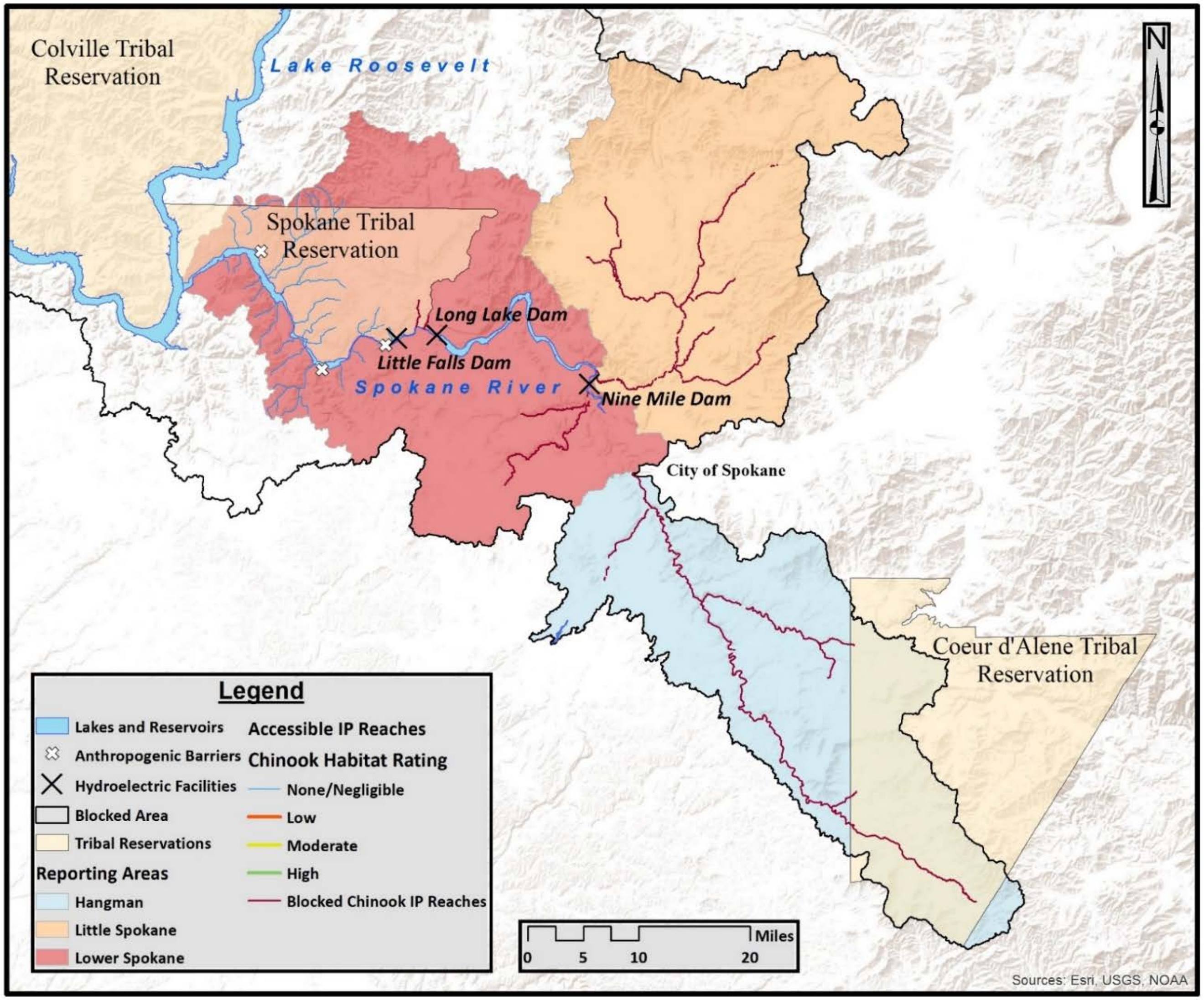

Figure B 10. Intrinsic potential stream reaches and habitat ratings for spring Chinook within the Spokane Subbasin immediately accessible from Lake Roosevelt. Blocked intrinsic potential (IP) habitats are those that scored higher than "low" production potential but are blocked by at least one anthropogenic barrier. Many barriers are located on smaller tributaries. The habitats they block are indicated by black stream reaches.

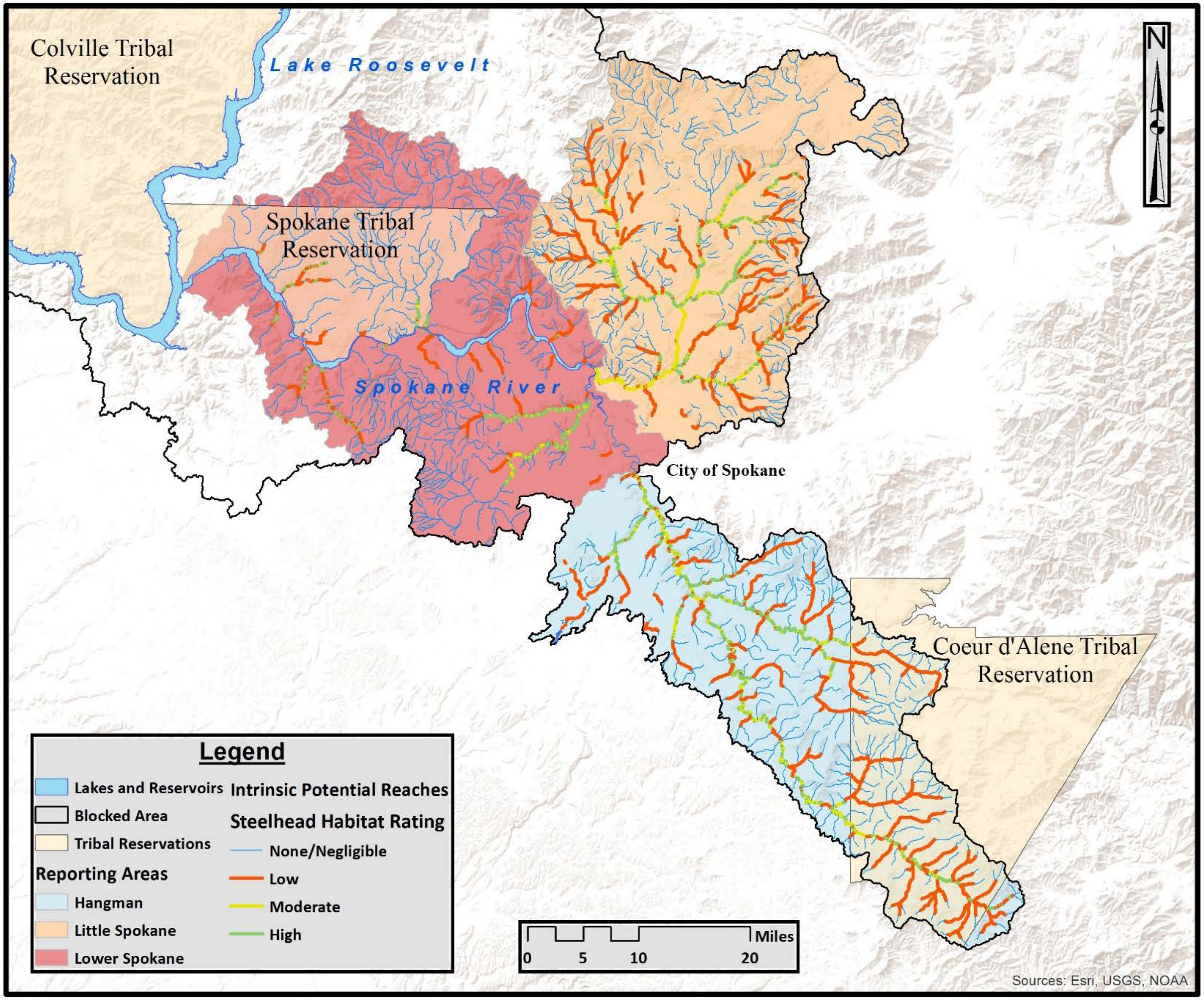

Figure B 11. All intrinsic potential stream reaches and habitat ratings for steelhead within the Spokane Subbasin.

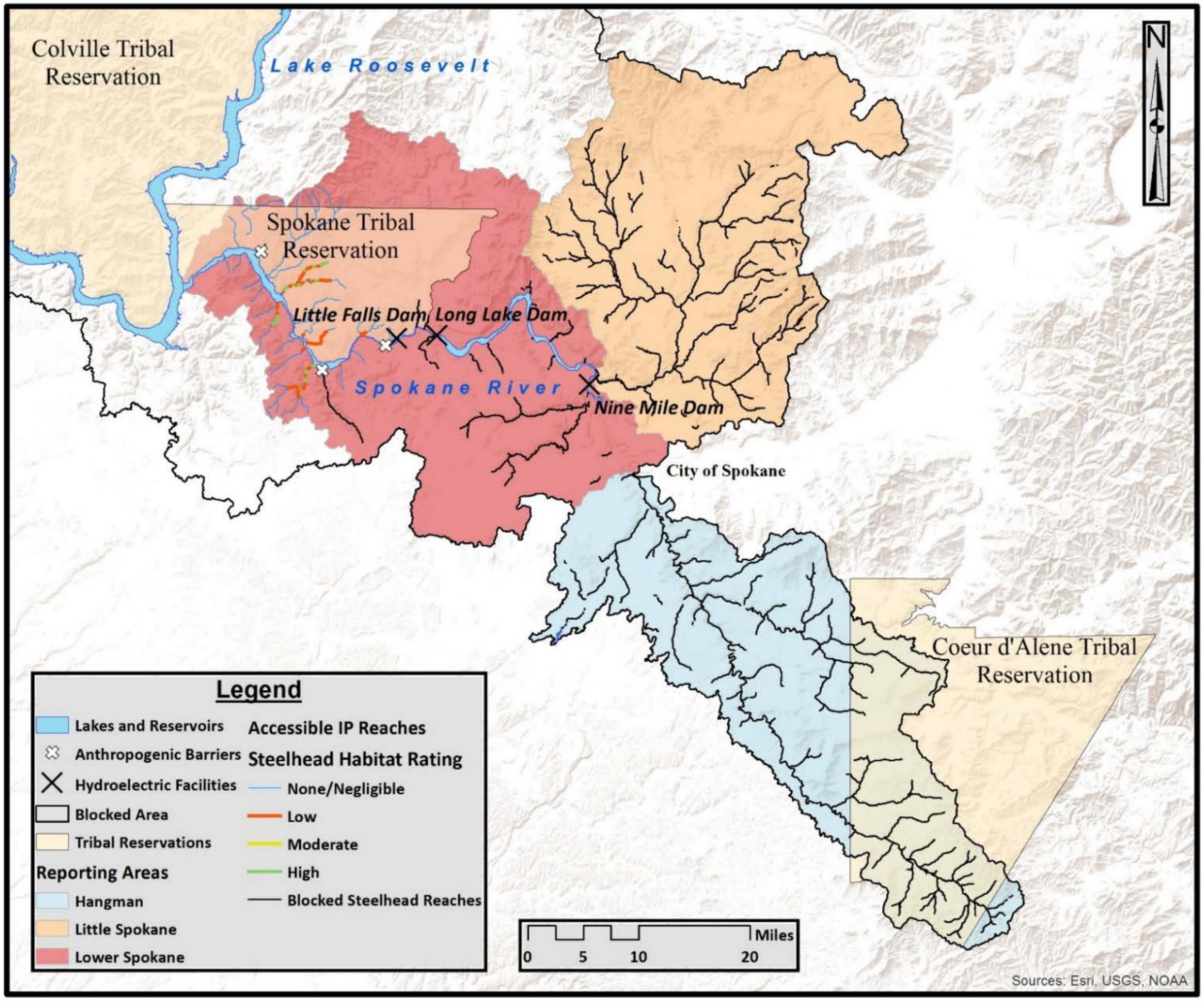

Figure B 12. Intrinsic potential stream reaches and habitat ratings for steelhead within the Spokane Subbasin immediately accessible from Lake Roosevelt. Blocked intrinsic potential (IP) habitats are those that scored higher than "low" production potential but are blocked by at least one anthropogenic barrier. Many barriers are located on smaller tributaries. The habitats they block are indicated by black stream reaches.

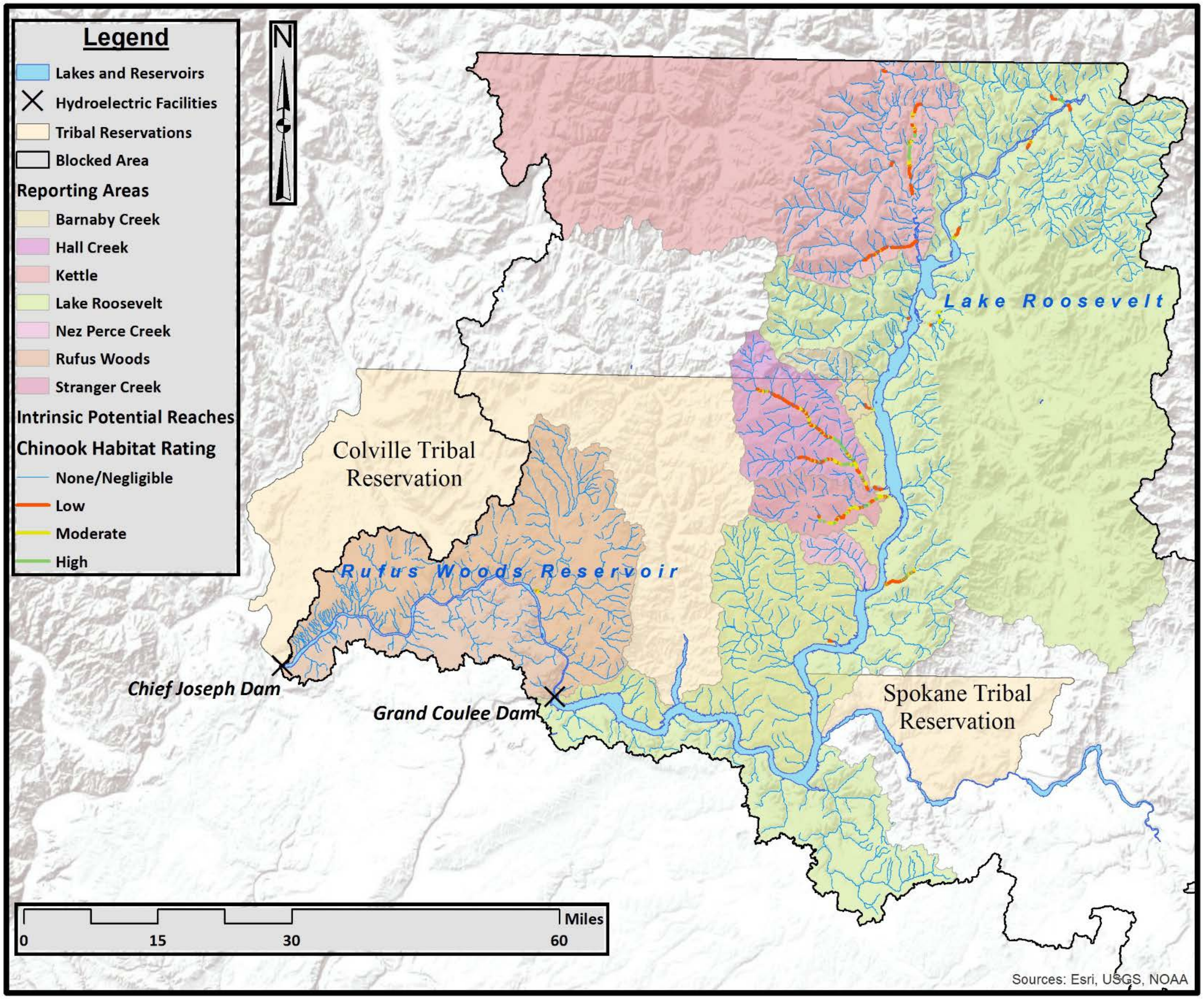

Figure B 13. All intrinsic potential stream reaches and habitat ratings for spring Chinook within the Upper Columbia Subbasin.

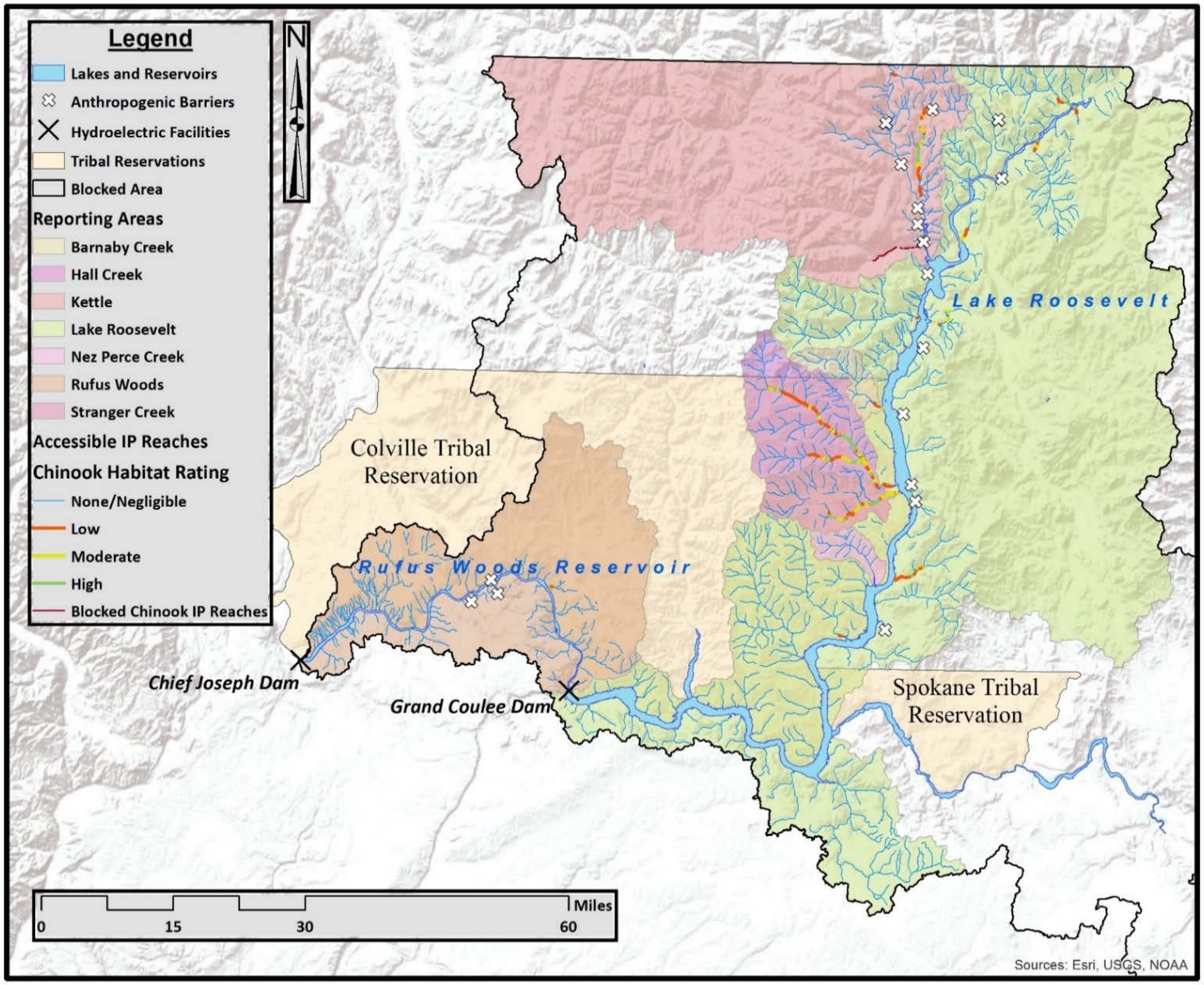

Figure B 14. Intrinsic potential stream reaches and habitat ratings for spring Chinook within the Upper Columbia Subbasin immediately accessible from Rufus Woods Reservoir and Lake Roosevelt. Blocked intrinsic potential (IP) habitats are those that scored higher than "low" production potential but are blocked by at least one anthropogenic barrier. Many barriers are located on smaller tributaries. The habitats they block are indicated by black stream reaches.

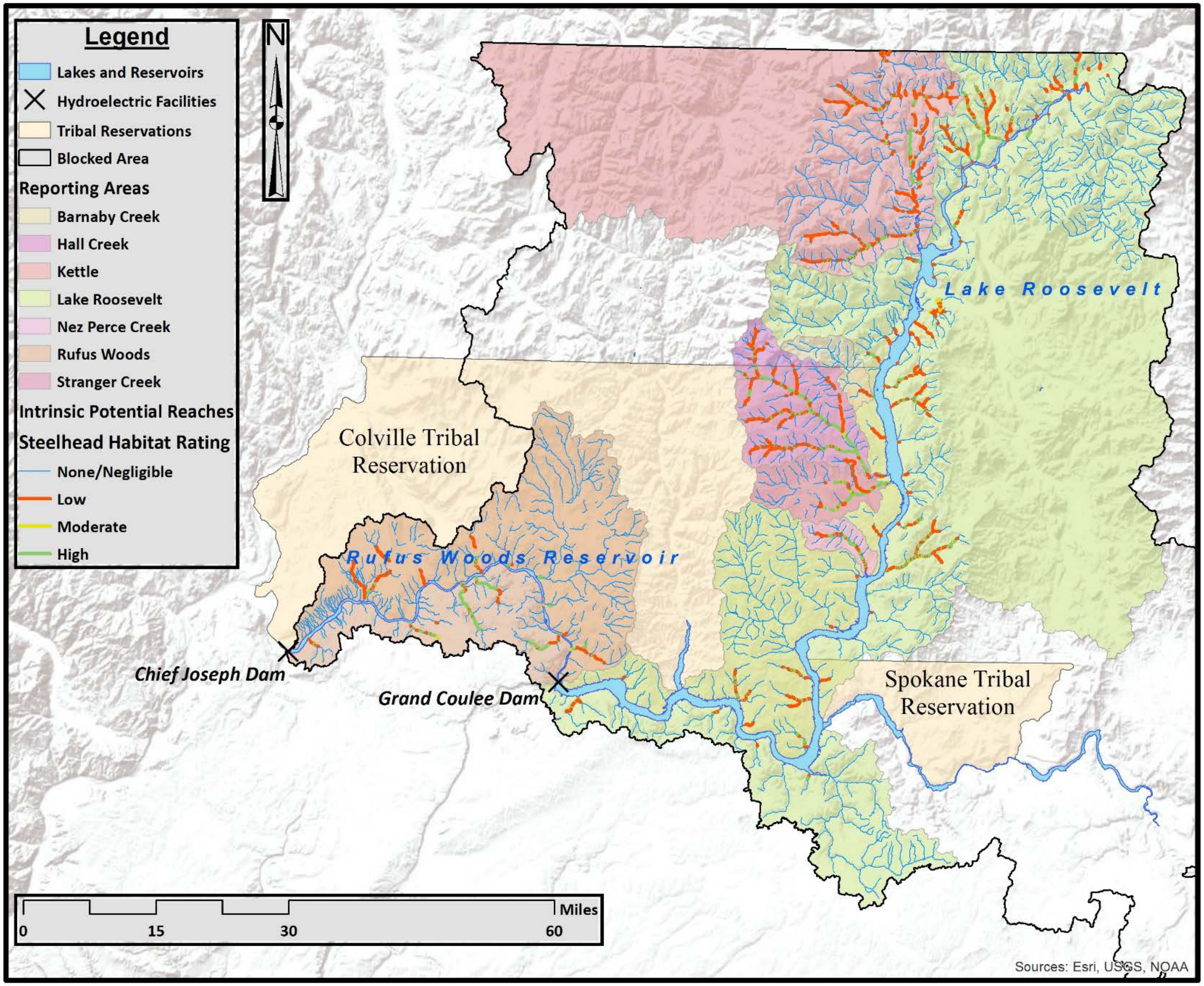

Figure B 15. All intrinsic potential stream reaches and habitat ratings for steelhead within the Upper Columbia Subbasin.

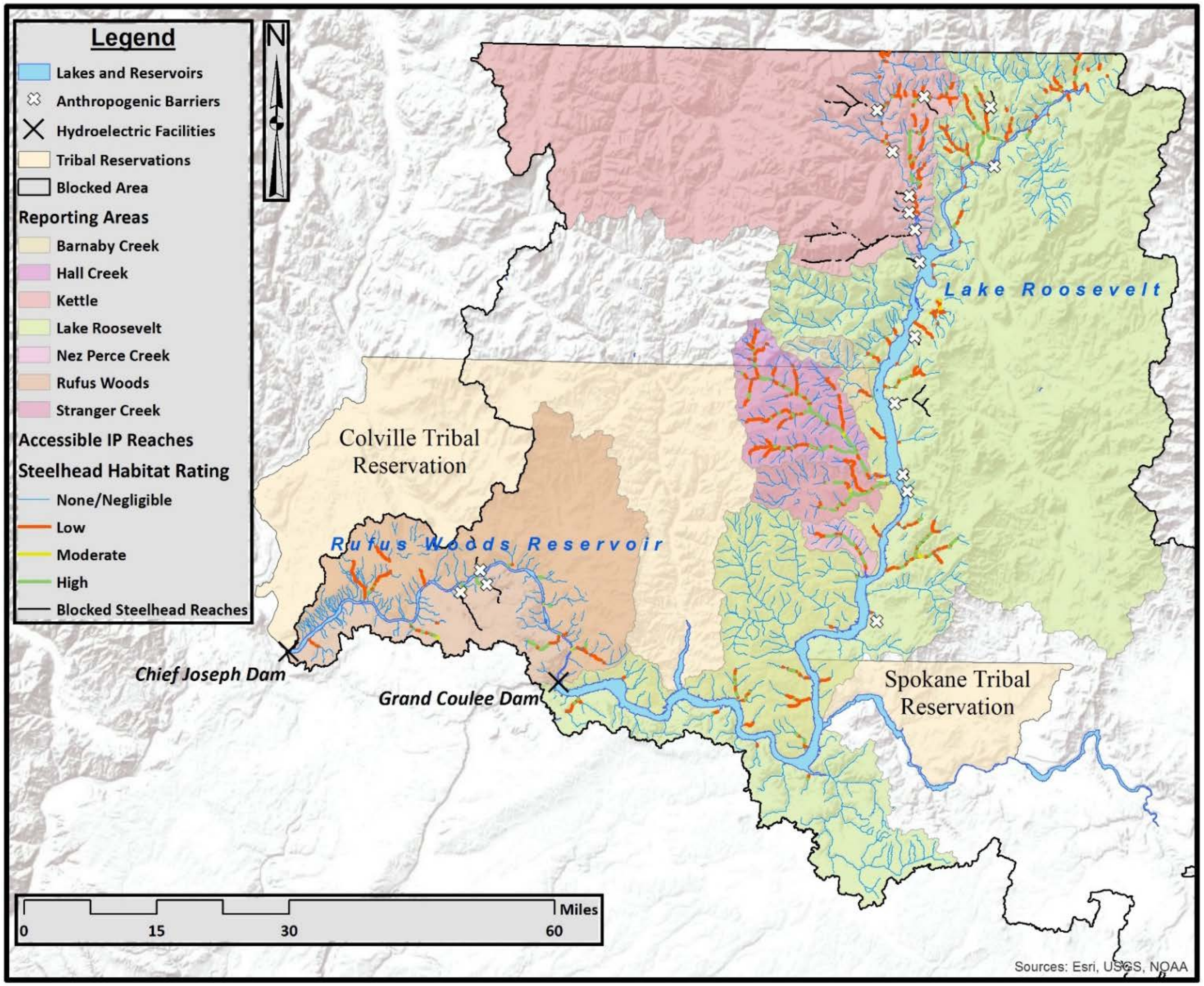

Figure B 16. Intrinsic potential stream reaches and habitat ratings for steelhead within the Upper Columbia Subbasin immediately accessible from Rufus Woods Reservoir and Lake Roosevelt. Blocked intrinsic potential (IP) habitats are those that scored higher than "low" production potential but are blocked by at least one anthropogenic barrier. Many barriers are located on smaller tributaries. The habitats they block are indicated by black stream reaches.