APPENDIX B- Habitat Based Population Recovery Goals

APPENDIX B. HABITAT-BASED POPULATION RECOVERY GOALS

1 INTRODUCTION

The purpose of this appendix is to explore the biological limits for Lake Ozette sockeye production. Since the Lake Ozette sockeye ESU is known to have been more abundant historically, it can be assumed that the lake could support increased production. Habitat capacity could be limited by food availability or spawning habitat capacity. A review of the available data and modeling results provides a basis for setting recovery goals.

2 FOOD AVAILABILITY AND COMPETITION

Lake Ozette provides a large rearing area capable of producing extremely large age 1+ sockeye smolts. Lake Ozette sockeye predominately emigrate as age 1+ smolts (LaRiviere 1990; MFM 1991; Jacobs et al. 1996). Recently collected otolith data (broodyears [BY] 2000, 2001, and 2002) indicate that less than 1 percent of sockeye emigrate as age 2+ smolts (n=981; MFM, unpublished otolith age data). Age 1+ smolt emigration is a common life history strategy employed by sockeye salmon within the southern range of the species (e.g., Lake Washington sockeye). Lake Ozette sockeye salmon smolts average between 113 to 130 mm (FL) for years 1978, 1984, 1989, 1990, 1991, and 1992 (Blum 1988; Jacobs et al 1996). Dlugokenski et al. (1981) evaluated the length and weight of Ozette sockeye smolts and concluded that they were the third largest yearling sockeye smolts in the documented literature. Recently collected smolt size data measured total length; smolts averaged 140 mm (TL; n=107) in 2003 and 144 mm (TL; n=231) in 2004.

Sockeye prey composition and availability, as well as competition for prey in Lake Ozette have been investigated in part or whole by Bortleson and Dion (1979), Dlugokenski et al. (1981), Blum (1988), Beauchamp and LaRiviere (1993), and Meyer and Brenkman (2001). Past surveys in Lake Ozette indicated that juvenile *O. nerka* occur at higher frequencies in the pelagic zone than all other fish species combined (Beauchamp and LaRiviere 1993). Approximately 94 percent of the fish >100mm (FL) caught in vertical gill nets in April 1991 were sockeye salmon pre-smolts or kokanee (Beauchamp et al 1995). *Daphnia pulicaria* dominate the diet of juvenile *O. nerka* salmon throughout the year (Beauchamp et al. 1995). Benthic invertebrates, adult insects, and copepods comprised 7-46 percent of the adult kokanee salmon diets from late-summer through early-spring (Beauchamp et al. 1995). Beauchamp et al. (1995) estimated that juvenile sockeye and all year classes of kokanee consumed far less than 1 percent of the monthly standing stock of *Daphnia pulicaria* > 1.0 mm in size, suggesting that food availability for rearing fish was not limiting *O. nerka* productivity.

All researchers (Bortleson and Dion 1979; Dlugokenski et al. 1981; Blum 1988; Beauchamp and LaRiviere 1993), independent of methodologies, have concluded that

Lake Ozette sockeye productivity and survival are not limited by food availability or competition. No direct estimates of total smolt production capacity of the lake have been developed. Blum (1988) used the Acre Plankton Index (API) model to estimate the carrying capacity of the lake and concluded that the lake could support total adult sockeye runs in the range of 306,000 to 563,000 (back calculations of adult run sizes based on API model results suggest smolt yields would range from 1.8 to 3.3 million per year at 17 percent marine survival). Blum (1988) concluded that spawning area limitations may represent the natural constraint to Lake Ozette sockeye abundance potential.

Beauchamp et al. (1995) determined that food supply is unlikely to limit large sockeye salmon enhancement efforts. They determined that competition for food resources would not limit extensive increases (10 – 50 fold) in age 0 sockeye fry production. Based on age 0 *O. nerka* population estimates during their study, it is suggested that the lake's zooplankton community could support annual fry production in the range of 40 to 80 million. Their analysis further suggests that the lake could support an annual smolt production of 2 to 8 million smolts (at 5 to10 percent fry to smolt survival[5]), given sufficient fry production. Smolts per spawner data are generally lacking for Ozette sockeye, but preliminary data for BY 2004 and return year (RY) 2008 suggest a range of 16 to 24 smolts[6] were produced per female spawner (MFM, unpublished sockeye population data). Given this range of current freshwater productivity it would require at least 640,000 spawners (assuming a 1:1 sex ratio) to fully seed the lake and produce 8 million sockeye smolts (see Figure B 1) and 80,000 spawners to produce 1 million smolts. If it is assumed that freshwater survival will double during the next 30 to 50 years, to 50 sockeye smolts per female spawner, then it would require 40,000 to 320,000 spawners to produce 1 to 8 million sockeye smolts.

[5] Literature average values for fry-to-smolt survival average 25.6 percent (summarized in Quinn 2005).
[6] Literature average values for smolts per female spawner average 75 (summarized in Quinn 2005).

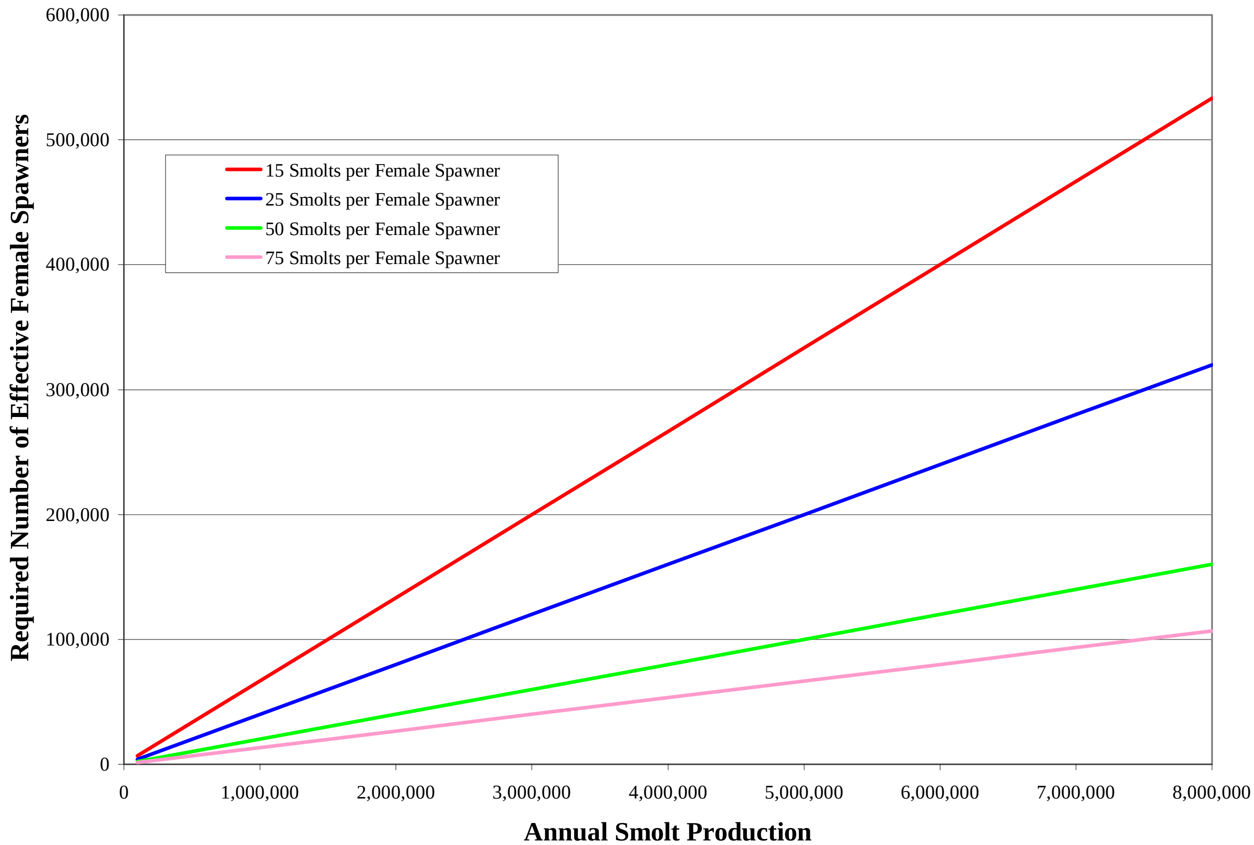


Figure B 1. Relationships between the required number of effective female spawners and the resulting range of annual smolt production values based on different smolts per female production yields.

The maximum sustainable annual smolt production capacity for Lake Ozette remains unknown. Future monitoring of the juvenile O. nerka population and the zooplankton community will help refine estimates of capacity. Currently (2002 to present) the lake is producing 35,000 to 70,000 sockeye smolts per year. Current smolt production has been 4 to 10 times higher than reported in Jacobs et al. (1996) for emigrations occurring between 1977 and 1992. Smolt size and smolts per spawner have remained constant or slightly increased, further suggesting that food limits in the lake are not being affected by increased juvenile abundance.

3 SPAWNING HABITAT CAPACITY

Spawning habitat availability and sockeye spawning capacity have been evaluated by past researchers working in Ozette but were re-evaluated based on extensive freshwater habitat inventories conducted in recent years and summarized in Haggerty and Ritchie (2004) and Haggerty et al. (2007). In addition, past efforts have not established beach spawning aggregation targets.

3.1 BEACH SPAWNING HABITAT CAPACITY

There are two known active beach spawning sites along the shores of Lake Ozette: Allen's and Olsen's Beaches. Spawning ground surveys conducted in 1978 and 1979 also found ~30 sockeye spawning just north of the confluence with Umbrella Creek (Umbrella Beach; Dlugokenski et al. 1981). The only other record of beach spawning sockeye locations is a one-time observation of a pair of sockeye spawning on the southwest shoreline of Baby Island (Meyer and Brenkman 2001). It is important to note that current and recent spawning locations, as well as vegetation and substrate conditions along the lake shoreline, may not be representative of past spawning distribution and shoreline conditions. Kemmerich (1926) stated that, "*The shores of the lake afford many ideal spawning beds and over a large area, also numerous small streams of gravel bottom empty into the lake which are ideal spawning beds.*" Kemmerich (1939) also recalled that, "*We made no special investigations of spawning beds during the years* [1923-1926] *but merely observed from time to time that most of the spawning seemed to be along the lake shore in suitable places and especially at the mouths of the several creeks.*" Nonetheless spawning habitat capacity for Ozette beaches in this analysis was only calculated for Allen's, Olsen's, Baby Island, and Umbrella Beaches.

Spawning habitat quality and quantity have been greatly reduced during the last 50 to 100 years from historical conditions. Factors contributing to decline in beach spawning habitat quality and quantity are discussed in detail in the Lake Ozette Sockeye LFA (Haggerty et al. 2007). Spawning habitat capacity estimates assume restored beach conditions for spawning habitat area calculations. In a review of the scientific literature no methods for determining spawning habitat capacity for beach spawning sockeye could be found. Beach spawning sockeye require both suitable substrate size and adequate flow for egg incubation (Foerster 1968). Sufficient intra-gravel flow may be provided by upwelling from springs and seeps, wave action, and/or lake currents. Intra-gravel flow data are not available for Ozette spawning beaches. Spawning use along Olsen's and Allen's Beaches, categorized as concentrated or dispersed, is thought to be a good indicator of where intra-gravel flow is sufficient to incubate eggs. Experiments with beach spawners in Lake Dalnee (Kamchatka) have shown that sockeye placed in penned-off areas with suitable substrate size but no intra-gravel flow do not deposit their eggs and die (Krogius and Krokhin 1956 *in* Foerster 1968).

3.1.1 Olsen's Beach Estimate

The quantity of suitable habitat for Olsen's Beach was estimated using recent spawning ground observations (1978-2004; summarized in Haggerty et al. 2007), and high resolution geo-rectified aerial photos. Spawning habitat was categorized based on current use: concentrated (including core use) and dispersed (Figure B 2). Spawning habitat polygons were delineated in ArcMap using aerial photos, where depths were estimated to be 1-3 meters during the spawning season along the entire length of Olsen's Beach.

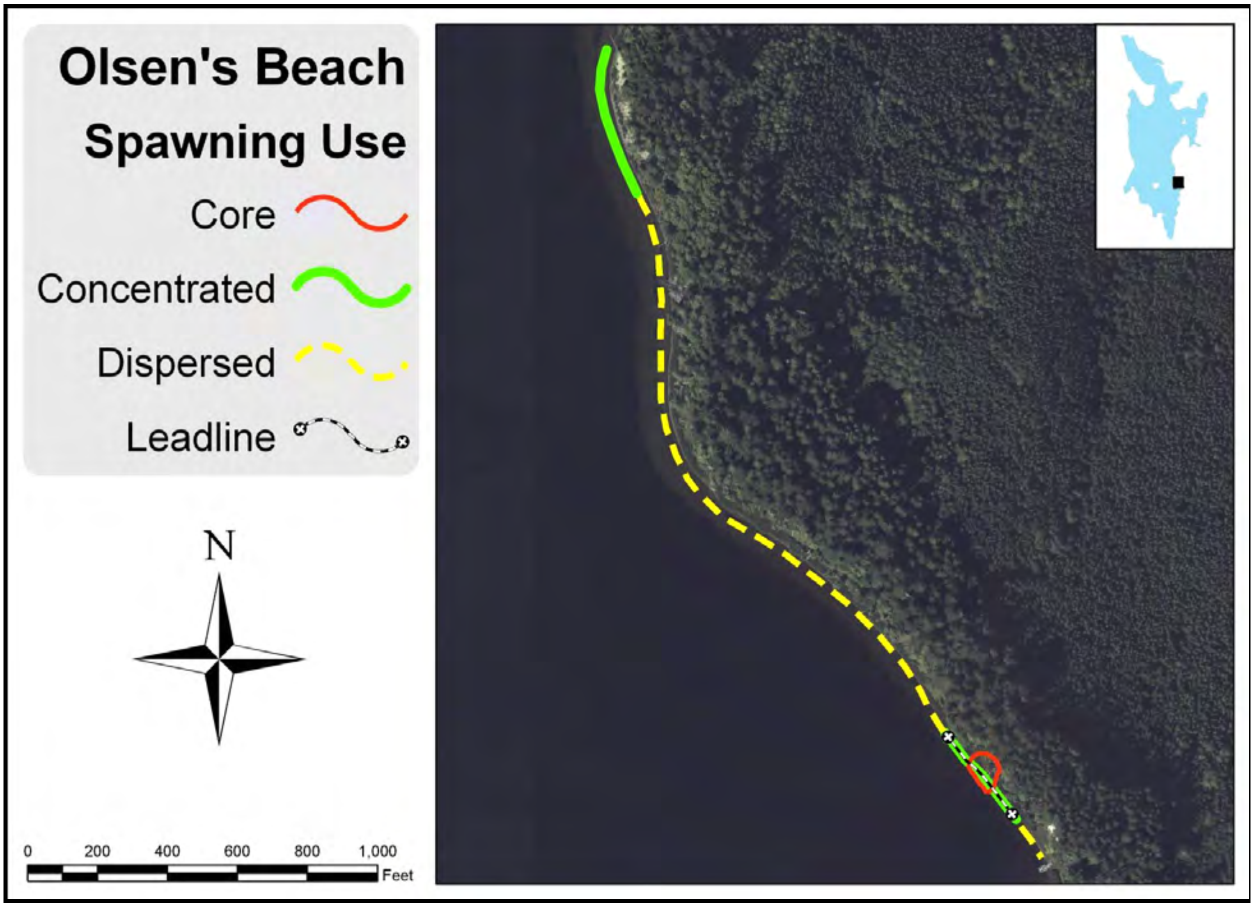


Figure B 2. Depiction of current Olsen's Beach sockeye spawning use categorized as concentrated, core, and dispersed, as well as the relative position of the spawning ground survey lead line used for data collection in 1999, 2000, and 2001 (source: Haggerty et al. 2007).

Two methods were used to estimate total spawning capacity on Olsen's Beach. Both methods assume a 1:1 sex ratio. Method 1 assumes the use of 3 square meters per female[7] and 100 percent suitable area utilization (defined by polygons) without overlapping redds within the concentrated spawning use habitat type. Spawning capacity in dispersed habitat areas was assumed to be one-third that of concentrated (based upon maximum range of spawning densities reported at full seeding levels of suitable habitat). Method 2 assumes 3 female spawners per linear meter of spawning beach in concentrated use areas and 1 female spawner per linear meter of spawning habitat in dispersed use areas. Spawning capacity for Olsen's Beach using methods 1 and 2 were 3,416 and 2,622 spawners respectively (Table B 1).

[7] The 3 square meters/per female is based on a review of natural spawning densities presented in Foerster 1968.

Table B 1. Summary of spawning habitat length and area and estimated spawning capacity using methods 1 and 2.

Sockeye Use Category	Habitat Length (Meters)	Habitat Area (Sq. Meters)	Method 1		Method 2	
			Sockeye Redd Capacity	Total Sockeye Spawners	Sockeye Redd Capacity	Total Sockeye Spawners
Concentrated	232	3,186	1,062	2,124	695	1,390
Dispersed	616	5,815	646	1,292	616	1,233
TOTAL	848	9,001	1,708	3,416	1,311	2,622

3.1.2Allen's Beach Estimate

The quantity of suitable habitat for Allen's Beach was estimated using recent spawning ground observations (1978-2004; summarized in Haggerty et al. 2007), spawning substrate characterization, and high resolution geo-rectified aerial photos. Spawning habitat was categorized based on current use: concentrated and dispersed (Figure B 3). Spawning habitat polygons were delineated in ArcMap using aerial photos where depths were estimated to be 1-3 meters during the spawning season along the entire length of Allen's Beach. The two methods used to estimate spawning capacity at Allen's Beach were the same as those described above for Olsen's Beach. Spawning capacity for Allen's Beach using methods 1 and 2 were 8,903 and 7,318 spawners respectively (Table B 2).

Table B 2. Summary of spawning habitat length and area and estimated spawning capacity using methods 1 and 2.

Sockeye Use Category	Habitat Length (Meters)	Habitat Area (Sq. Meters)	Method 1		Method 2	
			Sockeye Redd Capacity	Total Sockeye Spawners	Sockeye Redd Capacity	Total Sockeye Spawners
Concentrated	699	7,569	2,523	5,046	2,097	4,193
Dispersed	1,562	17,359	1,929	3,858	1,562	3,124
TOTAL	2,261	24,928	4,452	8,903	3,659	7,318

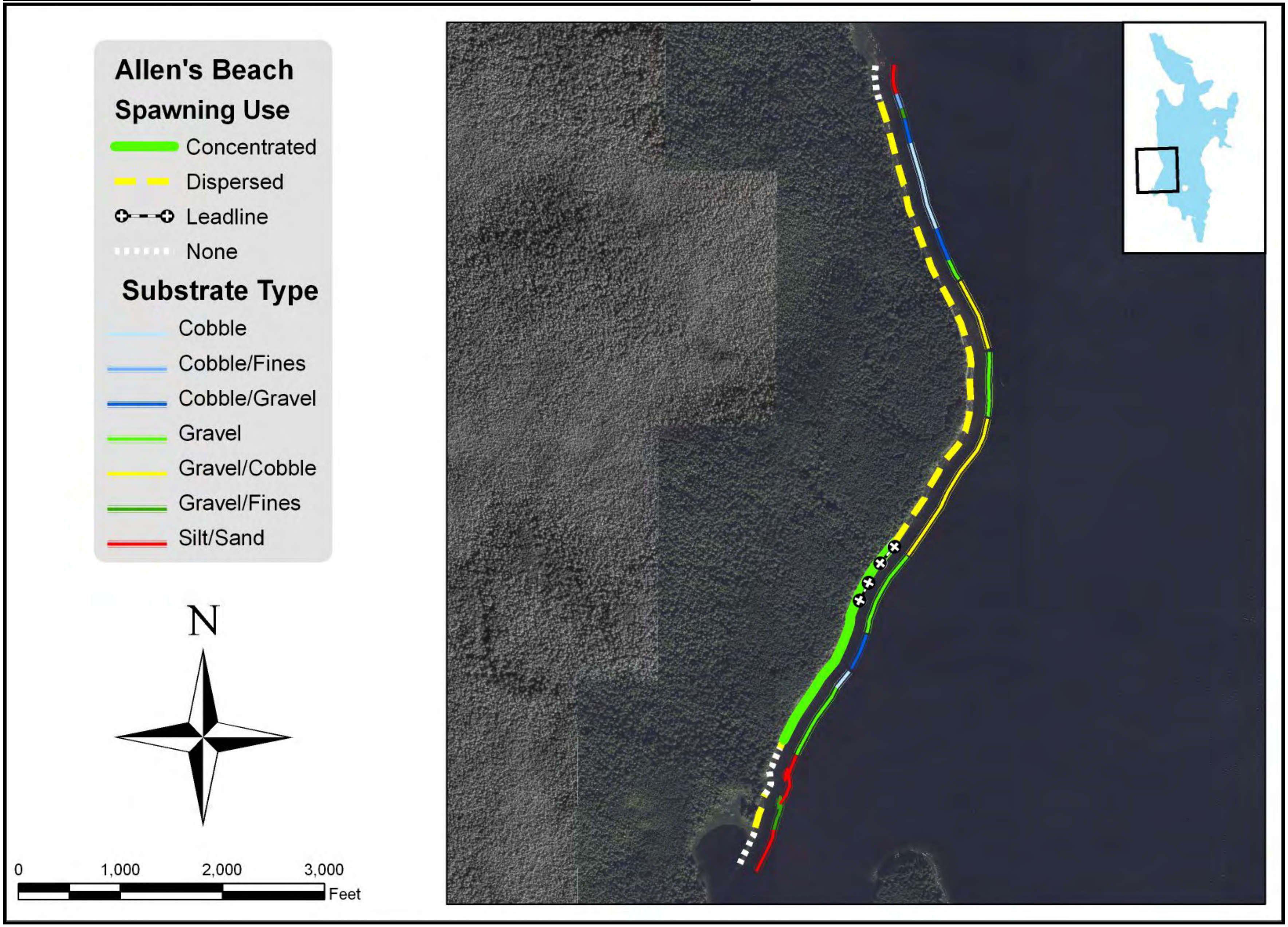


Figure B 3. Map depicting Allen's Beach spawning use and dominant substrate types (source: Haggerty et al. 2007).

3.1.3 Umbrella Beach Estimate

The quantity of future suitable habitat at Umbrella Beach was estimated using high resolution geo-rectified aerial photos in ArcMap. Beach spawning has not been documented since the 1970s at Umbrella Beach; therefore, it is difficult to anticipate how much suitable habitat can develop there and how fish utilization will occur. Three spawning habitat polygons were delineated in ArcMap using aerial photos where depths were estimated to be 1-3 meters during the spawning season along the south, north, and northwest portions of the Umbrella Creek delta and beach. Due to the large potential area of suitable habitat that may be recovered, all habitat was assigned a dispersed spawning use for this capacity estimate. Methods to estimate spawner capacity were the same as those described above for Olsen’s Beach. Spawning capacity estimates for Umbrella Beach using methods 1 and 2 were 2,661 and 924 spawners respectively.

3.1.4 Baby Island Estimate

The quantity of suitable habitat was estimated using recent spawning ground observations (1978-2004; summarized in Haggerty et al. 2007), spawning substrate characterization, and high resolution geo-rectified aerial photos. Very little spawning habitat at Baby Island has been documented. One spawning habitat polygon was delineated in ArcMap using aerial photos where depths were estimated to be 1-3 meters during the spawning season along the southwest side of Baby Island. The total length and area of this potential spawning site are 34 meters and 198 square meters respectively. Methods to estimate spawner capacity were the same as those described above for Olsen’s Beach. The entire area was assumed to have concentrated spawning use. Spawning capacity estimates for Baby Island using methods 1 and 2 were 132 and 204 spawners respectively.

3.1.5 Summary of Beach Spawning Habitat Capacity

All spawning habitat capacity estimates are crude, but based on the best available information for Lake Ozette sockeye spawning beaches. These estimates could drastically underestimate the total lake spawning habitat capacity because many areas where suitable habitat historically existed or where future habitat may develop were not included in these calculations. In addition, spawning at depths greater than 3 meters could be an important component of the spawning population in the future. Table B 3 depicts the estimated spawning capacity for Allen’s, Olsen’s, Baby Island, and Umbrella Beaches.

Table B 3. Summary of spawning habitat lengths and areas and estimated spawning capacity using methods 1 and 2 for historic and currently utilized Lake Ozette spawning beaches.

	Concentrated Use		Dispersed Use		Method 1		Method 2	
Beach Area	**Length (m)**	**Area (sq m)**	**Length (m)**	**Area (sq m)**	**Redds**	**Total Sockeye Spawners**	**Redds**	**Total Sockeye Spawners**
Allen's Beach	699	7,569	1,562	17,359	4,452	8,903	3,659	7,318
Olsen's Beach	232	3,186	616	5,815	1,708	3,416	1,311	2,622
Umbrella Beach	na	na	462	11,977	1,331	2,661	462	924
Baby Island	34	198	na	na	66	132	102	204
TOTALS	**965**	**10,953**	**2,641**	**35,151**	**7,557**	**15,113**	**5,534**	**11,068**

3.2 TRIBUTARY SPAWNING HABITAT CAPACITY

Researchers (Bortleson and Dion 1979; Dlugokenski et al. 1981; Blum 1988) in the past have attempted to quantify tributary spawning habitat capacity for Ozette tributaries. All of these estimates were made during a period when sockeye salmon were not utilizing spawning habitat in tributaries. These estimates of spawning habitat capacity are included below. Currently sockeye salmon spawn in several areas that were not identified as suitable spawning habitat in past estimates. In addition, extensive channel and habitat data were collected for all sockeye spawning streams in 1999 and 2000, allowing for more accurate estimates of available spawning habitat. Therefore, new estimates of spawning habitat capacity were conducted as part of this analysis.

3.2.1 Past Tributary Spawning Habitat Capacity Estimates

Three separate estimates of tributary spawning habitat capacity were conducted between 1977 and 1988. These capacity estimates are depicted in Table B 4. Bortleson and Dion (1979) estimated spawning habitat capacity for Umbrella Creek and Big River using peak-unit spawnable area obtained from equations using average wetted channel width at preferred flows and visual estimates of the length of stream channel suitable for sockeye spawning. Dlugokenski et al. (1981) used the results from Bortleson and Dion (1979) and applied the same methods to Siwash Creek, Crooked Creek, and one unnamed tributary (others in Table B 4). Bortleson and Dion (1979) and Dlugokenski et al. (1981) also present spawnable area estimates produced by Washington Department of Fisheries based on field surveys. Blum (1988) presents an estimated capacity of total redds but doesn't provide details on the methods used.

All researchers, independent of method, produced estimates within a fairly tight range; however, all the researchers based their methods on the same general assumptions, and likely made their suitable area calculations from the same set of field measurements. Spawning capacity estimates for tributaries ranged from 33,732 (Bortleson and Dion

1979 [low end estimate]) to 64,720 sockeye spawners (Dlugokenski et al 1981 [high end of range]).

Table B 4. Summary of spawning habitat capacity estimates.

Study (Citation)	Capacity Parameter	Umbrella Creek	Big River	Other Tributaries
Bortleson and Dion (1979)	River Mile Usage	RM 0.0 - 4.0	RM 3.0 - 9.0	na
	Area of spawning habitat at preferred flow (sq meters)	25,920 ± 6,940	32,610 ± 9,198	na
	Number of potential redds at preferred flow (2.51 sq m/ redd)	10,333 ± 2,767	13,000 ± 3,700	na
WDF *in* Dlugokenski et al. (1981)	River Mile Usage	RM 0.0 - 4.0	RM 3.0 - 9.0	na
	Area of suitable spawning habitat	25,084	32,610	na
	Number of potential redds (2.51 sq m/ redd)	10,000	13,000	na
Dlugokenski et al. (1981)	River Mile Usage	RM 0.0 - 4.0	RM 3.0 - 9.0	na
	Area of spawning habitat at preferred flow (sq meters)	25,920 ± 6,940	32,610 ± 9,198	5,017 ± 1,421
	Number of potential redds at preferred flow (2.51 sq m/ redd)	10,333 ± 2,767	13,000 ± 3,700	2,000 ± 560
Blum (1988)	Total Redds	30,000		

3.2.2 New Tributary Spawning Habitat Capacity Estimates

Two methods were used to estimate the quantity of suitable spawning habitat in Lake Ozette sockeye tributaries. Spawning habitat availability was only estimated for streams designated as Critical Habitat under the ESA. However, a significant quantity of suitable spawning habitat not designated as Critical Habitat could also be used by sockeye salmon in Ozette tributaries. No tributary sockeye salmon spawning has been documented outside of the stream segments currently designated as Critical Habitat. Each method presented below assumes that each female sockeye utilizes 3 square meters of suitable habitat. Measurements of redd size are not available for Ozette sockeye in tributaries but redd area data are available for other stream spawning sockeye stocks and range from 1.3 to 2.0 square meters (Foerster 1968). Past spawning habitat capacity methods employed in Ozette have used a similar range in redd size and have estimated capacity based upon the space required to separate individual redds with no overlapping redds. The assumption of 3 square meters per spawning female was used in this analysis so that comparisons between methods (past and new) were based upon similar spawning densities and focused more on distinguishing differences in suitable area.

Back calculations of actual female spawning densities on spawning grounds show that sockeye salmon can spawn at much higher densities than 3 square meters per female and still result in increased fry production. Data summarized in Foerster (1968) provide examples of densities as high as 1 female sockeye per 0.6 to 1.3 square meters in high density spawning populations. In the Adams River, during the dominant brood cycles in 1950, 1954, and 1958, female spawners per square meter of spawning habitat area utilized were 0.5, 1.4, and 2.2 respectively (IPSFC 1971; range of 2 to 0.45 square meters/female). The IPSFC (1971) found that optimal spawning densities in utilized spawning habitat for the Adams River were one female per 0.8 to 1.2 square meters. Within the Adams River suitable/utilized spawning habitat relative to average wetted width during the spawning season ranged from 51 to 89 percent. Burgner (1991) reports that in Bristol Bay stream spawning areas, capacity estimates are based on one female sockeye per 2 square meters. Maximum fry production per unit area in spawning channels in the Babine Lake system are achieved at a spawner density of about 1 female per square meter (Burgner 1991).

Streamflow measurements and other observations in Ozette tributaries indicate that average streamflow during the sockeye season results in wetted widths equal to 50-90 percent of the channel width depending upon cross-section site. Streamflow records and suitable flow conditions within channel cross-sections relative to channel width were examined in Umbrella Creek and Big River. It was determined that within areas where suitable substrate exists, at mean winter discharge 80 to 60 percent of the channel width could be utilized for sockeye spawning. However, these estimates are derived from only a few channel cross-sections.

Estimates of spawning habitat availability and spawning habitat capacity are based upon thousands of channel and habitat measurements conducted in Lake Ozette tributaries during 1999 and 2000. Channel data (slope, channel width, summer low flow wetted width) were collected at 15 to 33 meter intervals. Habitat data were collected continuously throughout each stream system. Stream channels were divided into major channel segments based upon channel confinement, slope, channel width, and major tributary confluences. Within each channel segment habitat sub-segments were established at ~500 meter intervals (see Haggerty and Ritchie 2004). These data are the basis for all spawning habitat availability calculations presented below. A summary of results and data are included in Appendix B-1

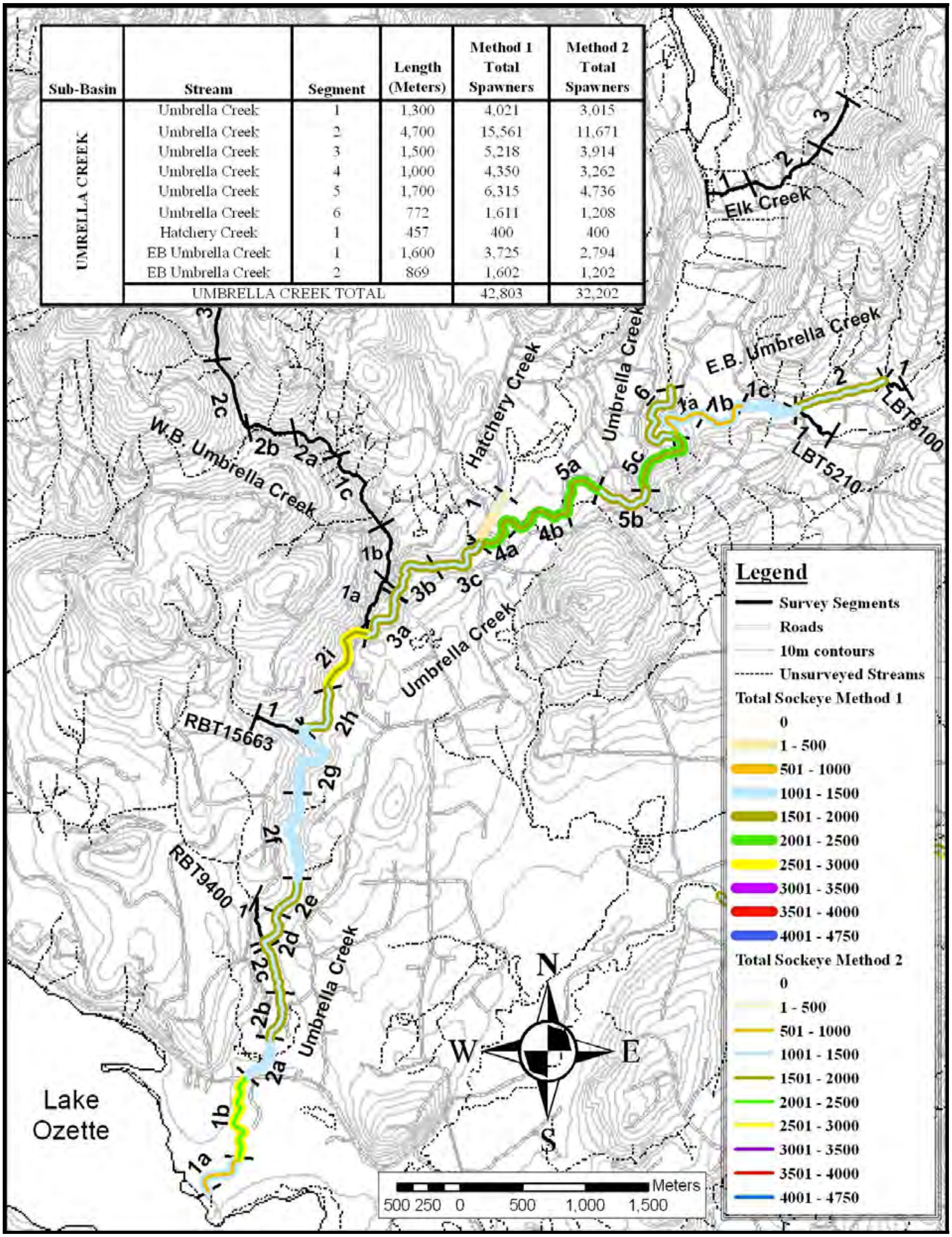
Method 1: Suitable spawning habitat area was calculated for each habitat sub-segment based on the following set of assumptions: 1) 80 percent of the channel width is suitable for sockeye spawning, 2) 80 percent of riffle habitat length is suitable spawning habitat, 3) Within pool habitat units, 20 percent of the pool length provides suitable spawning habitat (glides and pool tailouts).

Method 2: Suitable spawning habitat area was calculated for each habitat sub-segment based on the following set of assumptions: 1) 60 percent of the channel width is suitable for sockeye spawning, 2) 80 percent of the riffle length is suitable spawning habitat, 3) Within pool habitat units, 20 percent of the pools length provides suitable spawning habitat (glides and pool tailouts).

The resulting spawning habitat capacity from Methods 1 and 2, reported in total spawners per habitat sub-segment for the Umbrella, Big, and Crooked subbasins, is depicted in Figure B 4 through Figure B 6. Each figure also contains a segment level spawner capacity estimate for each method. These two methods of estimating spawning capacity result in a range of 79,247 to 105,528 sockeye spawners (assuming a 1:1 sex ratio). Table B 5 depicts the stream length containing suitable spawning habitat, estimated spawning habitat area, and spawning habitat capacity for each subbasin for each of the methods used to estimate capacity. Note that these estimates were only conducted for streams currently utilized for sockeye spawning and/or streams containing suitable spawning habitat designated as Critical Habitat. Additional suitable habitat outside of these habitat sub-segments may be used by spawning sockeye salmon in the future. All of the channel segments containing suitable sockeye spawning habitat that were not included in the sockeye spawning capacity estimate are currently used by coho salmon for spawning.

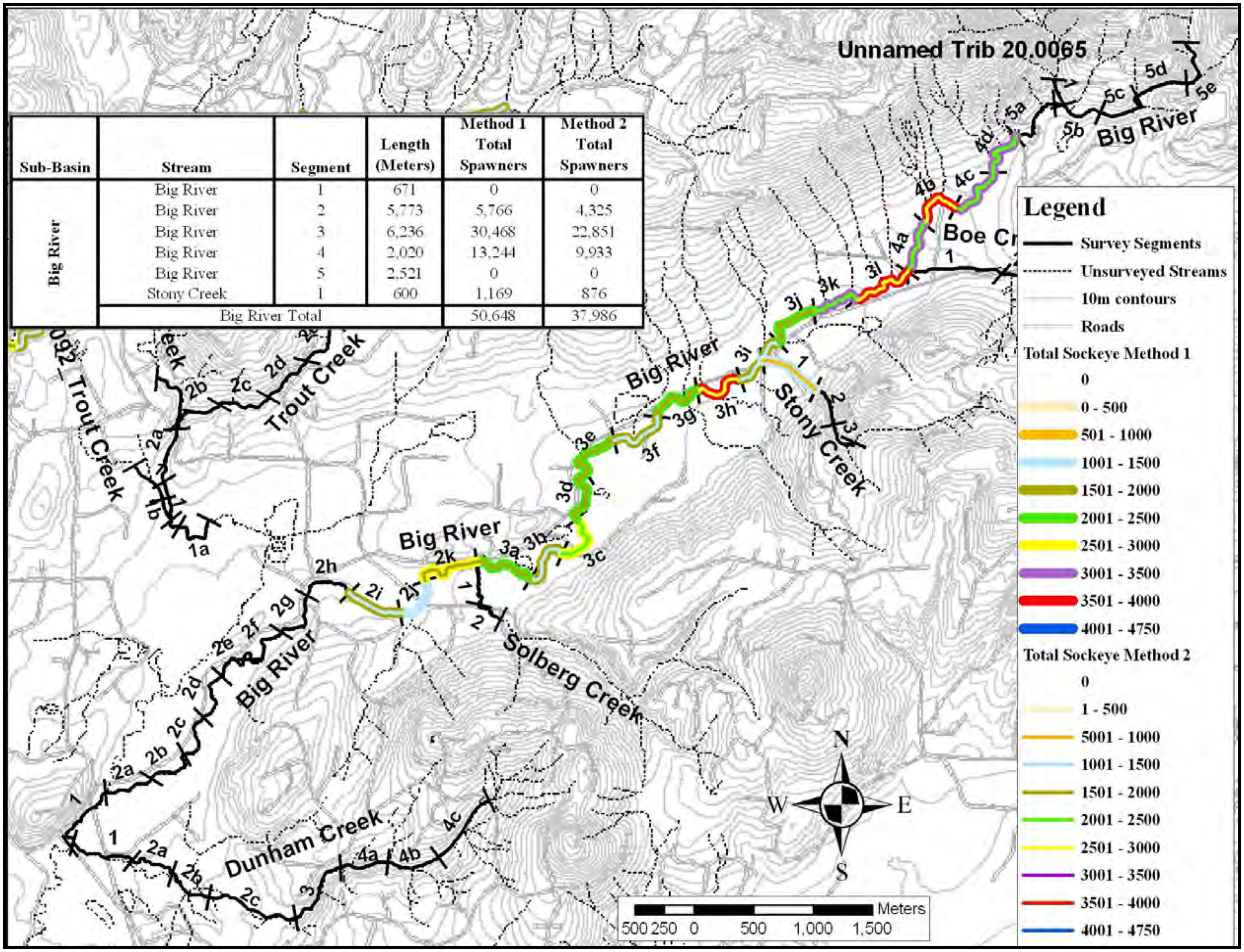
Table B 5. Spawning habitat capacity estimates using Methods 1 and 2 for the Umbrella, Big, and Crooked subbasins.

Subbasin	**Total Stream Length Containing Suitable Habitat (Meters)**	**Method 1**		**Method 2**	
		Area (Sq. Meters)	**Spawners**	**Area (Sq. Meters)**	**Spawners**
Umbrella Creek	13,898	64,205	42,803	48,304	32,202
Big River	14,629	75,971	50,648	56,978	37,986
Crooked Creek	6,072	18,115	12,077	13,588	9,059
TOTAL	**34,599**	**158,291**	**105,528**	**118,870**	**79,247**



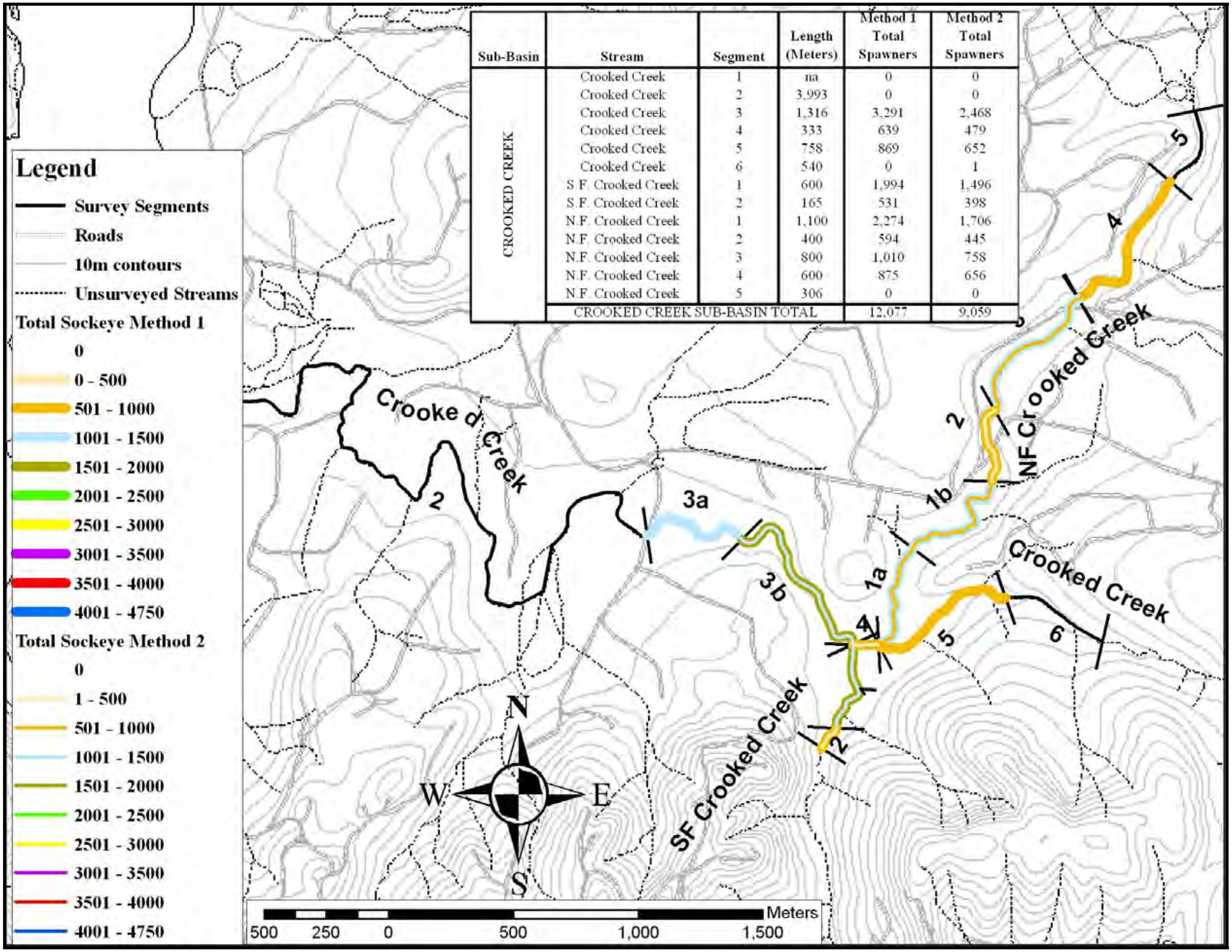
Sub-Basin	Stream	Segment	Length (Meters)	Method 1 Total Spawners	Method 2 Total Spawners
UMRELLA CREEK	Umbrella Creek	1	1,300	4,021	3,015
	Umbrella Creek	2	4,700	15,561	11,671
	Umbrella Creek	3	1,500	5,218	3,914
	Umbrella Creek	4	1,000	4,350	3,262
	Umbrella Creek	5	1,700	6,315	4,736
	Umbrella Creek	6	772	1,611	1,208
	Hatchery Creek	1	457	400	400
	EB Umbrella Creek	1	1,600	3,725	2,794
	EB Umbrella Creek	2	869	1,602	1,202
	UMBRELLA CREEK TOTAL			42,803	32,202

Figure B 4. Estimated number of sockeye spawners at 100 percent usage of suitable spawning habitat, by habitat sub-segment using Methods 1 and 2 for the Umbrella Creek subbasin.



Sub-Basin	Stream	Segment	Length (Meters)	Method 1 Total Spawners	Method 2 Total Spawners
Big River	Big River	1	671	0	0
	Big River	2	5,773	5,766	4,325
	Big River	3	6,236	30,468	22,851
	Big River	4	2,020	13,244	9,933
	Big River	5	2,521	0	0
	Stony Creek	1	600	1,169	876
	Big River Total			50,648	37,986

Figure B 5. Estimated number of sockeye spawners at 100 percent usage of suitable spawning habitat, by habitat sub-segment using Methods 1 and 2 for the Big River subbasin.



Sub-Basin	Stream	Segment	Length (Meters)	Method 1 Total Spawners	Method 2 Total Spawners
CROOKED CREEK	Crooked Creek	1	na	0	0
	Crooked Creek	2	3,993	0	0
	Crooked Creek	3	1,316	3,291	2,468
	Crooked Creek	4	333	639	479
	Crooked Creek	5	758	869	652
	Crooked Creek	6	540	0	1
	S.F. Crooked Creek	1	600	1,994	1,496
	S.F. Crooked Creek	2	165	531	398
	N.F. Crooked Creek	1	1,100	2,274	1,706
	N.F. Crooked Creek	2	400	594	445
	N.F. Crooked Creek	3	800	1,010	758
	N.F. Crooked Creek	4	600	875	656
	N.F. Crooked Creek	5	306	0	0
	CROOKED CREEK SUB-BASIN TOTAL			12,077	9,059

Figure B 6. Estimated number of sockeye spawners at 100 percent usage of suitable spawning habitat, by habitat sub-segment using Methods 1 and 2 for the Crooked Creek subbasin.

4 TOTAL ADULT ABUNDANCE GOALS

Spawning habitat capacity estimates for Ozette beaches and tributaries range from 90,315 (Beach Method 2 and Stream Method 2) to 120,641 (Beach Method 1 and Stream Method 1). These estimates are based upon a relatively low spawning density target (1 female per 3 sq meters of suitable habitat). At higher spawning densities (e.g., 1 female/sq meter) the spawning capacity would be three times higher than the range presented above. The results from Method 1 for the beaches and tributaries, presented above, are a conservative estimate of the watershed's spawning habitat capacity. As habitat conditions continue to recover and the sockeye population expands, a review of these goals will be necessary in order to refine watershed spawning and smolt production capacity estimates. Population abundance data at different life-history stages will be critical to refinement of these goals.

Based upon a spawning escapement of 120,600 sockeye (60,300 females), under the current freshwater productivity range of 16 to 24 smolts per female, resulting smolt production would range between 0.96 and 1.45 million (near the lower range of estimated smolt production capacity of the lake). Under improved freshwater survival conditions where 50 smolts per female could be produced, smolt production would be closer to 3.0 million. Smolt production of 1 to 3 million sockeye smolts/year and average marine survival conditions (~17 percent) would result in adult run sizes in the range of 170,000 to 510,000.

5 CITATIONS

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APPENDIX B-1: Channel and Habitat Sub-Segment Data Summaries and Estimated Spawning Areas Using Methods 1 and 2

Appendix B1. Channel and Habitat Sub-Segment Data Summaries and Estimated Spawning Areas Using Methods 1 and 2.

Stream Name	WRIA No.	Habitat Sub-Segment	PS-ID	Length (m)	Gradient Percent	Channel Confine-ment	Channel Width	Spawn Segment ID	Percent Pool	Riffle Length (m)	Method 1 Suitable Area (Sq. M)	Method 2 Suitable Area (Sq. M)
Umbrella Creek	20.0052	1a	PS-22	500	<1	U	15.9	22	87	65.0	1,768	1,326
Umbrella Creek	20.0052	1b	PS-23	800	<1	U	18.4	23	73	216.0	4,263	3,197
Umbrella Creek	20.0052	2a	PS-24	500	<1	U	14.7	24	72	140.0	2,164	1,623
Umbrella Creek	20.0052	2b	PS-25	500	<1	U	18.6	25	71	145.0	2,783	2,087
Umbrella Creek	20.0052	2c	PS-26	500	<1	U	16.7	26	74	130.0	2,378	1,784
Umbrella Creek	20.0052	2d	PS-27	500	<1	U	15.8	27	66	170.0	2,553	1,915
Umbrella Creek	20.0052	2e	PS-28	500	<1	U	17.1	28	72	140.0	2,517	1,888
Umbrella Creek	20.0052	2f	PS-29	500	<1	U-M	16.4	29	81	95.0	2,060	1,545
Umbrella Creek	20.0052	2g	PS-30	500	<1	U	16.5	30	79	105.0	2,152	1,614
Umbrella Creek	20.0052	2h	PS-31	500	<1	U	17.1	31	62	190.0	2,928	2,196
Umbrella Creek	20.0052	2i	PS-32	700	<1	U-M	13.6	32	50	350.0	3,808	2,856
Umbrella Creek	20.0052	3a	PS-33	500	1-2	M	12.7	33	46	270.0	2,662	1,996
Umbrella Creek	20.0052	3b	PS-34	500	1-2	M-C	12.8	34	59	205.0	2,284	1,713
Umbrella Creek	20.0052	3c	PS-35	500	1-2	M-C	11.4	35	28	360.0	2,882	2,161
Umbrella Creek	20.0052	4a	PS-36	500	1-2	U-M	13.5	36	37	315.0	3,121	2,341
Umbrella Creek	20.0052	4b	PS-37	500	1-2	U-M	15.7	37	43	285.0	3,404	2,553
Umbrella Creek	20.0052	5a	PS-38	500	1-2	C	13.0	38	25	375.0	3,380	2,535
Umbrella Creek	20.0052	5b	PS-39	500	1-2	C	10.1	39	22	390.0	2,699	2,024
Umbrella Creek	20.0052	5c	PS-40	700	1-2	C	9.5	40	27	511.0	3,394	2,546
Umbrella Creek	20.0052	6	PS-41	772	1-2	M-C	6.7	41	36	494.1	2,417	1,812
E.B. Umbrella Creek	20.0057	1a	PS-49	500	0-2	M-C	7.8	49	28	360.0	1,972	1,479
E.B. Umbrella Creek	20.0057	1b	PS-50	500	0-2	M-C	7.3	50	42	290.0	1,600	1,200
E.B. Umbrella Creek	20.0057	1c	PS-51	600	0-2	M	8.2	51	48	312.0	2,015	1,511
E.B. Umbrella Creek	20.0057	2	PS-52	869	1-2	U-M	5.8	52	34	573.5	2,403	1,802
Hatchery Creek	20.0056	1	PS-117	457	2.80	M-C	5.5	117	0	457.0	na	na
Big River	20.0058	2i	PS-65	500	<1	U	20.6	65	77	115.0	2,785	2,089
Big River	20.0058	2j	PS-66	500	<1	U	22.1	66	95	25.0	2,033	1,525
Big River	20.0058	2k	PS-67	744	<1	U	20.9	67	82	133.9	3,831	2,874
Big River	20.0058	3a	PS-68	556	0.1-2	U	20.7	68	74	144.6	3,278	2,458
Big River	20.0058	3b	PS-69	500	0.1-2	U	20.6	69	81	95.0	2,587	1,941

Stream Name	WRIA No.	Habitat Sub-Segment	PS-ID	Length (m)	Gradient Percent	Channel Confine-ment	Channel Width	Spawn Segment ID	Percent Pool	Riffle Length (m)	Method 1 Suitable Area (Sq. M)	Method 2 Suitable Area (Sq. M)
Big River	20.0058	3c	PS-70	500	0.1-2	U	20.0	70	43	285.0	4,336	3,252
Big River	20.0058	3d	PS-71	500	0.1-2	U	25.0	71	76	120.0	3,440	2,580
Big River	20.0058	3e	PS-72	500	0.1-2	U	20.0	72	68	160.0	3,136	2,352
Big River	20.0058	3f	PS-73	500	0.1-2	U	18.5	73	72	140.0	2,723	2,042
Big River	20.0058	3g	PS-74	500	0.1-2	U	23.7	74	71	145.0	3,546	2,659
Big River	20.0058	3h	PS-75	500	0.1-2	U	32.4	75	57	215.0	5,936	4,452
Big River	20.0058	3i	PS-76	500	0.1-2	U	23.0	76	79	105.0	2,999	2,249
Big River	20.0058	3j	PS-77	500	0.1-2	U	20.5	77	69	155.0	3,165	2,374
Big River	20.0058	3k	PS-78	500	0.1-2	U	27.4	78	64	180.0	4,559	3,420
Big River	20.0058	3l	PS-79	680	0.1-2	U	25.4	79	61	265.2	5,997	4,498
Big River	20.0058	4a	PS-80	520	0.1-2	U	19.5	80	40	312.0	4,543	3,407
Big River	20.0058	4b	PS-81	500	0.1-2	U	26.2	81	47	265.0	5,429	4,071
Big River	20.0058	4c	PS-82	500	0.1-2	U	26.1	82	55	225.0	4,907	3,680
Big River	20.0058	4d	PS-83	500	0.1-2	M	23.8	83	46	270.0	4,988	3,741
Stony Creek	0.0000	1	PS-90	600	1-3	C	5.10	90	14	516.0	1,753	1,315
Crooked Creek	20.0067	3a	PS-97	507	<1	U	15.2	97	76	121.7	2,121	1,591
Crooked Creek	20.0067	3b	PS-98	809	<1	U	14.7	98	84	129.4	2,816	2,112
Crooked Creek	20.0067	4	PS-99	333	<1	U	10.1	99	74	86.6	958	718
Crooked Creek	20.0067	5	PS-100	758	1-2	U-M	5.4	100	67	250.1	1,303	977
SF Crooked Creek	20.0068	1	PS-102	600	1-2	U	16.4	102	70	180.0	2,991	2,244
SF Crooked Creek	20.0068	2	PS-103	165	1-2	C	14.5	103	64	59.4	796	597
NF Crooked Creek	20.0071	1a	PS-104	500	<1	U	10.1	104	60	200.0	1,778	1,333
NF Crooked Creek	20.0071	1b	PS-105	600	<1	U	9.1	105	71	174.0	1,634	1,225
NF Crooked Creek	20.0071	2	PS-106	400	1-2	M	9.4	106	84	64.0	890	668
NF Crooked Creek	20.0071	3	PS-107	800	1-2	C	8.0	107	84	128.0	1,516	1,137
NF Crooked Creek	20.0071	4	PS-108	600	2-3	M	6.3	108	61	234.0	1,312	984
NF Crooked Creek	20.0071	5	PS-109	306	2-4	C	6.2	109	53	143.8	732	549