Final

# LAKE CHELAN VULNERABILITY AND HABITAT SUITABILITY ANALYSIS FOR AQUATIC INVASIVE SPECIES

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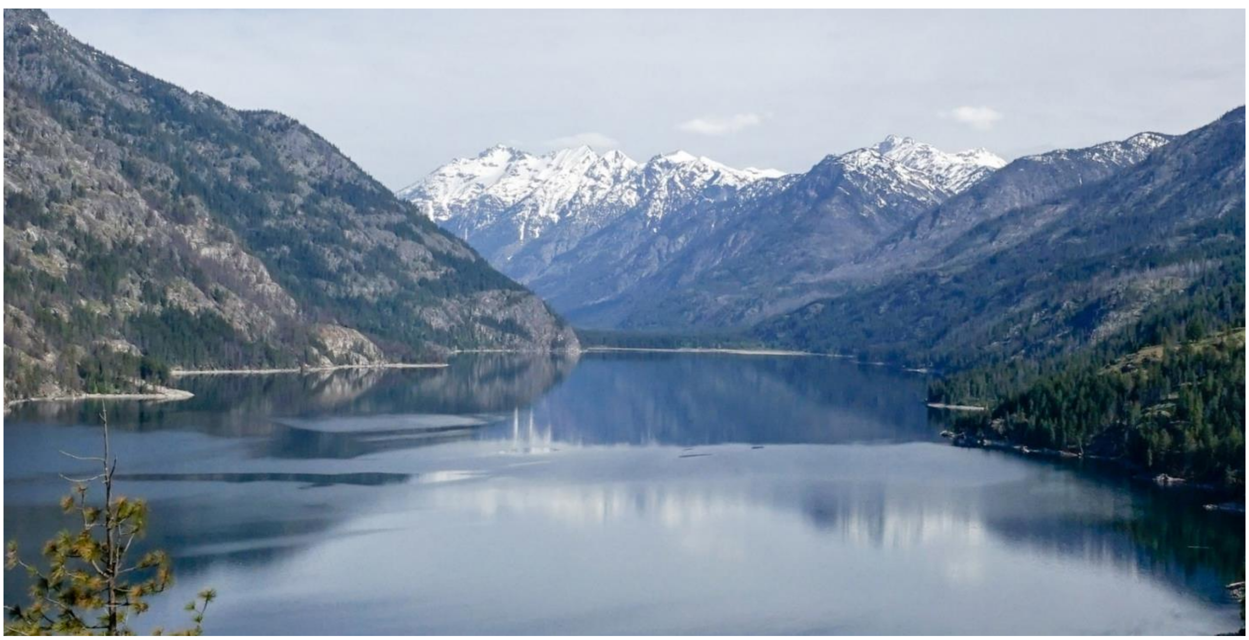

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# EXECUTIVE SUMMARY

Aquatic invasive species (AIS) are aquatic organisms that invade ecosystems beyond their natural, historic range. Their presence may harm native ecosystems or commercial, agricultural, or recreational activities dependent on these ecosystems. Dense growth of AIS are widely reported to impact aesthetics, recreation, real estate values and tourism.

Lake Chelan is the largest natural lake in Washington, located in the north-central portion of the state. The Lake Chelan Chamber of Commerce touts “four seasons of recreation” at Lake Chelan. In 2017, visitors to Chelan county spent an estimated $562 million on accommodations, food, transportation, entertainment, etc., including $67.3 million on arts, entertainment and recreation. In addition to ecological impacts of the introduction and establishment of AIS on biodiversity and ecosystem services, there has been a recent increase in estimating the economic costs associated with AIS that could impact these valuable resources for the local communities.

Hydropower has a long history in the Pacific Northwest and particularly in the Columbia River Basin and Lake Chelan. Of all the hydropower produced in the Northwest, the largest share is produced at dams on the Columbia River and its tributaries. It has been reported that a quagga/zebra mussel invasion would substantially reduce the efficiency of power production and increase injury to fish.

The successful invasion of a species to a novel environment relies on successful transport, release, and establishment. AIS are transported via natural and human-mediated vectors. A waterbody may be at a very high risk for introduction via these pathways, however, successful establishment is contingent upon a number of other factors including environmental conditions, propagule pressure, and food availability. Prevention is generally considered most cost effective at abating the effects of AIS. Watercraft inspection programs are being implemented at the statewide (Washington, Idaho, Oregon) and regional (e.g., Lakes Whatcom and Samish) level however no program is currently implemented at Lake Chelan.

Two spreadsheet tools were used to evaluate the risk quagga/zebra mussels pose to Lake Chelan, one developed by the Bureau of Reclamation (USBR) and another by Washington Department of Fish and Wildlife (WDFW). Available water quality data and information regarding recreation, hydroelectric, and water intake facilities were used in each spreadsheet analysis. The USBR tool scored Lake Chelan’s risk for mussel introduction in the moderate category and the WDFW risk assessment scoring system places Lake Chelan at the second to highest score for risk compared to other lakes they evaluated.

WDFW has been conducting a variety of AIS monitoring protocols intended for early detection of all life stages of mussel, including vertical and horizontal tows, petit Ponar grabs, samples collected for environmental DNA (eDNA) analysis, deployment and inspection of artificial substrates, and shoreline walks. Water samples are also collected to better understand water quality conditions that could favor or limit the establishment of AIS. It is recommended that reliable funding sources be dedicated to developing and implementing a Lake Chelan-specific AIS and water quality monitoring program; expanding current WDFW efforts and involving stakeholders from the community.

Lastly, data gaps were identified that would further improve understanding of the vulnerability of Lake Chelan to infestation of AIS, in particular quagga/zebra mussels. Specifically, information related to sediments and available substrates, dissolved calcium sampling, AIS surveys, boater surveys and watercraft inspections/decontamination, and funding.

# Lake Chelan Vulnerability and Habitat Suitability Analysis for Aquatic Invasive Species

## Setting

Lake Chelan is the largest natural lake in Washington, located in the north-central portion of the state, approximately 180 miles northeast of Seattle, WA and 32 miles north of Wenatchee, WA. Lake Chelan is surrounded by mountains of the Okanogan-Wenatchee National Forest and North Cascades National Park lands, two state parks, and the towns of Lake Chelan and Manson and the unincorporated community of Stehekin (Figures 1 to 3).

The lake has two distinct basins – the upper Lucerne Basin with a mean depth of 590.6 feet (1,486 feet maximum) and length of 38.4 miles; and the lower Wapato Basin with a mean depth of 141.1 feet (400 feet maximum) and length of 12 miles (Ecology 1989). The Wapato Basin offers far more services and boat launch access. The primary inflow to Lake Chelan from its 937 square mile watershed is the Stehekin River to the north. Other major tributaries include Railroad Creek which flows in from the northwest portion of the watershed, Twenty-five Mile Creek from the southwestern portion, and Stink Creek from the southeastern portion. The only outflow is the Chelan River below the Lake Chelan Hydroelectric Project operated by the Chelan County Public Utility District (PUD) at Chelan, WA on the southeast end of the lake.

The City of Chelan area is semi-arid, characterized by warm dry summers with average temperatures in the mid-80s and annual mean precipitation of 11 inches (mostly occurring during the winter months). The climate nearer Stehekin, located at the northwest end of Lake Chelan, is considerably different - with average annual precipitation nearer 36 inches (Figures 4 to 6). Stehekin is only accessible by boat, foot, or air.

## Aquatic Invasive Species (AIS)

The impacts of AIS are widely known to impact recreation, water quality, ecological conditions, biodiversity, and aesthetics (Sala et al. 2000, Pejchar and Mooney 2010). AIS come from a variety of taxa including invertebrates, fishes, and aquatic plants. Zebra (*Dreissena polymorpha*) and quagga (*D. rostriformis bugensis*) mussels have impacted waterbodies across much of the eastern and central U.S., but are thus far relatively less prevalent in waterways of the western U.S. Populations of invasive quagga/zebra mussels (hereafter collectively referred to as QZ mussels) have established in Arizona, California, Colorado, Nevada, North Dakota, South Dakota, and Utah with numerous reports of contaminated watercraft from inspection stations and larval detections in Montana in 2016. QZ mussels, however, are not established in Montana and no veligers or adults were detected in either 2018 and 2019. Other common invertebrate invaders in the region include New Zealand mudsnails (*Potamopyrgus antipodarum*), Asian clams

(*Corbicula fluminea*), mystery snails (*Cipangopaludina chinensis* and *C. japonica*), crayfish (*Faxonius* sp. and *Procambarus* sp.), and opossum shrimp (*Mysis relicta*).

The primary AIS of concern for Lake Chelan are QZ mussels; however, other AIS have the potential to dramatically alter the ecological and recreational value of the lake. For example, in Washington, there have been increased observations of flowering rush (*Butomus umbellatus*) and should be on the watch list at Lake Chelan.

# Recreation and Economics

The Lake Chelan Chamber of Commerce touts "four seasons of recreation" at Lake Chelan. For many, summer recreation activities such as golf, biking, paddle boarding, hiking, boating, fishing, and wine tours define the Lake Chelan experience. In 2017, visitors to Chelan county spent an estimated $562 million on accommodations, food, transportation, entertainment, etc., including $67.3 million on arts, entertainment and recreation (Dean Runyan Associates 2018).

In addition to ecological impacts of AIS on biodiversity and ecosystem services, there has been a recent increase in estimating the economic costs associated with AIS. Dense growth of AIS are widely reported to impact aesthetics, recreation, real estate values and tourism. High density of invasive aquatic plants have also been shown to have significant impacts to real estate values, corresponding to a 19% decline in mean property values (Olden and Tamayo 2014). One study by Michigan State University concluded that aquatic and terrestrial invasive species pose the greatest risk to Michigan's tourism industry (Nicholls 2012). Costs for management and especially eradication of mussels is not widely reported, however Wimbush et. al (2009) reported that 860 total diver hours were used between 1999 and 2007 to successfully eradicate more than 21,000 zebra mussels from Lake George, NY. Using current costs of diver-assisted hand-pulling for aquatic plants, this would result in a cost of roughly $120K (Personal communication, Toni Pennington, ESA)[1]. It should be noted that the area in Lake George was roughly 3,900 $m^2$ (slightly less than one acre).

Hydropower has a long history in the Pacific Northwest and particularly in the Columbia River Basin. Nowhere in the West, or elsewhere in the nation, is hydropower as important as an instrument of economic change or factor in the electricity supply as in the Pacific Northwest. Of all the hydropower produced in the Northwest, the largest share is produced at dams on the Columbia River and its tributaries (Northwest Power and Conservation Council 2019a).

Lake Chelan Dam was first operational in 1927 and has a normal operating output of 62 megawatts. Upgrades to the turbines and generators were most recently completed in 2009 and 2010 (Chelan County PUD 2019). In a report from 2010 that examined potential impacts to the Rocky Reach project (the hydroelectric facility downstream of the confluence of the Chelan and

[1] Estimate based on $135 per hour per diver used for diver-assisted hand-pulling in waters of the inland Pacific Northwest.

Columbia Rivers), Washington Department of Fish and Wildlife (WDFW) and Washington State Police (WSP) (2010) reported that a QZ mussel invasion would:

> *…result in both reduced power production and increased fish injury and potential mortality. Costs to the Chelan PUD would be through loss of efficient power production (flow restrictions and increased turbulence), increased maintenance to remove or prevent encrustations, and loss of power production through spill mitigation to prevent fish injury and mortality*.

Establishment of QZ mussels in Lake Chelan would also likely have a significant negative impact on agriculture in the basin. Currently water is pumped from the lake by the Lake Chelan Reclamation District to numerous other water districts and individual users. Mussels can foul and clog irrigation distribution systems, putting the entire agricultural system in the Lake Chelan Basin at risk.

The Pacific Northwest Economic Region Foundation has estimated the cost to the Columbia River basin if QZ mussels became established, fouling submerged equipment at dams, irrigation intakes, docks and other structures, to be as much as $600 million a year, not counting lost recreational dollars, which could total tens of millions of dollars (Northwest Power and Conservation Council 2019b). A recent assessment of the potential economic impacts to the hydroelectric facilities of the Columbia River Basin, should it become infested, estimated that costs to install chlorination systems to manage an infestation could be as high as $2 million for some facilities, with recurring operation costs of $100,000 per year (WRP 2010).

Information on the recreational uses at Lake Chelan are largely anecdotal as no detailed surveys have been performed to assess the types of watercraft, point of origin, or number of user-days. There are five major public boat launches serving Lake Chelan: 1) Chelan Riverwalk Park (no fee); 2) Lakeshore Marina (moorage and launch fees); 3) Lake Chelan State Park (launch fee); 4) Old Mill Park (launch fee); and 5) Twenty-five Mile Creek State Park (launch fee) (Figures 7 to 9). There are several other private launches, resorts, marinas, and boat-in only campgrounds and docks that require a federal dock permit. While there is no specific data regarding types and number of watercraft that utilize these public launches, data on the number of launch fees collected or permits sold provide a clear indication that Lake Chelan is a heavily used waterbody. The National Park Service (NPS) and the US Forest Service (USFS) share the responsibility of selling federal dock permits and over the past six years (minus 2015) sell on average 1,267 day use permits and 355 seasonal permits (Annelise Lesmeister, USFS, Personal communication). The City of Chelan estimates that between May 1st and September 30th, 2018, 500 to 550 boats were launched at the Lakeshore Marina (James Hayter, City of Chelan, Personal communication). The Manson Park and Recreation District estimates that 900 annual launch passes are sold each year with an estimated 2,400 daily launch passes sold for Old Mill Park (Robin Pittman, Manson Park and Recreation District, Personal communication).

Lake Chelan State Park and Twenty-five Mile Creek State Park are two heavily used public boat launches and access points that are available year-round. They are both located along the western shore of Lake Chelan with Twenty-five Mile Creek State Park being the furthest up-lake, or northern, public boat launch available. The average annual number of boat launch permits sold at Lake Chelan State Park was almost 1,300 for both 2017 and 2018 with the majority occurring from May through September (Brian Patnode, WA State Parks, Personal communication). There is still some use of the boat launch at Lake Chelan State Park during the spring and fall with a maximum of 25 daily launch permits sold in February, 130 in March, 42 in October, and 37 in November. Lake Chelan State Park also sees an average annual total occupancy of 863 for overnight moorage (Brian Patnode, WA State Parks, Personal communication). Total daily launch permits sold are slightly lower at Twenty-five Mile Creek State Park, with an average annual number of at 565 for both 2017 and 2018 and an average total occupancy of 593 for overnight moorage (Brian Patnode, WA State Parks, Personal communication).

# The Role of Watercraft in AIS Introductions

In Washington, non-state registered boat owners (including seaplanes and commercial transporters) must purchase an AIS prevention permit. A modest fee is applied to resident operators of watercraft upon registration. These funds are used to offset AIS prevention and management efforts within the state. Presently, the following watercraft are exempt from the AIS prevention permit: small watercraft (e.g., kayaks and canoes); government and tribal vessels; those registered as “tenders” to larger boats; and U.S. or internationally documented commercial vessels or seaplanes (WDFW 2019). For boaters that routinely travel outside of Washington, WDFW provides a Watercraft Passport designed to assist in tracking recently visited waterbodies and AIS inspection stations in an effort to expedite inspections outside the state.

WDFW is the lead agency for implementing AIS inspection and decontamination in Washington State and can identify an ex officio fish and wildlife officer capable of directing a person to clean, drain, and dry a contaminated vessel or move to a reasonable location (RCW 77.135).

Although a boat inspection program has not been implemented at Lake Chelan, other sources such as those run by the states of Washington and Idaho and the Lake Whatcom and Lake Samish boat inspection programs provide information about boat traffic/usage in the Lake Chelan area and the surrounding states. Washington currently has two stationary, mandatory watercraft inspection stations, one located at the Washington – Idaho border on I-90 and the other at Washington – Oregon border on I-82. Over 57,000 watercraft inspections were performed at these two location in 2018 and 2019 (Jesse Schultz and Pamela Taylor, WDFW, personal communication). Of these inspections, three watercraft came from infested waters (Lake Mead and Lake Powell) and were headed to Lake Chelan.

The 2018 AIS-inspection program at Lake Whatcom and Lake Samish, near Bellingham, WA, found that boaters had previously visited 806 different waterbodies in 47 different state/provinces at some point in the past, including 74 mussel-infested waters (LWMP 2019). Of those inspected in 2018, 65 boats had last been used in Lake Chelan prior to traveling to Whatcom County, and 387 boats had previously been used in Lake Chelan sometime in the past (Table 1; Teagan Ward, City of Bellingham, personal communication). Overall, there were 12,444 inspections at the Lake

Whatcom and Lake Samish stations in 2018. None of the 452 boats that had visited Lake Chelan prior to inspection had home residences at or near Lake Chelan (City of Bellingham 2018).

Similar data was obtained from the Idaho Department of Agriculture (IDA) Watercraft Inspection Stations. In 2009-2013, IDA inspected 56 boats headed to Lake Chelan and 143 boats that had previously visited Lake Chelan (Table 1; IDA 2013). In 2015, 16 boats that were inspected had identified Lake Chelan as their planned destination and 35 boats had visited Lake Chelan prior to inspection (Table 1; IDA 2015). Although the available data regarding watercraft movement to and from Lake Chelan is limited, the data provided in Table 1 shows that watercraft owners are traveling to Lake Chelan to recreate and whether they know it or not, could be potentially transporting non-native AIS between waterbodies.

**TABLE 1**
**BOAT INSPECTION DATA**

| Year | Lake Chelan Planned Destination | Last Visited Lake Chelan | Previously Visited Lake Chelan | Previously Visited Other Lakes in Lake Chelan Drainage |
|---|---|---|---|---|
| 2018[a] | -- | 65 | 387 | 2 (Domke Lake) |
| 2009-2013[b] | 56 | -- | 143 | 2 (Wapato Lake) |
| 2015[c] | 16 | -- | 35 | 1 (Wapato Lake) |

SOURCES:
[a] Lake Whatcom & Lake Samish Boat Inspections
[b] IDA 2013
[c] IDA 2015

# Available AIS and Water Quality Information

A number of sources were queried to identify available information on Lake Chelan water quality, species distribution, existing AIS, periphyton, benthic invertebrates, etc., including:

- Washington Department of Ecology's Environmental Information Management (EIM) System,
- Local monitoring reports,
- Nonindigenous Aquatic Species (NAS), and
- Results from WDFW AIS monitoring since 2009

Appendix A includes a summary of data sources including the type of data available from each source, the date/year of data collection, locations and frequency at which the data was collected, and the parameters or analysis that was completed.

A number of non-native fish species have been introduced to Lake Chelan which now supports reproducing populations of rainbow trout (*Oncorhynchus mykiss*), kokanee (*O. nerka*), brook trout (*Salvelinus fontinalis*), Chinook salmon (*O. tshawytscha*), lake trout (*S. namaycush*) and smallmouth bass (*Micropterus dolomieu*). While non-native, these fish species provide popular recreational value and are generally not considered nuisance in the same manner other AIS such as northern pike (*Esox lucius*) which has become an increasing problem in WA.

Invasive aquatic plants in Lake Chelan include Eurasian watermilfoil (*Myriophyllum spicatum*) and curlyleaf pondweed (*Potamogeton crispus*) (AquaTechnex 2015). Plants were surveyed in 2014 with limited observations of Eurasian watermilfoil noted in the upper Lucerne Basin.

Invasive mollusks in Lake Chelan include Asian clams and Chinese mystery snails (*Cipangopaludina chinensis*). Asian clams were first reported in 2010 when they were observed by WDFW while conducting visual shoreline surveys at Chelan River Park, Lake Chelan State Park, Twenty-five Mile Creek State Park and Old Mill Park (Nonindigenous Aquatic Species [NAS] Database). The first collection of Asian clams in the United States occurred in 1938 along the banks of the Columbia River near Knappton, Washington (Counts 1986). The NAS Database has the first listing of Asian clams for Washington state in 1937 when an established population was reported in Raymond, Washington near the Willapa River, although no specific water body name is recorded with the specimen collection.

Asian clams were also observed during visual shoreline surveys in 2017 at the same four locations and in 2018 at Lake Chelan State Park. The NAS Database also indicates that Asian clams were detected in water plankton tow samples by microscopy in 2011 and 2013 – 2017 at Chelan River Park. Chinese mystery snails have also been reported to be established in Lake Chelan though their densities and distributions are largely unknown (Jesse Schultz, WDFW, Personal Communication). The Lake Chelan Research Institute conducted a preliminary Asian clam survey on March 28, 2018 with the help of Chelan High School science students (April Slagle's, Environmental Science class). The survey extended from the boat launch near the Chelan Dam up lake to just beyond the USFS offices. The highest concentrations of Asian Clams were found just up lake from the USFS offices with a maximum concentration of 99 live Asian clams in a square meter to a depth approximately 25 cm. (Phil Long, personal communication) (Figure 3).

# Pathways and Risk of Establishment

It is generally accepted that a successful invasion of species to a novel environment relies on a number of factors including transport, release, and establishment (Colautti and MacIsaac 2002, Leung and Mandrak 2007). AIS are transported via natural (e.g., waterfowl, connected waterbodies) and more importantly, human-mediated vectors (e.g., boats, recreation equipment, live bait) (Johnson et al. 2001). A waterbody may be at a very high risk for introduction via these pathways, however, successful establishment is contingent upon a number of other factors including environmental conditions, propagule pressure, and food availability. For QZ mussels, this means, for example, optimal water temperature, pH, and dissolved calcium for all life stages, including spawning, egg release, and larval development to adult.

There are several methods used to evaluate the risk of introduction and establishment of QZ mussels. Many are based on European and Eastern North American invasions or use water quality data from zebra mussel infested flowing waters (Whittier et al. 2008). These approaches may or may not be appropriate for risk assessment in western waterbodies (Chandra et al. 2019). Also, Whittier et al. (2008) as well as Chandra et al. (2009) point out that quagga mussels have different environmental tolerances compared to zebra mussels (Baldwin et al. 2002, Stoeckmann 2003, Roe and MacIssac 1997, Zhulidov 2004), therefore reliance on models developed from zebra mussel infested waters may underestimate the potential risk for quagga mussel establishment. Additionally, quagga mussels exhibit morphological differences in their shells attributed to environmental conditions (Peyer et al. 2010). This variation in shell morphotypes has been shown to lead to changes in locomotion, allowing quagga mussels to utilize a broader range of substrates and habitats compared to zebra mussels and displacing zebra mussels in some areas (Peyer et al. 2011, Karatayev et al. 2015). Quagga mussels have also been shown to have lower rates of byssal thread[2] synthesis, likely resulting in zebra mussels having greater anchoring capacity in flowering water (Peyer et al. .2009). Some of these attributes may be why quagga mussels are susceptible to decontamination by hot water (Comeau et al. 2011).

Risk assessment methods routinely use water column calcium concentration as an index for determining potential QZ mussel establishment, growth, and reproduction potential (Ramcharan et al. 1992, Sousa et al. 2008, and Whittier et al. 2008). In general, waterbodies with low calcium concentrations (≤ 12 mg/L) have been deemed “low risk” for QZ establishment, growth and reproduction (Cohen 2007, Whittier et al. 2008). However, more recent studies have shown that very low calcium waters (12 – 15 mg/L; Lake Tahoe) can support mussels through key life stage and life history processes and that small differences in calcium concentrations (e.g. 9 vs 12 mg/L) can improve mussel survival, growth, and reproduction potential (Davis et al. 2015, Chandra et al 2009). Calcium “hotspots”, such as dense beds of bivalves (Asian clams) and stream inputs, could facilitate localized QZ mussel infestations and should be considered during any risk assessment of western waterbodies (Davis et al. 2015). Lake Superior (12 – 15 mg/L calcium) has shown localized establishment of QZ mussels around the Apostle Island National Lakeshore and tributary/river plumes with higher calcium concentrations (nearly all exceeding 15 mg/L and some exceeding 20 mg/L) strongly influenced nearshore water chemistry and therefore ecology and may have exacerbated the establishment of QZ mussels (Lafrancois et al. 2018). It has been estimated that Asian clams require roughly 6 mg/L calcium and pH >6.5 (Cooper 2007). Conditions well within those at Lake Chelan. Further, there is evidence that Asian clam beds can elevate ambient dissolved calcium levels sufficient to support shell development for quagga and zebra mussels (Green 1980; Hessen et al. 2000; Chandra et al. 2009; Davis et al. 2015).

Chandra et al. (2009) evaluated the survival, growth, and reproduction potential of quagga mussels in Lake Tahoe, a low calcium, deep oligotrophic lake, similar to Lake Chelan. Quagga mussels were exposed to waters collected from Lake Tahoe with low (average 13 mg/L) calcium concentrations over a 51-day period during which time a number of parameters were measured, including dissolved calcium, temperature, dissolved oxygen, and phosphorus. Mussel survival, growth rate, and reproductive potential were also measured. After 51 days, 86% of quagga mussels survived the very low to low calcium waters. The authors noted that overall mussel

[2] Byssal thread are strong, silky fibers that are made from proteins that are used by mussels and other bivalves to attach to rocks, pilings or other substrates. Zebra and quagga mussels hold the distinction of being the only freshwater bivalve in North America to produce byssal threads.

growth was positive for the first 36 days but that from days 37 to 51, growth was static or negative – attributed to “environmental stress, lack of calcium or appropriate food source, or a natural seasonal shift in growth period” (Chandra et al. 2009).

Davis et al. (2015) evaluated the invasion potential of quagga mussels in low calcium waters from the Tahoe Keys using laboratory experiments. Similar to Chandra et al. (2009), they evaluated the survival, growth, and reproductive potential of adult mussels in low (9 to 12 mg/L), moderate (15 to 32 mg/L) and high (72 mg/L) calcium waters. Adult survival after 90 days was extremely high (80-95%) and growth rates were positive in Tahoe Keys water (12 mg/L Ca) and Tahoe Keys calcium amended water (15, 21, 24, 32 mg/L Ca). Adult survival was only 30% in Tahoe Cave Rock water with calcium concentration of 9 mg/L and growth rates were negative. Their experimental results indicate, however, that slight increases in calcium concentrations otherwise considered “low” (e.g., 12 -15 mg/L) can support mussels through key life stages and life history processes and that mussels of various life stages transported to lower calcium waters of the western US can successfully complete vital life stages and events that are critical for establishment and continued recruitment.

Karatayev et el. (2015) examined data from 553 glacial lakes in eastern Europe to develop models to predict the spread of zebra mussels. They used 16 environmental variables to identify the most important factors that differentiated invaded lakes from those deemed “suitable for invasion” but not yet invaded. In order of decreasing importance, they found distance to nearest infestation, lake area, color, average depth, and concentrations of chloride, magnesium and bicarbonate were the key environmental parameters. The authors noted that no zebra mussels were found in lakes in eastern Europe with calcium levels less than 24.7 mg/L.

In 2016, WDFW began collection of samples for analysis of dissolved calcium at the majority of their sampling locations (Table 2; Figure 1). Calcium concentrations over the monitoring period ranged from 6.95 to 7.50 mg/L with an average of 7.26 mg/L. Concentrations were consistent across locations (Table 3). In June – September 2018, the Lake Chelan Research Institute collected samples at three locations for calcium analysis; in the Stehekin River, Railroad Creek and the Chelan River (located in the lake near the dam). Calcium concentrations ranged from 4.4 to 6.9 mg/L in the Stehekin River, from 5.2 to 11.3 mg/L in Railroad Creek, and 6.5 to 7 mg/L in the Chelan River, with higher concentrations occurring in September. Current monitoring efforts by the Lake Chelan Research Institute include water quality monitoring at several tributary locations, including calcium analysis. Data from these monitoring efforts was not available at the time of this report but will be available early 2020.

The EIM database (Washington State Department of Ecology Environmental Information Management Database) included multiple samples which were analyzed for calcium, both surface and groundwater. Many of these samples were collected part of the Holden Mine Remediation and Railroad Creek studies. Holden Mine, closed in 1957, is located 12 miles up Railroad Creek and is the site of substantial mine tailings that drain to Railroad Creek where portal drainage has pH values as low as 3 (Johnson et al. 1997). Most recently (2018) samples were collected along Railroad Creek from RM 6.2 to RM 11.1 and analyzed for dissolved calcium. Dissolved calcium concentrations in Railroad Creek ranged from 6.09 mg/L to 16.0 mg/L, with higher concentrations found at lower river miles. Limited groundwater and tributary calcium data are reported in the *Lake Chelan Water Quality Assessment* (Pelletier et al. 1989) from April and July 1987. Groundwater and tributary calcium concentrations ranged from 19 mg/L to 159 mg/L. It is unclear in the report whether the reported concentrations are total or dissolved fractions.

Established AIS in Lake Chelan also have the potential to alter water quality conditions in the lake which could make conditions more favorable for QZ mussels. For example, high densities of invasive aquatic plants can directly impact water column pH (optimal larval survival occurs at a pH of 8.4 and optimal adult growth occurs between 7.4 – 8.0 [NAS Database]) and provide suitable substrate for colonization (NAS Database). Established beds of Asian clams within Lake Chelan have the potential to create localized higher calcium environments which could facilitate the invasion of QZ mussels.

Dissolved calcium levels from near the mouth of Twenty-five Mile Creek (at Twenty-five Mile Creek State Park) range from 7.1 to 7.4 mg/L and from 7.1 to 7.5 mg/L where First Creek enters Lake Chelan (Lake Chelan State Park). There are, however, reported calcium concentrations in Mitchell Creek (82 mg/L, Pelletier et al. 1989; 36 mg/L dissolved calcium, August 2019, Personal communication, Phil Long) which have adjacent boat launches, access points or boat-in campgrounds nearby. Pelletier et. al (1989) do not clarify if the calcium results are dissolved or calcium carbonate.

In addition to environmental conditions, suitable habitat for attachment is essential to the life history of QZ mussels. Chelan PUD estimates there are a combined 1,336 piers, boatlifts and buoys on the lake. This includes several large marinas that have more than one boat slip even though they are only given one permit by state and/or federal regulatory agencies (Personal communications, Edrie Risdon, and Marcie Clement, both of Chelan PUD). Unknown are how many private docks provide potential habitat for attachment though this could be evaluated through a desktop GIS exercise. A component of an outreach and education campaign could easily include education materials on AIS to permittees. Additionally, they could participate in citizen science efforts to inspect their docks or attach a substrate sampler that can easily be removed, inspected, and returned.

# Risk Assessment Tools

Two spreadsheet tools were used to evaluate the risk QZ mussels pose to Lake Chelan. One was developed by the Invasive Species and IPM Coordinator for the Pacific Northwest Regional Office of the Bureau of Reclamation (USBR) and another by the WDFW Aquatic Invasive Species Unit.

The criteria used in the USBR spreadsheet tool includes both qualitative and quantitative parameters to assess risk (introduction, establishment, and economic) and was used to prioritize the vulnerability assessments being done at USBR dams. The criteria were pulled together from multiple sources and includes information from British Columbia, Colorado, USBR's Mid-Pacific Office, and the Midwest. The spreadsheet calculates a weighted "risk" score based on each parameters importance as determined by USBR's QZ mussel personnel in each region. Risk values were assigned as high (4), moderate (3), medium (2), and low (1). Parameters included in the tool include dissolved calcium, pH, total phosphorus, Secchi disk transparency, dissolved oxygen, temperature, conductivity, alkalinity, hardness, chlorophyll, total nitrogen, number of boat launches, restrictions on motorized watercraft, whether boat moorage is present, number of water-based events, endangered/threatened species present, and the number of hydropower facilities and water intakes. Endangered/threatened species and the number of hydropower facilities and water intakes is included to capture the risk of introduction and establishment to specific waterbody beneficial uses as well as the economic risk of establishment. Water intakes and hydropower facilities do provide additional substrate for QZ establishment, but their beneficial use would be severely impacted if QZ mussels were able to establish within these facilities.

Applying the USBR scoring tool using available water quality data, mostly from the AIS monitoring conducted by WDFW and the long-term monitoring conducted by the Lake Chelan Research Institute, and information regarding recreation, hydroelectric, and water intake facilities, Lake Chelan's risk for QZ mussel introduction and establishment scored in the moderate category with a score of 74 (Table 2). A score of greater than 75 would be considered high risk for QZ mussel introduction and establishment and a substantial economic risk to water intake and hydroelectric facilities. The categories within the USBR spreadsheet tool that are weighted the most include calcium concentration, pH, dissolved oxygen, and mean temperature. Available Lake Chelan calcium concentrations measured by WDFW and the Lake Chelan Institute are all below 12 mg/L which is considered "low risk" for QZ mussel establishment.  Unfortunately, though, Lake Chelan pH, dissolved oxygen, and mean temperatures measured at the WDFW AIS monitoring locations fall within the range for each parameter that would be considered "high risk" or suitable for QZ establishment. The number of boat launches, no restrictions on motorized watercraft, available boat moorage, water-based community events also contribute to the "moderate risk" score for QZ introduction and establishment.

Lowering the risk associated values for mean temperature, pH, dissolved oxygen and total nitrogen from high or moderate to medium, still result in a total risk score for Lake Chelan in the moderate category (54.5). This is mostly due to the risk associated with the number of boat launches, boat moorage available, no restrictions on motorized watercraft, and number of at-risk water intakes and hydroelectric facility. Raising the risk associated with calcium concentrations to medium, or calcium concentrations of 12 to 15 mg/L, bumps the total risk score up higher into the "high risk" category with a score of 77. This indicates that with just slight changes in calcium, Lake Chelan is at a high risk for QZ mussel establishment.  Results from 2019 sampling efforts from the major tributaries are forthcoming and will better inform whether they contribute to "hot spots", therefore potentially increasing the risk of establishment.

**TABLE 2**
**LAKE CHELAN PARAMETERS FOR USBR AIS RISK ASSESSMENT TOOL**

| Parameter | Units | Data | Risk Value | Source |
|---|---|---|---|---|
| Dissolved calcium | mg/L | 7.26 | 1 | WDFW |
| pH | -- | 8.1 | 4 | WDFW |
| Total phosphorus | µg/L | 8.1 | 2 | EIM (‘16-’18) |
| Secchi disk transparency | m | 6.6 | 2 | WDFW |
| Dissolved oxygen | mg/L | 9.2 | 4 | WDFW |
| Temperature | °C | 18.1 | 4 | WDFW |
| Conductivity | µS/cm | 49.5 | 2 | EIM(‘07) |
| Alkalinity, Total as $CaCO_3$ | mg/L | 18.3 | 1 | EIM (‘16-’18) |
| Hardness | mg/L | n/a | 1 | No data |
| Chlorophyll | µg/L | 1.1 | 1 | EIM (‘16-’18) |
| Total nitrogen | µg/L | 151 | 3 | EIM (‘16-’18) |
| Number of boat launches | -- | >5 | 4 | Mapping |
| Restrictions on motorized watercraft | -- | No | 4 | WDFW |
| Presence of boat moorage | -- | Yes | 4 | WA State Parks, NPS, |
| Number of water-based events | -- | >1 per year | 4 | Chamber of Commerce |
| Endangered/threatened species present | -- | No | 1 | USFW IPaC |
| Number of hydropower facilities & water intakes | -- | >10 | 4 | City of Chelan, Lake Chelan Reclamation District, Phil Long |

The criteria used in the WDFW risk tool relies on similar qualitative parameters to assess risk, including but not limited to: number of boat ramps, whether motorized watercraft are allowed, if there is an imposed speed limit, if boat moorage is available and/or allowed, number of water-based community events, and presence of hydropower and/or flood control facilities as well as water intakes. If hydropower/flood control facilities, irrigation and/or municipal water intakes are present in a waterbody the WDFW risk assessment tool assigns the highest points (4) for that parameter. The WDFW risk assessment tool also uses several different qualitative parameters than the USBR too including: year-long access, ease of access, whether the waterbody is in the Columbia River Basin, whether fish are stocked, whether there is a hatchery/net pens present, whether there is a boatyard present, and proximity to source population. The WDFW risk tool also includes quantitative parameters but is limited to dissolved calcium concentration and waterbody size. Points are summed for each waterbody in the assessment tool and used to determine risk as well as the AIS monitoring frequency for each waterbody conducted by WDFW.

Results of the WDFW risk assessment scoring system places Lake Chelan at the second to highest score for risk with 67 points out of 76 possible points. Factors that contribute to this high score are similar to the those that contribute to the USBR score and are largely attributed to high rates of potential introduction. That is, high scores for number of public boat launches, the presence of motorized watercraft, high numbers of moorages, docks, and ease of access. Similarly, WDFW weighs the presence of a hydropower facility and irrigation/municipal water intakes with the highest scores.

# AIS and Water Quality Monitoring

## QZ Mussel Monitoring

A variety of methods are available to monitor for QZ mussels and the selected methods are intended to target particular life stages, e.g., veliger or adult, but also particular geomorphic locations in the waterbody. WDFW has been conducting a variety of AIS monitoring protocols, briefly described below and summarized in Table 3.

### *Tow Sampling and Petit Ponar*

Horizontal and vertical zooplankton tows are used to capture QZ mussel veligers. Samples are generally collected during the summer months when conditions are suitable for mussel spawning and larval dispersal and analyzed for veligers using cross-polarized light microscopy. WDFW began collecting plankton tows in earnest in 2009. WDFW has been sampling in Lake Chelan since 2009 to detect adult QZ mussels at six locations around Lake Chelan, including Old Mill Park, Chelan River Park, Twenty-Five Mile Creek State Park, Chelan State Park, Sunset Marina, Lakeshore Marina, and beginning in 2020 – Stehekin Landing. Vertical tows are collected from a boat using a mesh size of 65 microns at the deepest areas near the substrate monitoring sites. Monitoring depths have ranged from 6 to 15 m. No QZ mussel veligers have been collected using this method. At the same time and general location that tow samples are collected, WDFW uses a petit Ponar is to sample sediments for other AIS, including adult QZ mussels.

### *Shoreline Surveys*

Shoreline surveys are conducted to identify a variety of AIS taxa by physically walking the shoreline for a specified duration and recording all occurrences of AIS, or collecting specimen for identification. WDFW conducts tactical and visual surveys along the shore by using a 10-minute survey of all artificial and natural substrates in the same previously described areas around Lake Chelan. This includes, buoys, docks, rocks, etc. All species are noted, including New Zealand mudsnails, Asian clams, etc. These surveys also occur three times per year.

### *Substrate Sampling*

Devices can be suspended by rope from a dock or other substrate and used as a platform for adult QZ mussel attachment. These substrates can be constructed of a variety of materials including PVC, plastic plates, or mesh. The idea is to provide a substrate for adult mussels to settle and attach but that can be easily inspected from a boat dock or similar structure without having to fully enter the water. Substrates should be concealed to prevent vandalism and located to avoid interfering with boat traffic or other recreational activities. Locating the substrates within the photic zone (where planktonic algae are found) is recommended. Substrates should be inspected at least monthly by visual observation but also gently patting to feel for small mussels that may be attached. In addition to monthly inspection of artificial substrates, other hard structures such as docks, sheet piling, anchors, buoys, logs, and ropes can be inspected regularly. WDFW has been monitoring substrates in Lake Chelan since 2009 to detect adult QZ mussels at in the same previously described areas around Lake Chelan. WDFW leaves substrates deployed year-round (unless the object it is attached will be removed) and are typically monitored from around June to November.

### *Environmental DNA*

Environmental DNA (eDNA) comes from a variety of sources including feces, sloughed-off cells, and decomposition of organisms (Valentini et al. 2009, Klymus et al. 2015). Tools are used to amplify and detect DNA of target organisms such as QZ mussels. In remote or large areas, this approach provides a more cost effective approach for monitoring for AIS. WDFW began collecting samples for eDNA analysis in 2018 for a limited number of samples and analyzed for QZ mussel, New Zealand mudsnails, and northern pike eDNA with no detections to date. Due to budget constraints, frequency of sampling is limited to once per year.

## Water Quality Monitoring

Current water quality monitoring efforts conducted by the Lake Chelan Research Institute are focused on baseline monitoring of main lake stations. These monitoring efforts should continue in order to track long term changes in overall water quality and ecological health of the lake. WDFW has been regularly conducting a number of AIS-related inventories since 2008, although monitoring locations and types were limited prior to 2010. This nearshore monitoring includes the collection of general water quality parameters including temperature, pH, salinity, dissolved oxygen, Secchi disk transparency, and dissolved calcium (2016 – 2018). Table 4 describes the location and frequency of sampling for AIS-related water quality data collected by WDFW from

2010 – 2018 and Table 5 summarizes those results. The WDFW AIS specific water quality monitoring should be continued and expanded to all public boat launches.

**TABLE 3**
**AIS-RELATED DATA COLLECTED BY WDFW 2010 – 2018**

| Data Type and Location | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **2018** | **2017** | **2016** | **2015** | **2014** | **2013** | **2012** | **2011** | **2010** |
| **AIS - Plankton Tow** | | | | | | | | | |
| 25 Mile Creek State Park | July | Sep., Oct. | June | July, Sep. | June, Aug. | June, July | August | Aug., Oct. | June, Aug. |
| Chelan Lake State Park | July | Sep., Oct. | June, Aug. | July, Sep. | June, Aug. | Jun., Jul., Sep. | August | - | - |
| Chelan River Park | July | Sep., Oct. | June, Aug. | July, Sep. | June, Aug. | Jun., Jul., Sep. | May, Aug. | Aug., Oct. | June, Aug. |
| Old Mill Park (Manson) | July | Sep., Oct. | June, Aug. | July, Sep. | June, Aug. | Jun., Jul., Sep. | August | Aug., Oct. | June, Aug. |
| Sunset Marina | July | - | - | - | - | - | - | - | - |
| **AIS - Shoreline Survey** | | | | | | | | | |
| 25 Mile Creek State Park | July, Oct. | Sep., Oct. | June | - | - | - | - | - | March |
| Chelan Lake State Park | July, Oct. | Sep., Oct. | June, Aug. | - | - | - | - | - | March |
| Chelan River Park | July, Oct. | Sep., Oct. | June, Aug. | - | - | - | - | - | March |
| Old Mill Park (Manson) | July, Oct. | Sep., Oct. | June, Aug. | - | - | - | May | - | March |
| Sunset Marina | July, Oct. | - | - | - | - | - | - | - | - |
| **AIS - Substrate (artificial)** | | | | | | | | | |
| 25 Mile Creek State Park | July | Sep., Oct. | June | July, Sep. | June, Aug. | Jun., Jul., Sep. | May, Aug. | Aug., Oct. | June, Aug. |
| Chelan Lake State Park | July | Sep., Oct. | June, Aug. | July, Sep. | June, Aug. | June, July | May, Aug. | - | - |
| Chelan River Park | July | Sep., Oct. | June, Aug. | July, Sep. | June, Aug. | Jun., Jul., Sep. | May, Aug. | Aug., Oct. | June, Aug. |
| Old Mill Park (Manson) | July | Sep., Oct. | June, Aug. | July, Sep. | June, Aug. | June, July | May, Aug. | Aug., Oct. | June, Aug. |
| Sunset Marina | July | - | - | - | - | - | - | - | - |
| **AIS - eDNA** | | | | | | | | | |
| 25 Mile Creek State Park | Oct. | - | - | - | - | - | - | - | - |
| Chelan Lake State Park | Oct. | - | - | - | - | - | - | - | - |

| Data Type and Location | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 |
| Chelan River Park | Oct. | - | - | - | - | - | - | - | - |
| Old Mill Park (Manson) | Oct. | - | - | - | - | - | - | - | - |
| Sunset Marina | Oct. | - | - | - | - | - | - | - | - |

**TABLE 4**
**WATER QUALITY DATA COLLECTED BY WDFW 2010 – 2018**

| Data Type and Location | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 |
| **General Water Quality** | | | | | | | | | |
| 25 Mile Creek State Park | July, Oct. | Sep., Oct. | June | July, Sep. | June, Aug. | Jun., Jul., Sep. | August | Aug., Oct. | June, Aug. |
| Chelan Lake State Park | July, Oct. | Sep., Oct. | June, Aug. | July, Sep. | June, Aug. | Jun., Jul., Sep. | May, Aug. | - | - |
| Chelan River Park | July, Oct. | Sep., Oct. | June, Aug. | July, Sep. | June, Aug. | Jun., Jul., Sep. | May, Aug. | Aug., Oct. | June, Aug. |
| Old Mill Park (Manson) | July, Oct. | Sep., Oct. | June, Aug. | July, Sep. | June, Aug. | Jun., Jul., Sep. | May, Aug. | Aug., Oct. | June, Aug. |
| Sunset Marina | July, Oct. | - | - | - | - | - | - | - | - |
| **Dissolved Calcium** | | | | | | | | | |
| 25 Mile Creek State Park | July, Oct. | Sep. | June | - | - | - | - | - | - |
| Chelan Lake State Park | July, Oct. | Sep. | June | - | - | - | - | - | - |
| Chelan River Park | July, Oct. | Sep. | June | - | - | - | - | - | - |
| Old Mill Park (Manson) | July, Oct. | Sep. | June | - | - | - | - | - | - |
| Sunset Marina | July, Oct. | Sep. | - | - | - | - | - | - | - |

**TABLE 5**
**MEAN NEARSHORE WATER QUALITY CONDITIONS MEASURED BY WDFW 2009 – 2018**

| Monitoring Location | Temperature (°C) | pH | Salinity (ppt) | Dissolved Oxygen (mg/L) | Secchi Disk Depth (m) | Dissolved Calcium (mg/L) |
|---|---|---|---|---|---|---|
| 25 Mile Creek State Park | 17.0 (11.7 – 22.5) | 8.1 (6.9 – 10.1) | 0.02 (0.01 – 0.05) | 8.8 (3.9 – 14.2) | 6.1 (2.0 – 11.0) | 7.25 (7.05 – 7.36) |
| Chelan Lake State Park | 17.9 (8.6 – 23.4) | 8.2 (7.7 – 9.4) | 0.02 (0.01 – 0.04) | 8.4 (337 – 12.9) | 7.4 (4.0 – 11.0) | 7.25 (7.06 – 7.50) |
| Chelan River Park | 19.5 (14.2 – 23.7) | 7.9 (6.4 – 9.1) | 0.02 (0.01 – 0.04) | 9.3 (3.6 – 12.9) | 6.5 (3.0 – 10.0) | 7.25 (7.00 – 7.40) |
| Old Mill Park (Manson) | 18.3 (10.7 – 23.2) | 8.3 (7.7 – 9.7) | 0.02 (0.01 – 0.04) | 9.4 (4.5 – 14.7) | 6.4 (3.0 – 11.0) | 7.37 (7.28 – 7.50) |
| Sunset Marina | 17.7 (14.4 – 20.9) | 8.9 (8.6 – 9.3) | 0.03 (0.02 – 0.04) | 14.2 (8.3 – 20.1) | 7.5 (5.0 – 10.0) | 7.12 (6.95 – 7.30) |

# Data Gaps and Recommendations

Table 5 summarizes data gaps that would improve understanding of the vulnerability of Lake Chelan to infestation of AIS, particularly QZ mussels. In particular, information related to sediments and available substrates, dissolved calcium sampling, AIS surveys, boater surveys and watercraft inspections/decontamination, and funding. The additional water quality monitoring is directed specifically to understand conditions associated with potential AIS establishment in Lake Chelan and is not meant to be a traditional comprehensive list of water quality parameters. Results from the recommended water quality monitoring listed in Table 6 may be used to refine future AIS surveys and monitoring and may only be necessary every other year depending on results.

**TABLE 6**
**DATA GAPS AND RECOMMENDATIONS**

| Topic | Data Gap(s) | Recommendation(s) |
|---|---|---|
| **Sediment Types and Available Substrates** | Chelan PUD estimates there are a combined 1,336 permitted piers, boatlifts and buoys on the lake; however, permits are issued on a per facility basis which could include multiple docks, boat slips, pilings, and/or buoys available for mussel attachment. Installations are permitted by the state and federal regulatory permitting agencies. | This could be a potential GIS exercise to attempt to inventory individual docks, boat slips, pilings and buoys that are currently within Lake Chelan. Obtain information on the number and location of mooring buoys and, if applicable, information on permit requirements. |
| | What sediment types are found in the lake and basin that could play a role in nutrient availability, aquatic plant growth, and mussel attachment? Is lake substrate dominated by soft or hard substrate? For example, there is limited information found on sediment and substrate type for the Wapato Basin and little to no information for the Lucerne Basin. | Conduct sediment and suitable habitat study at key locations. Key locations should include near popular access points, boat-in only campgrounds, and near potentially high calcium inputs or high calcium substrates. |
| **Water Quality Monitoring** | Location of dissolved calcium "hot spots", e.g., near Asian clam beds, stream inputs, irrigation returns and drains, sediment porewater (especially near Asian clam bed), and where concentrations may be higher than ambient conditions in the lake. Currently WDFW monitors dissolved calcium at six nearshore locations within Lake Chelan, usually three times per year. | Implement WDFW's plan to conduct water quality monitoring specifically to determine dissolved calcium concentrations in and near Asian clam beds, stream inputs, agricultural irrigation returns/drains and other potential sources. Flow monitoring at major tributaries and inputs should also be conducted to provide better understanding of calcium loading and seasonality of input. |
| | Currently there is no known dissolved calcium data for the small lakes that drain into Lake Chelan. This information could provide useful insight on habitat suitability and potential establishment with risk to Lake Chelan, especially given their history of established AIS other than mussels. | Continue conducting baseline survey for dissolved calcium in the small lakes that drain into Lake Chelan (e.g., Wapato and Roses Lakes) |
| | Water quality in the mouth of main tributaries and in the nearshore areas downstream of tributary confluences | Collect AIS-related water quality parameters including dissolved calcium, temperature, pH, conductivity, Chlorophyll a, and Secchi disk transparency at least four times per year to capture seasonality. Samples should be collected using current WDFW protocols. |

| Topic | Data Gap(s) | Recommendation(s) |
|---|---|---|
| **AIS and Aquatic Plant Survey** | No known comprehensive survey of Asian Clam beds in Lake Chelan. | Conduct a lake-wide survey during low water periods (e.g., April) to document location, size, and density of established Asian Clam beds in Lake Chelan as well as other AIS animals such as New Zealand mudsnails, crayfish, and Chinese mystery snails. |
| | No known aquatic plant survey for portions of the lake north of Fields Point Landing. Most recent aquatic plant survey for lower end of the lake (Wapato Basin) was conducted in 2014. It is important to track the trends in aquatic plant distribution, density, and species composition not only for early detection of new populations of invasive plant species but also to better understand the overall ecological health and diversity of the lake. | Conduct a lake-wide aquatic plant survey every three to five years to document location, size, and density of aquatic plant beds in Lake Chelan. Focus should be on location and identification on non-native, invasive plants such as Eurasian watermilfoil and curlyleaf pondweed. Survey could be conducted using a combination of methods, including drones, boat survey, and diving. |
| **Boater/Watercraft Survey, Boat Inspection, and Boat Decontamination** | Detailed information regarding boater use, watercraft types, point of origin, and planned destination specific to Lake Chelan is not available for the multiple access points across the lake. Some recent data are available for number of boat launch permits or federal dock permits for various public launches; however, details regarding the boat point of origin, whether it had been in mussel-infested waters prior to Lake Chelan, and the occupants planned destination within Lake Chelan is not available. | Conduct boater surveys at all public launches for at least one season (May – September) to collect data regarding boater use, watercraft type, point of origin, familiarity with AIS best practices (Clean, Drain Dry), and planned destination with Lake Chelan. Collect data such that information provides understanding regarding boat traffic into Lake Chelan and within Lake Chelan (for example 25 Mile Creek State Park to Mitchell Creek campground). |
| | No known survey of private boat launches and access points. | Educate private boat launch and access point owners, marinas, boat yards, and boat repair shops on vulnerability and risks of AIS and with AIS best practices (Clean, Drain, Dry). Provide training for owners to conduct AIS inspection of boat ramps and facilities. |
| | Currently the best options for off-site inspection sites and boat decontamination sites are unknown. There has been some discussion within the Lake Chelan Watershed Planning Unit on potential locations. | Identify potential off-site boat inspection station locations to capture boaters arriving from the Seattle, Canada, and Spokane areas. Sites for potential consideration: Stayman Flats near the Navaree Coulee Rd. cutoff, west side of Beebe Bridge, and junction of Hwy 97 and 97A east of the Lake Chelan Airport. Almost all boat traffic entering the Lake Chelan Basin could be intercepted via Hwy 97 and 97A with an inspection station near the intersection of SR 150 and 97A. Investigate options for stand-alone waterless systems, for example the CD3 system. |

| Topic | Data Gap(s) | Recommendation(s) |
|---|---|---|
| **Funding and Planning** | Explore potential options to establishing an AIS program for Lake Chelan | Identify creative sources of funding including private businesses in the area that could be deleteriously impacted by the introduction and establishment of AIS, public-private partnerships, partner with other interested non-profits, and take advantage of matching funds from federal organizations such as the Aquatic Nuisance Species Task Force. Using these combined resources, develop a comprehensive AIS management plan specific to Lake Chelan, including measures on rapid response planning. |
| | Identify and secure long-term funding opportunities to implement an AIS program for Lake Chelan | Explore other "models" where successful programs are being implemented across the country. Examples include Lake Tahoe and Lake Whatcom. Elizabeth Brown with Colorado Parks and Wildlife suggested the following elements necessary for a successful program:<br>• Public Support<br>• Political Support and Priority<br>• Dedicated Staff<br>• Dedicated Funding<br>• Legal and Regulatory Authority for Management Actions<br>• Law Enforcement<br>• Coordinated Partnerships<br>• Infrastructure for Staff and Operations<br>• Clear and Concise Signage and Education and Outreach Materials<br>• Communication Plan with Clear Roles and Responsibilities of Partners<br>• Early Detection Monitoring<br>• Existing AIS Population Monitoring<br>• Rapid Response Infrastructure<br>• Baseline Resource Information |

# Conclusions

- The sheer number of boats utilizing and traveling to Lake Chelan results in a high risk for introduction of AIS from a variety of taxa;
- Results of the USBR risk assessment tool indicate that while dissolved calcium levels are low and point to low risk for establishment, other environmental conditions (i.e., dissolved oxygen and temperature) indicate a moderate risk for QZ mussels at Lake Chelan;
- There is limited but compelling evidence that “hot spots” of favorable environmental conditions could favor presence and establishment of Asian clams. Examples of “hot spots” include areas over or near Asian clam beds and tributaries that could, even seasonally, introduce increased dissolved calcium levels;
- There is little information about how watercraft are moved between other nearby waterbodies (e.g., Roses, Wapato, and Dry Lakes);
- A comprehensive AIS program that incorporates and expands WDFW water quality monitoring and AIS surveys is strongly recommended;
- There are a number of data gaps that if filled could provide more insight and understanding regarding habitat suitability for QZ mussel establishment as well as introduction and establishment of other AIS

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# Figures

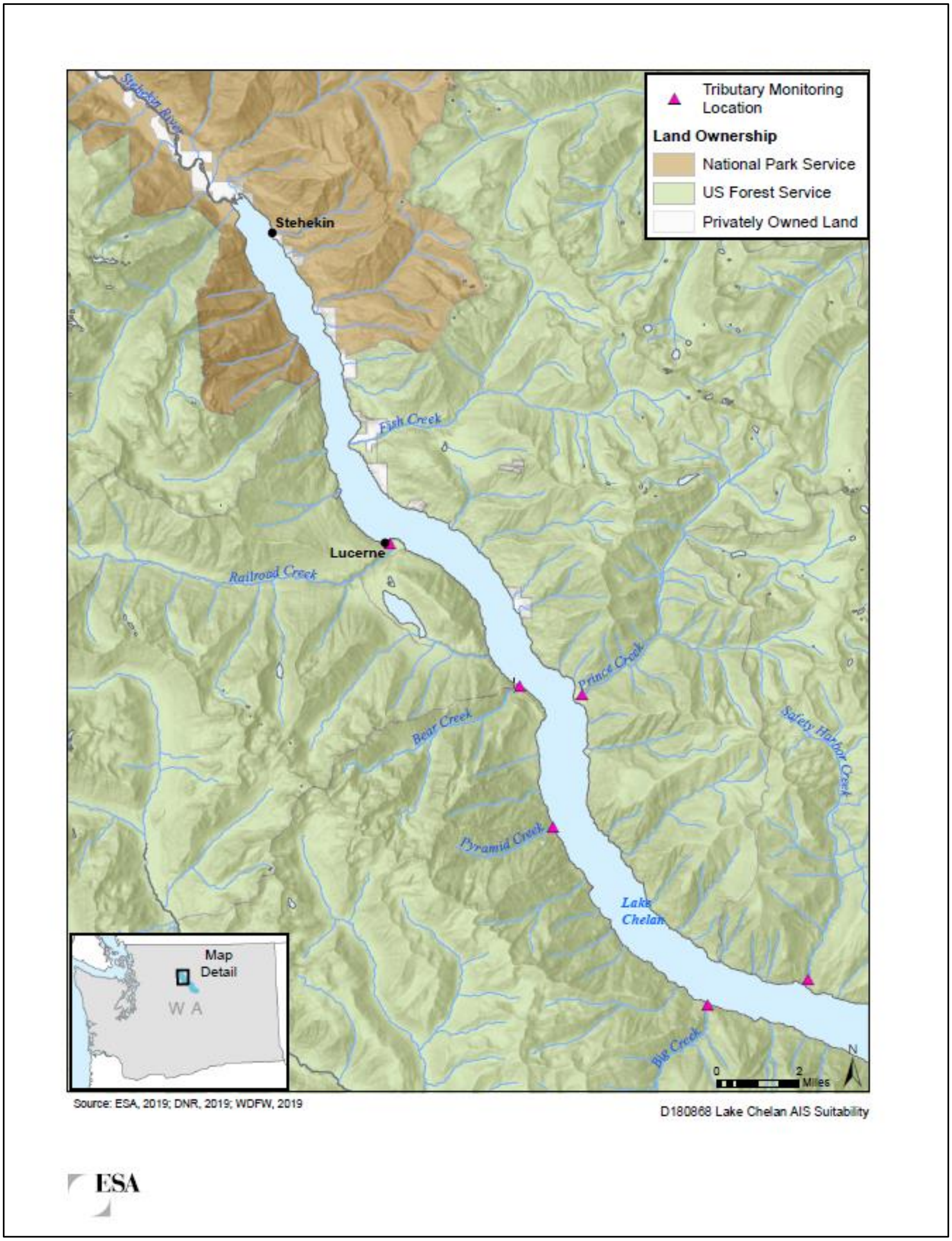



**Figure 1. Location of Lake Chelan and surrounding land ownership (1 of 3)**

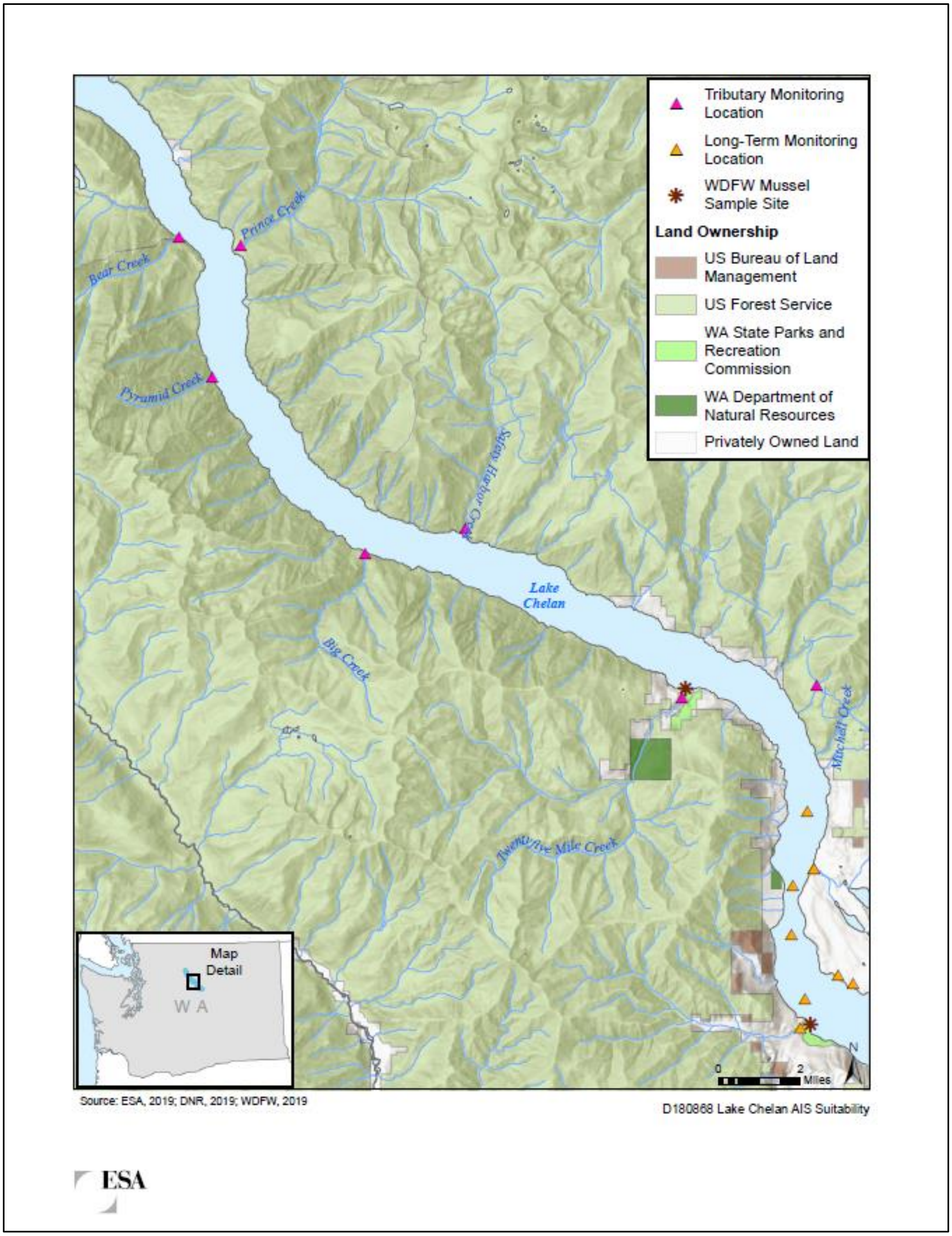



**Figure 2. Location of Lake Chelan and surrounding land ownership (2 of 3)**

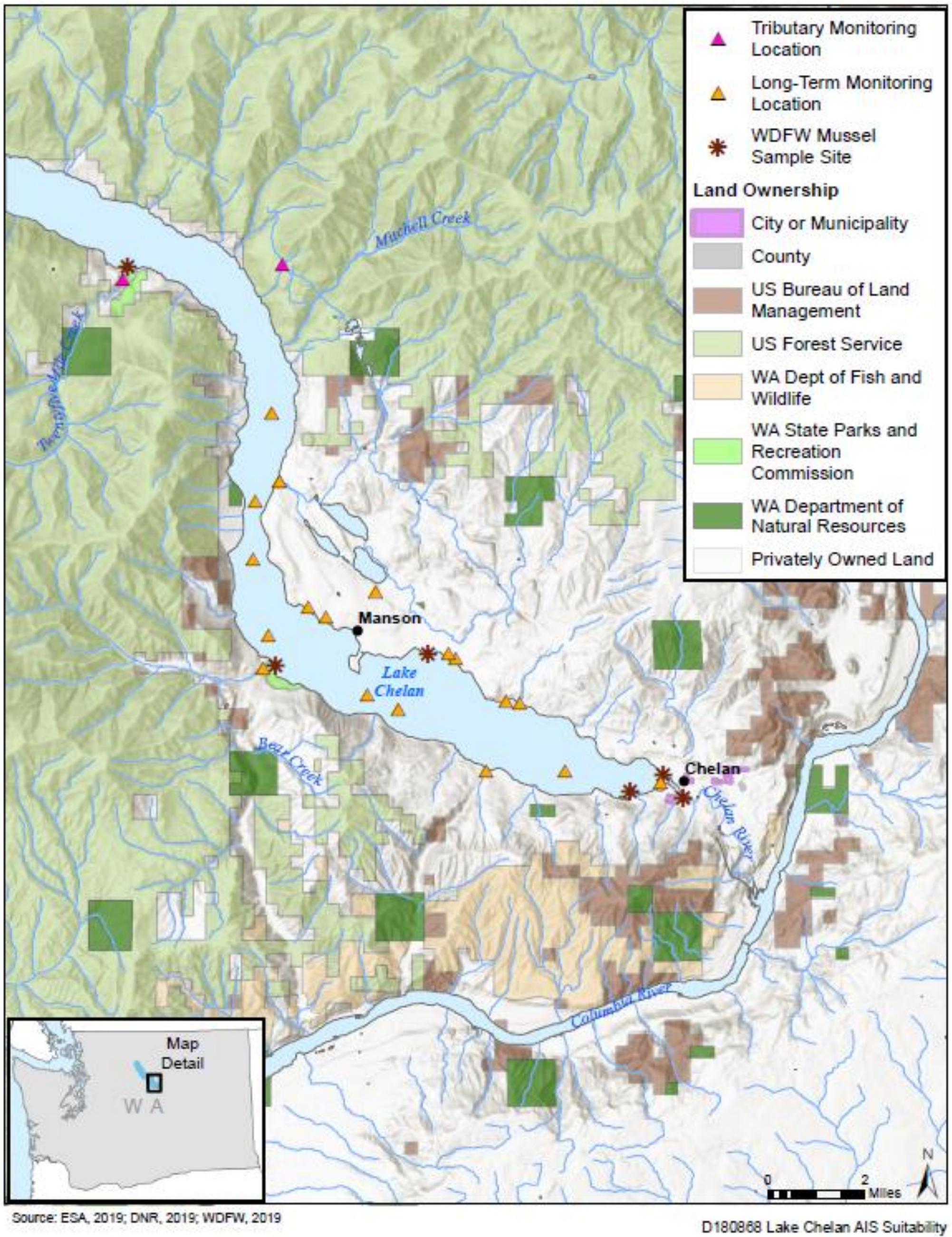



**Figure 3. Location of Lake Chelan and surrounding land ownership (3 of 3)**

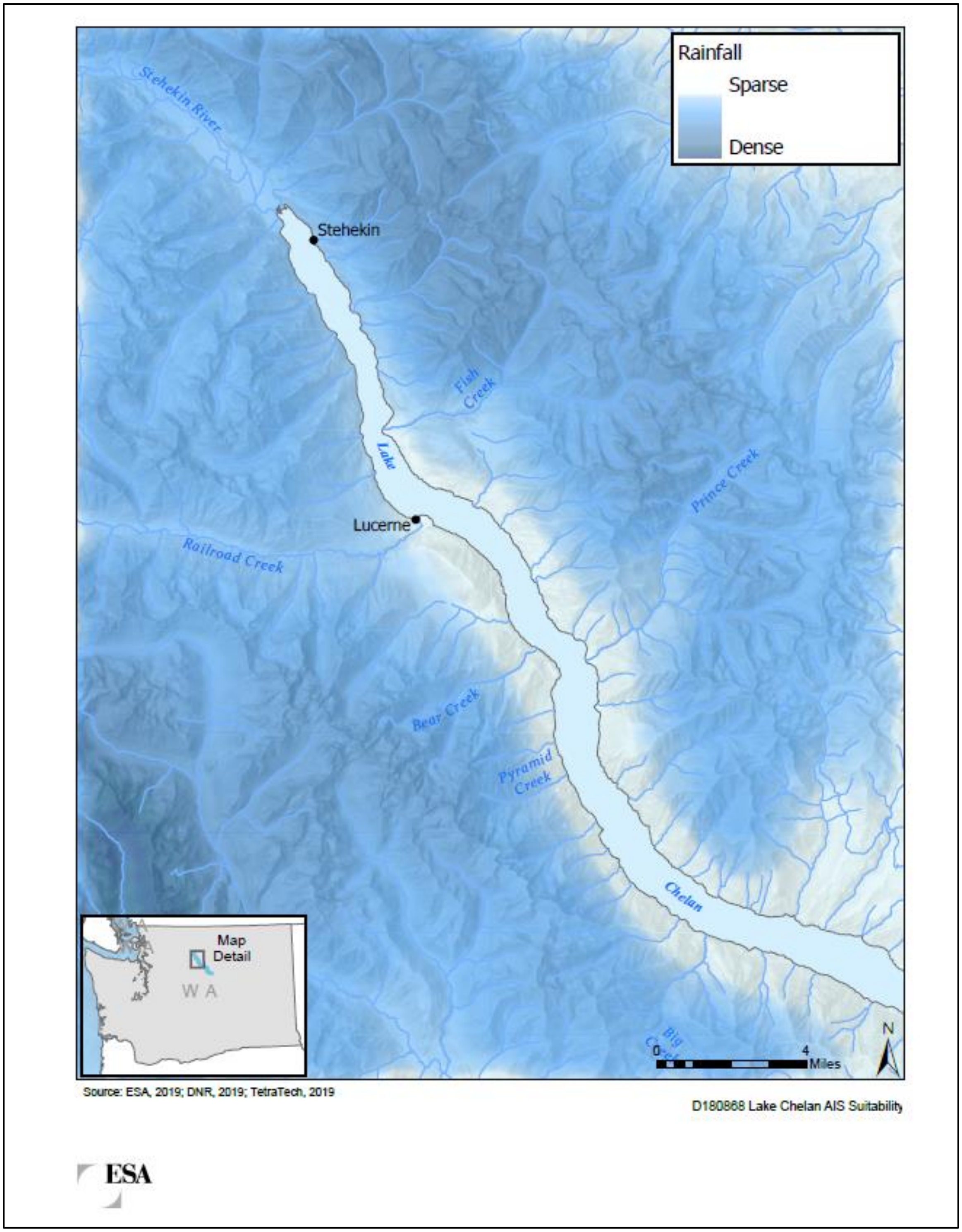



**Figure 4. Heatmap of rainfall in the Lake Chelan Basin as well as water quality and AIS monitoring stations (1 of 3).**

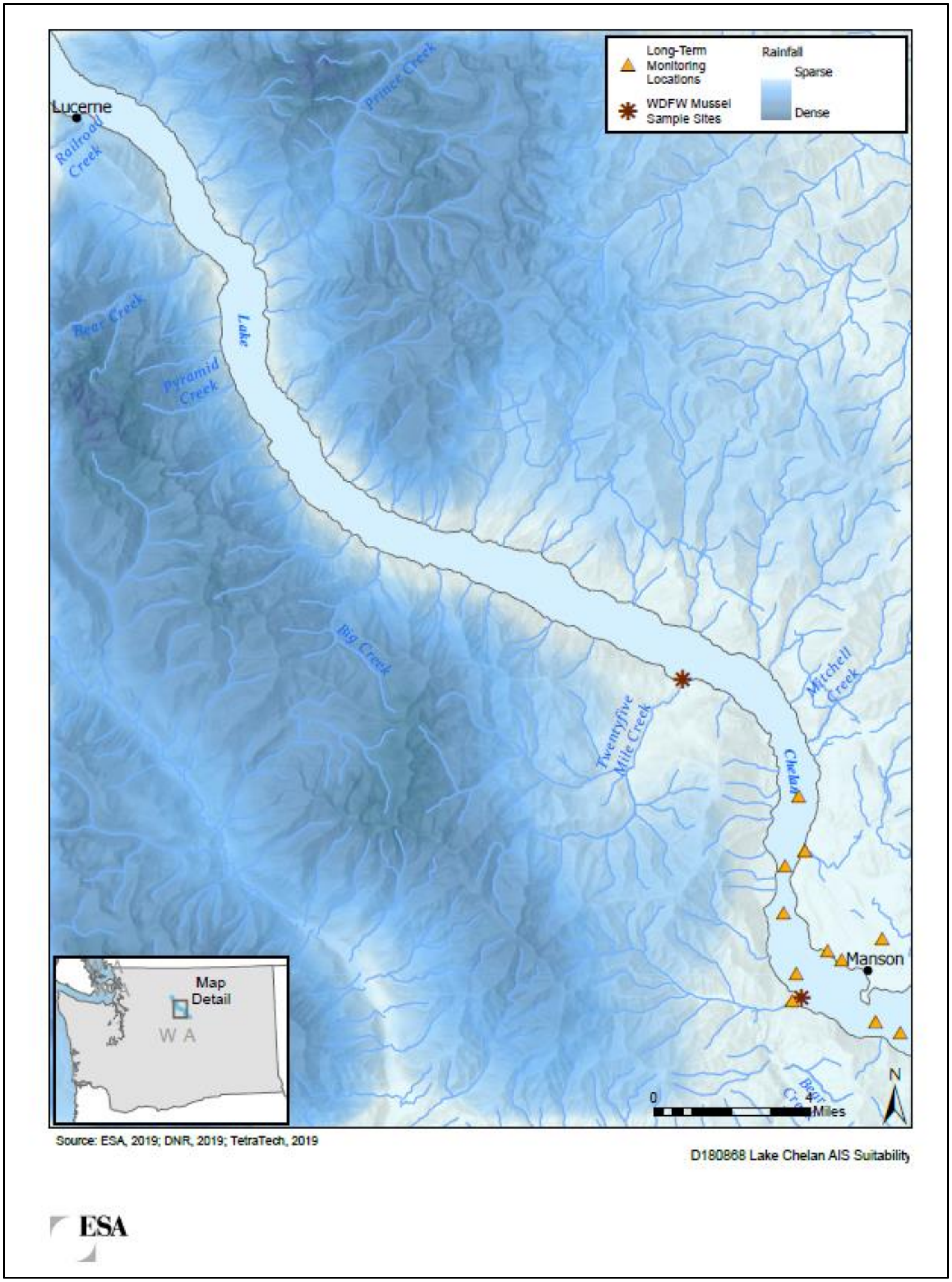



**Figure 5. Heatmap of rainfall in the Lake Chelan Basin as well as water quality and AIS monitoring stations (2 of 3)**

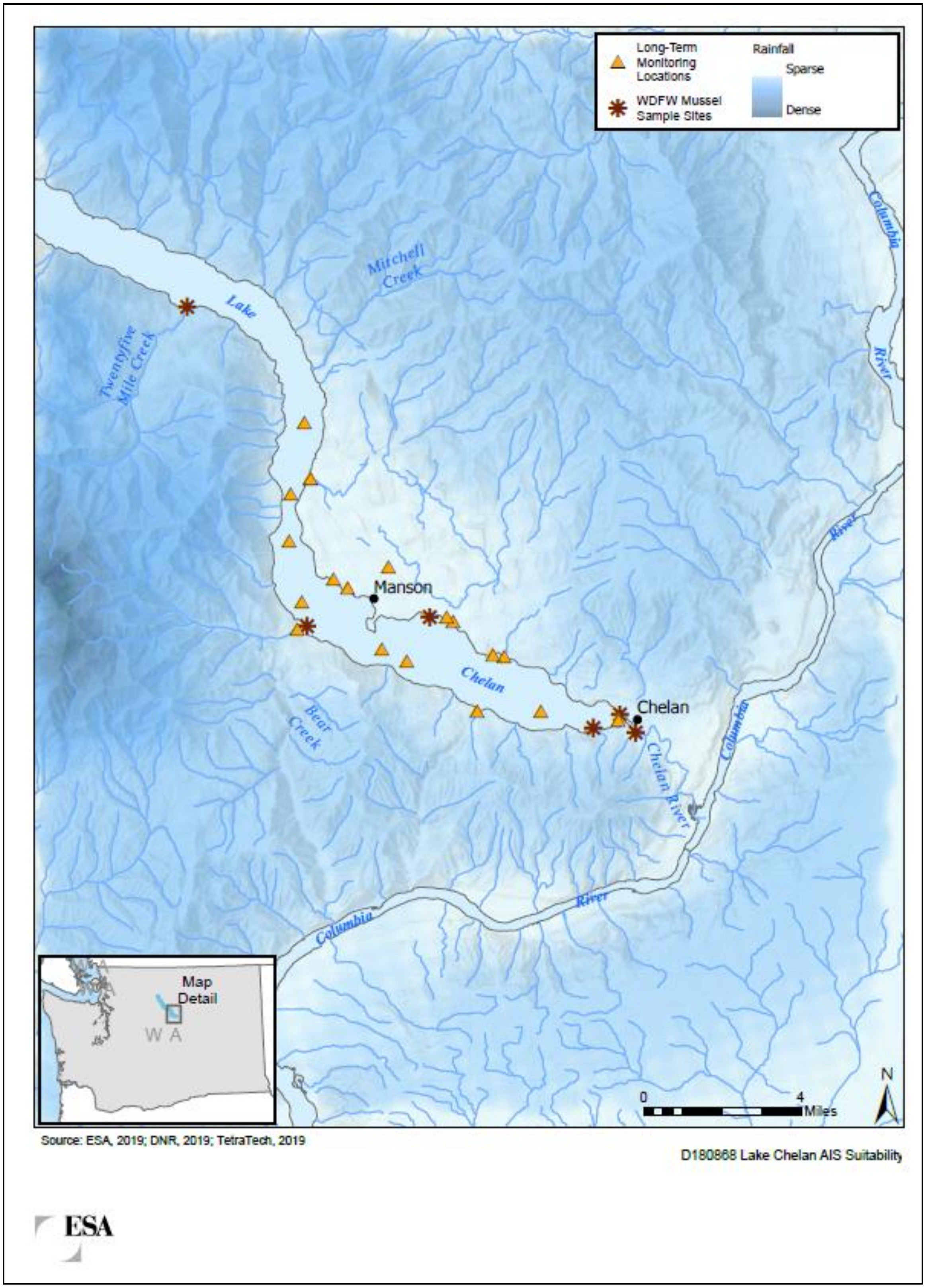
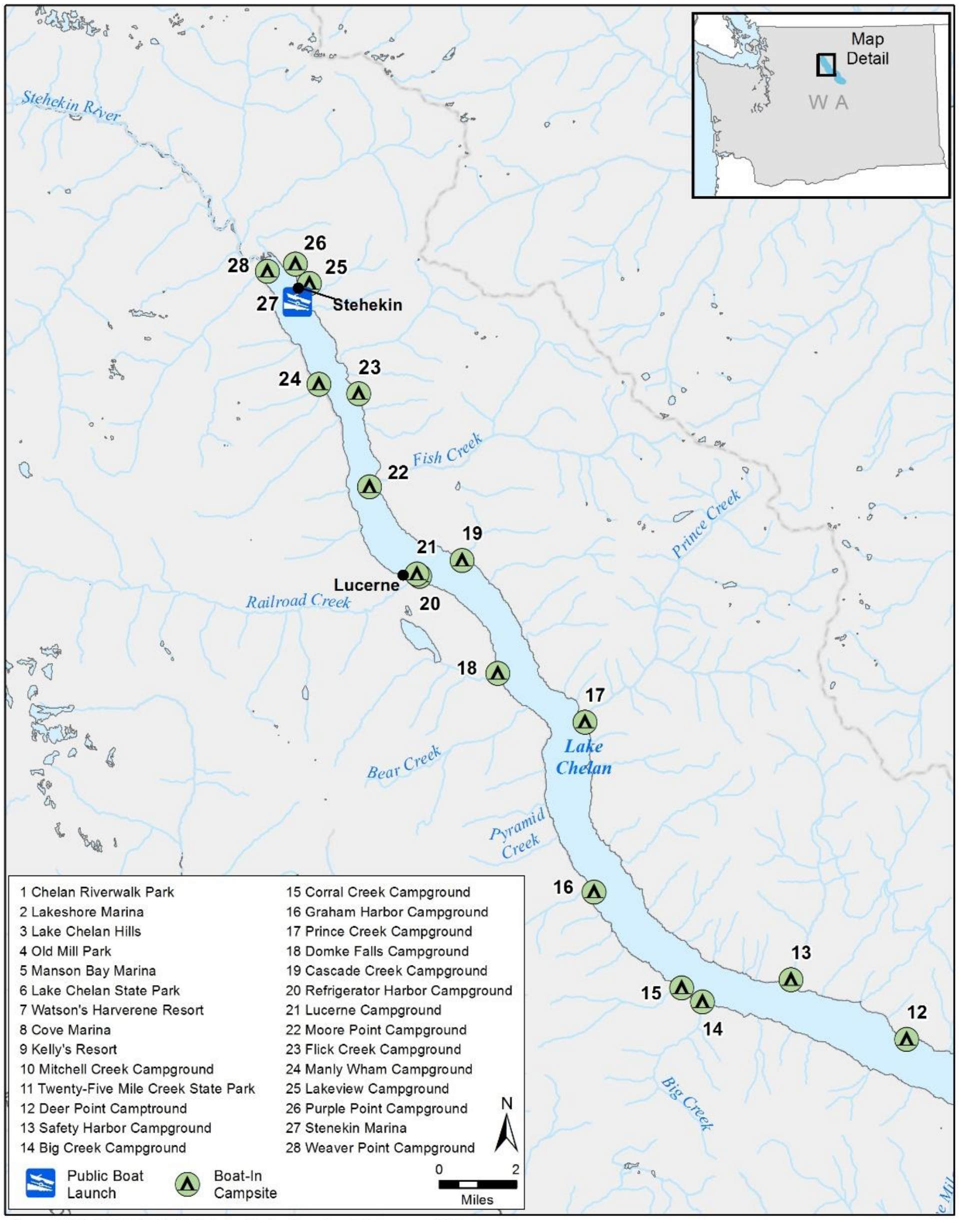



**Figure 6. Heatmap of rainfall in the Lake Chelan Basin as well as water quality and AIS monitoring stations (3 of 3)**

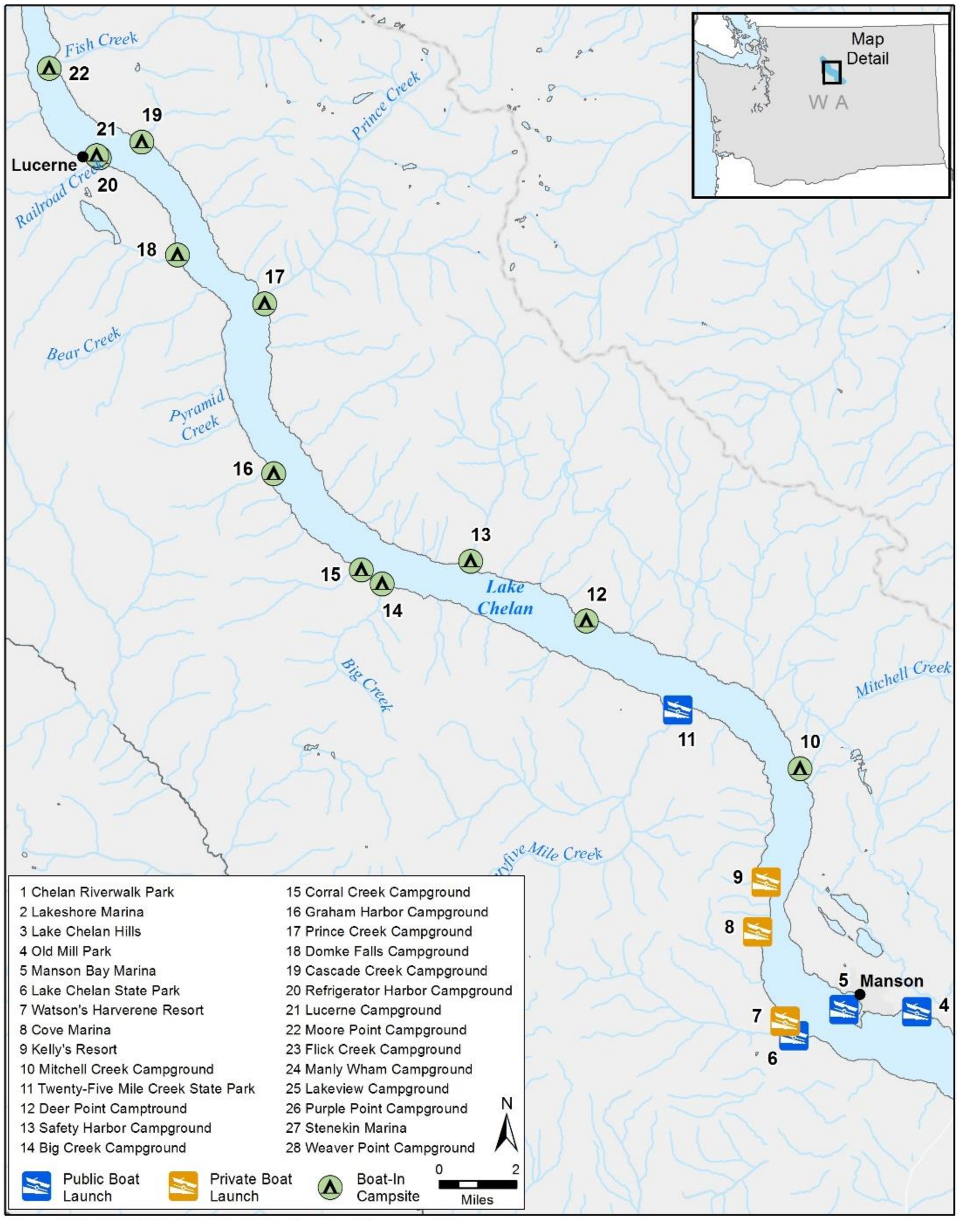



Source: ESA, 2019; USFS, 2019; Lake Chelan Chamber of Commerce, 2019

D180868 Lake Chelan AIS Suitability

ESA

**Figure 7. Public boat launches and boat-in campsites of Lake Chelan (1 of 3)**

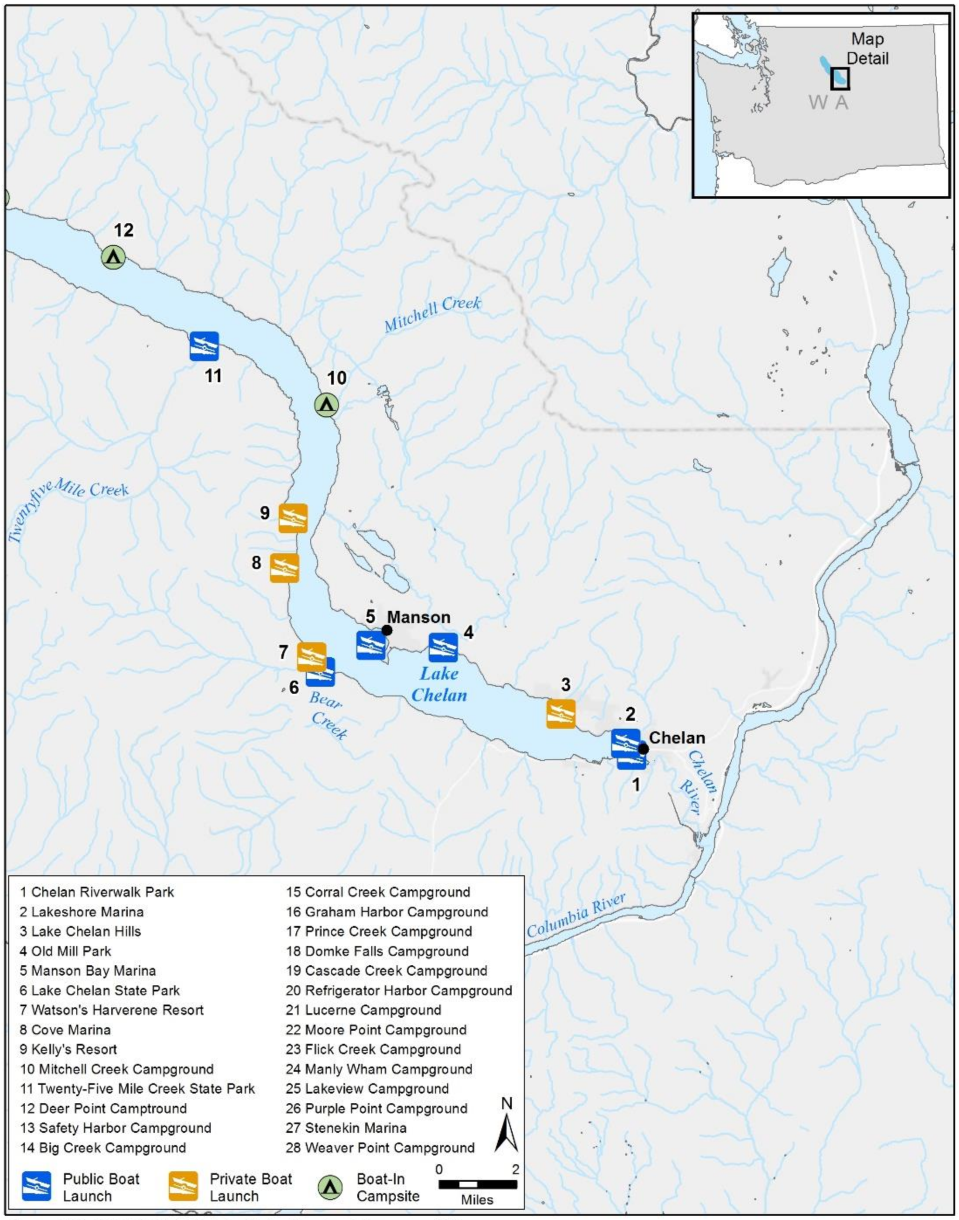



Source: ESA, 2019; USFS, 2019; Lake Chelan Chamber of Commerce, 2019

D180868 Lake Chelan AIS Suitability

ESA

**Figure 8. Public and private boat launches and boat-in campsites of Lake Chelan (2 of 3)**




Source: ESA, 2019; USFS, 2019; Lake Chelan Chamber of Commerce, 2019

D180868 Lake Chelan AIS Suitability

ESA

**Figure 9. Public and private boat launches and boat-in campsites of Lake Chelan (2 of 3)**

**Figure 10. Live Asian clams found by students in Lake Chelan in 2018 (Photo by Phil Long, Lake Chelan Research Institute).**

# Appendix A. Summary of Available Data

| **Source** | **Data Type** | **Date/Year** | **Locations** | **Frequency** | **Parameters/Analysis** |
|---|---|---|---|---|---|
| Washington Department of Fish and Wildlife | AIS – Zebra/Quagga Mussels | 2001, 2007 – 2018 | 25 Mile Creek State Park<br>Chelan Lake State Park<br>Chelan River Park<br>Old Mill Park (Mason)<br>Sunset Marina | 1x – 2x per year | Plankton Tow _ Veliger<br>Shoreline Surveys<br>Substrate (artificial) |
| | AIS - eDNA | 2018 | 25 Mile Creek State Park<br>Chelan Lake State Park<br>Chelan River Park<br>Old Mill Park (Mason)<br>Sunset Marina | 1x per year | eDNA – WDFW Molecular Genetics Lab |
| | General Water Quality | 2009 - 2018 | 25 Mile Creek State Park<br>Chelan Lake State Park<br>Chelan River Park<br>Old Mill Park (Mason)<br>Sunset Marina | 1x – 3x per year | Temperature<br>pH<br>Dissolved Oxygen<br>Salinity<br>Secchi Disk Depth |
| | Water Quality - Calcium | 2016 - 2018 | 25 Mile Creek State Park<br>Chelan Lake State Park<br>Chelan River Park<br>Old Mill Park (Mason)<br>Sunset Marina | 1x – 2x per year | Calcium, mg/L |
| Nonindigenous Aquatic Species Database | AIS – Mollusks & Crustaceans | 2009, 2010, 2011, 2013 – 2018 | Lake Chelan (Chelan River Park, Chelan Lake State Park, 25 Mile Creek State Park, Old Mill Park [Mason])<br>Wapato Lake | n/a | Asian Clams identified at Lake Chelan sites (2010)<br><br>Virile Crayfish identified at Wapato Lake (2009) |
| | AIS – Fishes | 1935, 1997, 2003, 2005, 2008 | Lake Chelan<br>Wapato Lake<br>Antilon Lake<br>Roses (Alkali) Lake<br>Domke Lake | n/a | Bluegill, Black Crappie, Smallmouth and Largemouth Bass, Channel Catfish, Lake Trout, Tench, Pumpkinseed |
| | AIS - Plants | 1990, 1994 – 1997, 1999, 2001, 2004, 2006 – 2008, | Lake Chelan<br>Wapato Lake<br>Roses (Alkali) Lake<br>Domke Lake | n/a | Eurasian watermilfoil identified in Lake Chelan (1994), Wapato Lake (1994), Roses Lake (2001), Domke Lake (1990) |

| Source | Data Type | Date/Year | Locations | Frequency | Parameters/Analysis |
|---|---|---|---|---|---|
| | | 2011 – 2013, 2017 | | | American white waterlily identified in Roses Lake (1997)<br><br>Reed Canary Grass identified in Wapato Lake (2001) and Roses Lake (2001) |
| Aquatechnex – Survey of Submerged Noxious Weed Species in Lake Chelan Washington | Aquatic Plants | Fall 2014 | Lake Chelan | 1x | Aerial and boat survey of aquatic plants from dam to Fields Point<br><br>EWM and Curlyleaf Pondweed Identified |
| Chelan County PUD – 1999 Final Water Quality Monitoring Report | Water Quality | May – September 1999 | Lake Chelan (4 sites in Wapato Basin, 1 site in Lucerne Basin) | 8x (Wapato Basin)<br><br>5x (Lucerne Basin) | Temperature, Dissolved Oxygen, pH, Specific Conductance, Transparency, TDG, TP, TN, Nitrate+Nitrite, Chlorophyll a |
| | | June – August 1999 | Lake Outlet and Tailrace | 8x | Temperature, Dissolved Oxygen, pH, Specific Conductance, TDG, TSS |
| | | | Bypass Reach | 8x | Temperature, Dissolved Oxygen, pH, Specific Conductance, TDG, TSS |
| Lake Chelan Research Institute | Water Quality | June – September 2018 | Stehekin River, Railroad Creek, Chelan River (in lake near dam) | 1x month | Total Phosphorus, Carbonate, Bicarbonate, Sulfate, Chloride, Calcium, Magnesium, Sodium, Potassium, TDS, Alkalinity, TSS |
| | | May – September 2018 | Ag Drain 6, 8, 10, 11, 13, 14 and 15; Beebe Creek, Purtteman Creek, Knapp Coulee, Wapato Lake Outlet, Stink Creek, First Creek | 1x month | Nitrate+Nitrite, Ortho-Phosphorus, Total Phosphorus, Ammonia, TKN, Carbonate, Bicarbonate, TDS, Alkalinity, TOC, TSS |

| Source | Data Type | Date/Year | Locations | Frequency | Parameters/Analysis |
|---|---|---|---|---|---|
| Lake Chelan Water Quality Assessment – January 1989 | Water Quality | December 1986 – November 1987 | 10 lake stations<br><br>Stehekin River, Railroad Creek, Mitchell Creek, First Creek, 3 agricultural return flow drains | 1x month; Every 3 weeks in spring-summer | Temperature, Flow (tribs only), pH, Dissolved Oxygen, Specific Conductance, Transparency, light extinction, SRP, TP, ammonia, nitrate+nitrite, TN, turbidity, chloride, alkalinity, TSP, TSN, chla, phytoplankton, bacteria, arsenic, iron, zinc, PTHM |
| | | April – September 1987 | Wapato Lake, Stink Creek, Purtteman Gulch, Knapp Coulee, 3 urban drains | | |
| | Sediment | November 1986, July 1987 | Off shore 2 urban drains, off shore 3 agricultural drains, Station 4 in Wapato Basin, Station 6 in Lucerne Basin, and nearshore Safety Harbor Creek | 1x | Grain size, Solids, TOC, TN, TP, metals, pesticides/PCBs, priority pollutant organic compounds |
| EIM – Database Study: 1984 BWMP Fish Tissue and Sediment | Animal Tissue | September 1984 | Lake Chelan (47A070) | 1x | Fish statistics, Metals and Trace Elements, Lipids, Organochlorine Pesticides and PCBs, Mercury, Lead |
| | Freshwater Sediment | September 1984 | | | Organics, Metals and Trace Elements, Organochlorine Pesticides and PCBs, Grain Size, Mercury, Lead |
| EIM – Database Study: 1992 Lakes Toxics Screening Survey | Animal Tissue | August 1992 | Roses Lake | 1x | Fish statistics, Pesticides, Lipids, Mercury, Metals and Trace Elements, Lead, Selenium |
| | Freshwater Sediment | June 1992 | | | Grain Size, TOC, Metals and Trace Elements, Organochlorine Pesticides and PCBs, Pesticides, Semi-volatile Organic Compounds, Chlorinated Herbicides, Mercury, Lead |
| EIM – Database Study: 2007 Lake Chelan Wapato Basin TMDL | Water Quality | May – September 2007 | Wapato Basin 1<br>Wapato Basin 2<br>Wapato Basin 3<br>Wapato Basin 4 | 1x – May, June & September | Temperature, pH, Dissolved Oxygen, Conductivity, Ammonia, Nitrite-Nitrate, TPN, TP, Ortho-P, |

| Source | Data Type | Date/Year | Locations | Frequency | Parameters/Analysis |
|---|---|---|---|---|---|
| Effectiveness Monitoring | | | | 2x – July & August | Chlorophyll-a, Water Transparency |
| | | August 2007 | Domke Falls<br>Lucerne Basin 1<br>Lucerne Basin 2 | 1x | Domke Falls: Temperature, pH, Dissolved Oxygen, Conductivity, Ammonia, Nitrite-Nitrate, TPN, TP, TOC, Ortho-P<br><br>Lucerne Basin: Temperature, pH, Dissolved Oxygen, Conductivity, Ammonia, Nitrite-Nitrate, TPN, TP, TOC, Ortho-P, Chlorophyll-a, Water Transparency |
| EIM – Database Study: Chemical Contaminants in Ten Lakes WA | Freshwater Sediment | June 1992 | Roses Lake | 1x | Grain Size, TN, Organochlorine Pesticides and PCBs, Metals and Trace Elements, Semi-volatile Organic Compounds, Mercury |
| EIM – Database Study: DDT Concentrations in Lake Chelan | Water Quality | May & June 2006 | Lake Chelan Off Wapato Point<br><br>Lake Chelan Off Chelan Riverwalk Park | 1x per month | 4, 4’-DDD<br>4,4’-DDT<br>4,4’-DDE |
| | Freshwater Sediment | July 2007 | Mouth of Stink Creek<br>Mouth of First Creek<br>Mouth of Purtteman Creek<br>Mouth of Knapp Coulee Creek<br>Keupkin St/Buck Orchard Irrigation Drain<br>Bennet Rd/Cooper Irrigation Drains | 1x | Grain Size, TOC, 4, 4’-DDD, 4,4’-DDT, 4,4’-DDE, cis-Chlordane, trans-Chlordane, Dieldrin |
| EIM – Database Study: Don Morse Park, Lake Chelan, | Freshwater Sediment | March 2011 | DMPLC11Comp1 | 1x | Grain Size, TOC, Total Volatile Solids, Total Solids, Ammonia, Sulfide, Metals, Tributyltin Ion, PCBs, Semi-volatile Organic |

| Source | Data Type | Date/Year | Locations | Frequency | Parameters/Analysis |
|---|---|---|---|---|---|
| Sediment Dredging Study | | | | | Compounds, Organochloride Pesticides |
| EIM – Database Study: Effectiveness Monitoring to Assess Aquatic Life Uses in Railroad Creek | Water Quality | September & October 2015 | Railroad Creek at RM 6.2, 8.8, 9.3, 10.0, 10.8, 11.1 | 2x September<br>1x October | Flow, Alkalinity, Hardness, TPN, Sulfate, Chloride, TP, DOC, Metals and Trace Elements, Calcium |
| | Freshwater Sediment | | | | Grain Size, Metals and Trace Elements, Calcium, Phosphorus |
| | Periphyton | August 2013<br><br>September & October 2015 | | 1x August 2013<br><br>2x September<br>1x October 2015 | Cell count, Biomass as Chlorophyll a, Chlorophyll a, TOC, Metals and Trace Elements, Calcium, Phosphorus, Volatile Organic Matter |
| EIM – Database Study: Effectiveness Monitoring to Assess Aquatic Life Uses in Railroad Creek – Provisional Data | Water Quality | September 2018 | Railroad Creek at RM 6.2, 7.2, 8.8, 9.2, 9.3, 9.5, 10.0, 10.8, 11.1 | 1x | Flow, pH, Temperature, Dissolved Oxygen, Conductivity, Alkalinity, Hardness, TPN, Sulfate, Chloride, TP, DOC, Metals and Trace Elements, TSS, Calcium |
| | Freshwater Sediment | September 2018<br><br>October 2018 | Railroad Creek at RM 6.2, 8.8, 9.2, 9.3, 9.5, 10.0, 10.8, 11.1<br><br>Lake Chelan Lucerne Basin (9 stations)<br><br>Lucerne Bar (7 stations) | | Solids, TN, TOC, Mercury, Metals and Trace Elements, Phosphorus, Stable Carbon Isotopes, Stable Nitrogen Isotopes, Polonium-210 |
| | Benthic Macroinvertebrates | September 2018 | Railroad Creek at RM 6.2, 8.8, 9.3, 9.5, 10.0, 10.8, 11.1 | | ID and Count |
| | Periphyton | | Railroad Creek at RM 6.2, 7.2, 8.8, 9.2, 9.3, 9.5, 10.0, 10.8, 11.1 | | Biomass as Chlorophyll a, Chlorophyll a, TOC, Metals and Trace Elements, Calcium, Phosphorus, TN, Stable Carbon Isotopes, Stable Nitrogen Isotopes, |

| Source | Data Type | Date/Year | Locations | Frequency | Parameters/Analysis |
|---|---|---|---|---|---|
| | | | | | Volatile Organic Matter, Total Solids |
| EIM – Database Study: Effects of Holden Mine on Railroad Creek | Water Quality | June & September 1996 | Railroad Creek (8 stations) | 1x per month | Conductivity, pH, Turbidity, Alkalinity, Sulfate, TSS, TP, Nitrite-Nitrate, Mercury, Hardness, Cyanide, Metals and Trace Elements, Color |
| | Freshwater Sediment | September 1996 | Railroad Creek (6 stations) | 1x | Grain Size, Solids, Metals and Trace Elements |
| | Invertebrates | | Railroad Creek (4 stations) | | ID and Count |
| EIM – Database Study: Lake Chelan DDT and PCBs in Fish TMDL | Animal Tissue | March, April, May, July, August, September, October 2003<br><br>April 2006 | Lake Chelan – Wapato Basin<br>Lake Chelan – Lucerne Basin<br>Lake Chelan – Roses Lake | 1x per month | Fish statistics, Lipids, PCBs, Organochlorine Pesticides, Chlorinated Biphenyls, Dioxins and Furans |
| | Water Quality | May – November 2003 | Wapato-A, Lucerne-A, First Creek, Knapp Coulee, Railroad Creek, Fish Creek, Prince Creek, 25 Mile Creek, Culvert E of Crystal View, Purtteman Creek, Culvert at Veroske's, Keupkin St., Buck Orchards, Mill Bay Boat Ramp, Bennet Rd., Cooper Drainage, Wapato Lake+Joe Creek, Stink Creek, Stehekin River | Varies, usually 1x per month | Flow, Temperature, 4, 4'-DDD, 4,4'-DDT, 4,4'-DDE, TOC, TSS, Turbidity |
| | Freshwater Sediment | June 2003 | Railroad Creek, Stehekin River, Lake Chelan Lucerne Basin, Lucerne, Wapato, Lake Chelan Wapato Basin, First Creek | 1x | Grain Size, TOC, 4, 4'-DDD, 4,4'-DDT, 4,4'-DDE, PCBs |

| **Source** | **Data Type** | **Date/Year** | **Locations** | **Frequency** | **Parameters/Analysis** |
|---|---|---|---|---|---|
| EIM – Database Study: Lake Chelan Long Term Monitoring | Water Quality | June, August, October 2016<br><br>April – December 2017<br><br>January – April 2018 | Lake Chelan Stations 1-8 | 1x per month | Alkalinity, Ammonia, Chlorophyll a, Nitrate, Nitrite, Nitrate+Nitrite, TPN, TKN, TP, Ortho-P, TOC |
| | Water Quality | June 2017<br><br>May – September 2018 | Agricultural Drain 6, 8, 10, 11, 13 | 1x per month | Alkalinity, Ammonia, Chlorophyll a, Nitrate, Nitrite, Nitrate+Nitrite, TPN, TKN, TP, Ortho-P, TOC |
| | Water Quality | June, August, October 2016<br><br>April, June 2017<br><br>May – September 2018 | Beebe Creek Outlet, First Creek near Outlet, Knapp Coulee Outlet, Purtteman Creek Outlet, Stink Creek Outlet, Wapato Lake Outlet | 1x per month | Alkalinity, Ammonia, Chlorophyll a, Nitrate, Nitrite, Nitrate+Nitrite, TPN, TKN, TP, Ortho-P, TOC |
| EIM – Database Study: Lake Mini-Monitoring TP and Secchi | Water Quality | August 2011 | Wapato Station 2<br>Roses Station 2 | 1x | TP and Water Transparency |
| EIM – Database Study: National Study of Chemical Residues in Lake Fish Tissue (EPA) | Animal Tissue | September 2000 | Lake Chelan | 1x | Fish Statistics, PCBs, Chlorinated Biphenyls, Mercury, Organochlorine Pesticides, Lipids, Dioxins and Furans, Semi-volatile Organic Compounds, Arsenic, Organophosphorus Pesticides |
| EIM – Database | Animal Tissue | October 2005 | Lake Chelan, South End Near Woodin St. Bridge | 1x | Fish Statistics, Lipids, PBDEs |

| Source | Data Type | Date/Year | Locations | Frequency | Parameters/Analysis |
|---|---|---|---|---|---|
| Study: PBT Monitoring PBDE Levels in WA Rivers and Lakes | | | | | |
| EIM – Database Study: Statewide Freshwater Aquatic Plant (Macrophyte) Monitoring Data | Aquatic Plant Survey | 1994 | Antilion Lake | 1x per year | Visual Survey, Aquatic Plant ID |
| | | 1994, 2017 | Lake Chelan | 1x per year | 1994: Visual Survey from shore near Chelan City Park, Aquatic Plant ID<br><br>2017: Visual Survey from dam to Manson, Aquatic Plant ID |
| | | 1990, 2012, 2013 | Domke Lake | 1x per year | 1990: Reported EWM sighting, Aquatic Plant ID<br><br>2012: Confirmed presence of EWM, Aquatic Plant ID<br><br>2013: Visual Survey, Aquatic Plant ID |
| | | 1994 | Dry (Grass) Lake | 1x per year | Visual Survey from Southeast shore, Aquatic Plant ID |
| | | 1994, 1997, 2001, 2007, 2008, 2011 | Roses (Alkali) Lake | 1x per year | 1994: Visual Survey of 200 m either side of boat ramp, Aquatic Plant ID, Water Transparency<br><br>1997: Visual Survey, Aquatic Plant ID, Water Transparency<br><br>2001: Visual Survey (EWM & fragrant waterlily present), Aquatic Plant ID, Water Transparency |

| Source | Data Type | Date/Year | Locations | Frequency | Parameters/Analysis |
|---|---|---|---|---|---|
| | | | | | 2007: Visual Survey (EWM & fragrant waterlily present), Aquatic Plant ID, Water Transparency<br><br>2008: Visual Survey (EWM & fragrant waterlily present), Aquatic Plant ID, Water Transparency<br><br>2011: Visual Survey (EWM & fragrant waterlily present), Aquatic Plant ID, Water Transparency |
| | | 1994 – 1997, 1999, 2001, 2006, 2008, 2011 | Wapato Lake | 1x per year, 2x per year in 1995 | 1994: Visual Survey (EWM present), Aquatic Plant ID, Water Transparency<br><br>1995: Visual Survey (EWM present), Aquatic Plant ID, Water Transparency<br><br>1996: Visual Survey (EWM present), Aquatic Plant ID, Water Transparency<br><br>1997: Visual Survey (EWM present), Aquatic Plant ID, Water Transparency<br><br>1999: Visual Survey (EWM present), Aquatic Plant ID, Water Transparency<br><br>2001: Visual Survey (EWM & reed canary grass present), Aquatic Plant ID, Water Transparency |

| Source | Data Type | Date/Year | Locations | Frequency | Parameters/Analysis |
|---|---|---|---|---|---|
| | | | | | 2006: Visual Survey (EWM & reed canary grass present), Aquatic Plant ID, Water Transparency<br><br>2008: Visual Survey (EWM present), Aquatic Plant ID<br><br>2011: Visual Survey (EWM & reed canary grass present), Aquatic Plant ID, Water Transparency |
| EIM – Database Study: Statewide Lake Monitoring | Water Quality | June – September 1990 | Lake Chelan | 1x per month | Temperature, pH, Dissolved Oxygen, Conductivity, TPN, TP, Water Transparency |
| | | May and August 1997 | Roses (Alkali) Lake | 1x per month | Temperature, pH, Dissolved Oxygen, Conductivity, TPN, TP, Water Transparency, Chlorophyll a, Hardness, Turbidity |
| | | | Wapato Lake | | Temperature, pH, Dissolved Oxygen, Conductivity, TPN, TP, Water Transparency, Chlorophyll a, Hardness |
| EIM – Database Study: Statewide River and Stream Ambient Monitoring 1980-1988 | Water Quality | 1980 – 1988 | Chelan River at Chelan (47A070) | 1x per month | Flow, Temperature, pH, Dissolved Oxygen, Conductivity, Ammonia, BP, COD, Fecal Coliform, Chlorophyll a, Nitrate, Nitrite, Nitrate+Nitrite, TP, Ortho-P, TKN, TSS, Turbidity |
| EIM – Database Study: Statewide River and Stream Ambient Monitoring pre-1980 | Water Quality | 1960 – 1972, 1974 – 1979 | Chelan River at Chelan (47A070) | 1x per month | Flow, Temperature, pH, Dissolved Oxygen, Conductivity, Alkalinity, Ammonia, BP, COD, Fecal Coliform, Chlorophyll a, Hardness, Nitrate, Nitrite, Nitrate+Nitrite, TP, Ortho-P, TKN, TSS, Turbidity |

| Source | Data Type | Date/Year | Locations | Frequency | Parameters/Analysis |
|---|---|---|---|---|---|
| EIM – Database Study: Statewide River and Stream Ambient Monitoring WY1989 – WY1999 | Water Quality | 1988 – 1991, 1993, 1994 | Chelan River at Chelan (47A070) | 1x per month | Flow, Temperature, pH, Dissolved Oxygen, Conductivity, Ammonia, BP, COD, Fecal Coliform, Chlorophyll a, Hardness, Nitrate, Nitrate+Nitrite, TP, Ortho-P, TKN, TSS, Turbidity |
| EIM – Database Study: Status and Trends WA Statewide Sentinel Site Monitoring | Water Quality | 2010 - 2016 | 25 Mile Creek | 1x per year | Temperature, pH, Dissolved Oxygen, Conductivity, Chloride, Flow, TPN, TP, TSS, Turbidity |
| | Freshwater Sediment | | | | Grain Size, Semi-volatile organic compounds, Solids, TOC, Metals and Trace Elements, |
| | Freshwater Taxonomy | | | | ID and Count (Fish, Amphibians, Invertebrates, Perpiphtyon) |
| | Periphyton | | | | 2010 – 2015: Areal Biomass as Chlorophyll a, Chlorophyll a<br><br>2016: Areal Biomass as Chlorophyll a, Chlorophyll a, Solids, Volatile Organic Matter, TOC, TN, TP, Metals and Trace Elements |
| EIM – Database Study: Status and Trends WA Statewide Sentinel Site Monitoring – Provisional Data | Water Quality | 2017 – 2018 | 25 Mile Creek | 1x per year | Temperature, pH, Dissolved Oxygen, Conductivity, Chloride, Flow<br><br>2017 only – TSS, Chloride, TPN, TP |
| | Freshwater Sediment | | | | Grain Size, TOC, Arsenic, Lead, Copper, Zinc<br><br>2018 only – Particle Size |
| | Freshwater Taxonomy | | | | ID and Count (Fish, Invertebrates, Periphyton) |

| Source | Data Type | Date/Year | Locations | Frequency | Parameters/Analysis |
|---|---|---|---|---|---|
| | Periphyton | | | | 2017: Chlorophyll a, TOC, Stable Carbon Isotopes, Stable Nitrogen Isotopes, TN, Volatile Organic Matter, Solids, Metals and Trace Elements, TP, Areal Biomass as Chlorophyll a<br><br>2018: TOC, TN, Stable Carbon Isotopes, Stable Nitrogen Isotopes |
| EIM – Database Study: Wapato Lake Pesticides | Animal Tissue | September 1996 | Wapato Lake Fish Survey Stations | 1x | Fish Statistics, Lipids, Organochlorine Pesticides, PCBs, Lead, Arsenic, |
| | Freshwater Sediment | | Wapato Lake Upper Lake Sediment Station | 1x | Grain Size, TOC, Arsenic, Lead, Chlorinated Herbicides, Pesticides, |
| | Freshwater Taxonomy | | | | Invertebrate ID and Count |
| EIM – Database Study: WA State Toxics Monitoring Program pre-QAPP Trend Monitoring | Animal Tissue | May 2003 | Chelan-WAP-F | 1x | Fish Statistics, Lipids, Mercury, Chlorinated Biphenyls, PCBs |
| EIM – Database Study: WA State Toxics Monitoring Program Exploratory Monitoring | Animal Tissue | August 2003 | Roses Lake | 1x | Fish Statistics, Lipids, Mercury, PCBs, 4,4'-DDD, 4,4'-DDT, 4,4'-DDE |
| EIM – Database Study: WA State Toxics Monitoring Program Exploratory Monitoring 2010 | Animal Tissue | June 2010 | Lake Chelan – Wapato Basin | 1x | Fish Statistics, Lipids, Mercury, Organochlorine Pesticides, PCBs, Semi-volatile Organic Compounds, Dioxins and Furans |
| EIM – Database Study: WA State Toxics Monitoring | Animal Tissue | August 2012 | Battalion Lake (5 Miles NW of Lake Chelan) | 1x | Fish Statistics, Lipids, Mercury, PCBs, Semi-volatile Organic Compounds, Organochlorine Pesticides, |
| | | September 2012 | Stehekin River between RM 4-5 | 1x | |

| **Source** | **Data Type** | **Date/Year** | **Locations** | **Frequency** | **Parameters/Analysis** |
|---|---|---|---|---|---|
| Program Exploratory Monitoring 2012 | | | | | |
| EIM – Database Study: Water Quality Assessment Manson Lakes | Water Quality | March – December 2002<br><br>February – December 2003<br><br>January 2004 | Drain-ST11, ST11S, ST11W (Roses Lake), Dry Lake-D1, Dry Lake-D2, Dry Lake Drains ST1-4, Joe Creek below Joe Creek Road, Roses Lake R1 and R2, Stink Creek ST8 and ST10, Wapato Lake W1 and W2, Wapato Lake Drain, Wapato Lake Overflow, Waterway between Roses and Dray Lakes | 1x each month | Temperature, pH, Dissolved Oxygen, Flow, Chlorophyll, 4,4'-DDD, 4,4'-DDT, 4,4'-DDE, Nitrate+Nitrite, Ortho-P, PCBs, TP, TSS, Tetrachloro-m-xylene |
| | Freshwater Sediment | June 2012 | Dry Lake (3 Stations), Roses Lake (3 Stations), Wapato Lake (3 Stations) | 1x | TOC, pH, Organochlorine Pesticides |
| EIM – Database Study: WSPMP 1992 Pesticides in Fish Tissue | Animal Tissue | September 1992 | Lake Chelan | 1x | Fish Statistics, Lipids, Pesticides |
| EIM – Database Study: WSPMP 1994 Pesticides in Fish Tissue | Animal Tissue | September 1994 | Lake Chelan | 1x | Fish Statistics, Lipids, Pesticides |
| EIM – Database Study: WSPMP 1994 Pesticides in Sediment | Freshwater Sediment | September 1994 | Lake Chelan | 1x | Pesticides, Grain Size, Solids, TOC, Chlorinated Herbicides |
| EIM – Database Study: WSPMP 1994 Pesticides in Surface Water | Water Quality | April, June, October 1994 | Stink Creek | 1x | Flow, Temperature, pH, Conductivity, Nitrate+Nitrite, TSS, TOC, Pesticides, Chlorinated Herbicides, |

NOTES:

*Table does not include data in EIM from Holden Mile Remediation or other remediation projects (groundwater and soil)